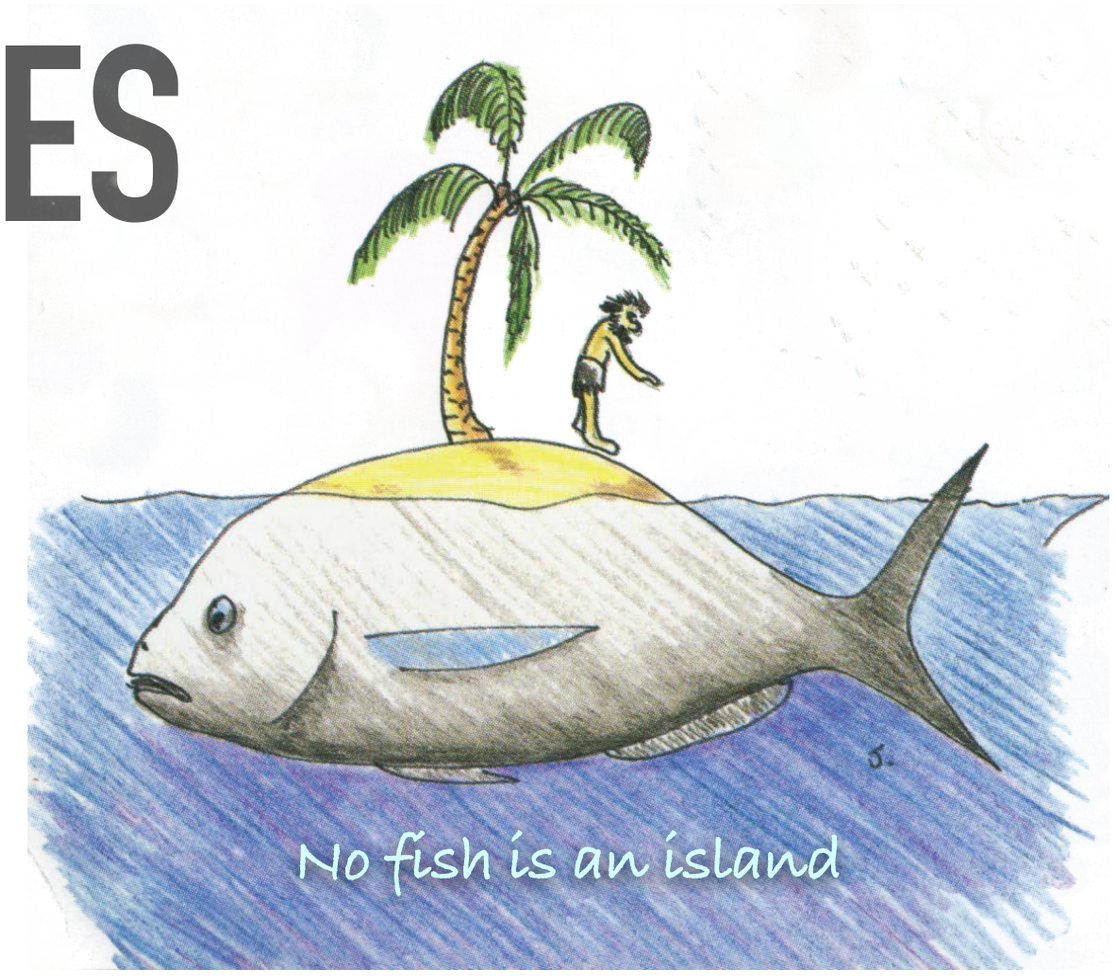
OPTIMAL FISHERIES YIELD — AN ECOSYSTEM PERSPECTIVE



Villy Christensen

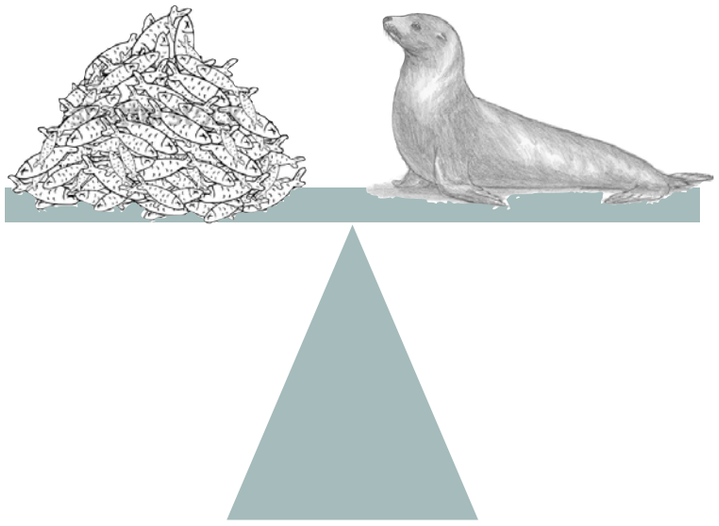
Institute for the Oceans and Fisheries
The University of British Columbia
Vancouver, BC, Canada

HILBORN ON IMPACT OF FORAGE FISHERIES

Saving Seafood. Oct 31, 2017 *Sea video : https://vimeo.com/240210294*

HILBORN ON MANAGING RECOVERED STOCKS

- Ray's core messages:
  - "predators seems to go up and down, largely independent of the abundance of forage fish"
- Recovering stocks raise the issue of how we optimize yield from the ocean
  - What are the objectives for management?
  - i.e., how do we tackle trade-offs?



THE LENFEST – HILBORN CONTROVERSY

Economic importance of forage fish

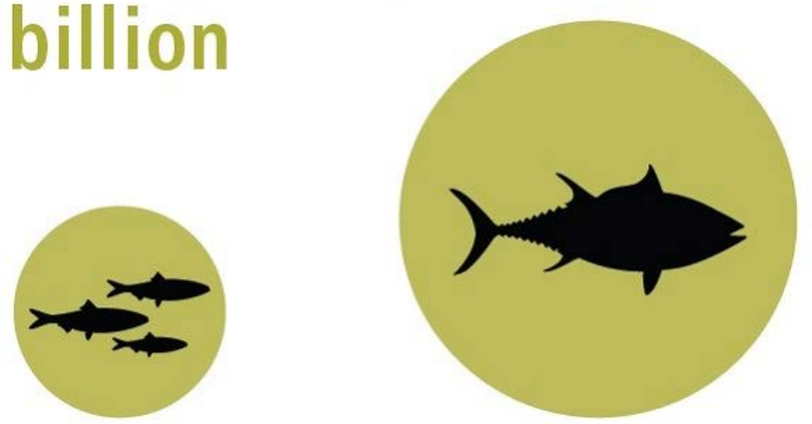
TOTAL $16.9 BILLION

Direct value
of commercial forage catch

$5.6 billion

Supportive value
of forage fish to other commercial catch

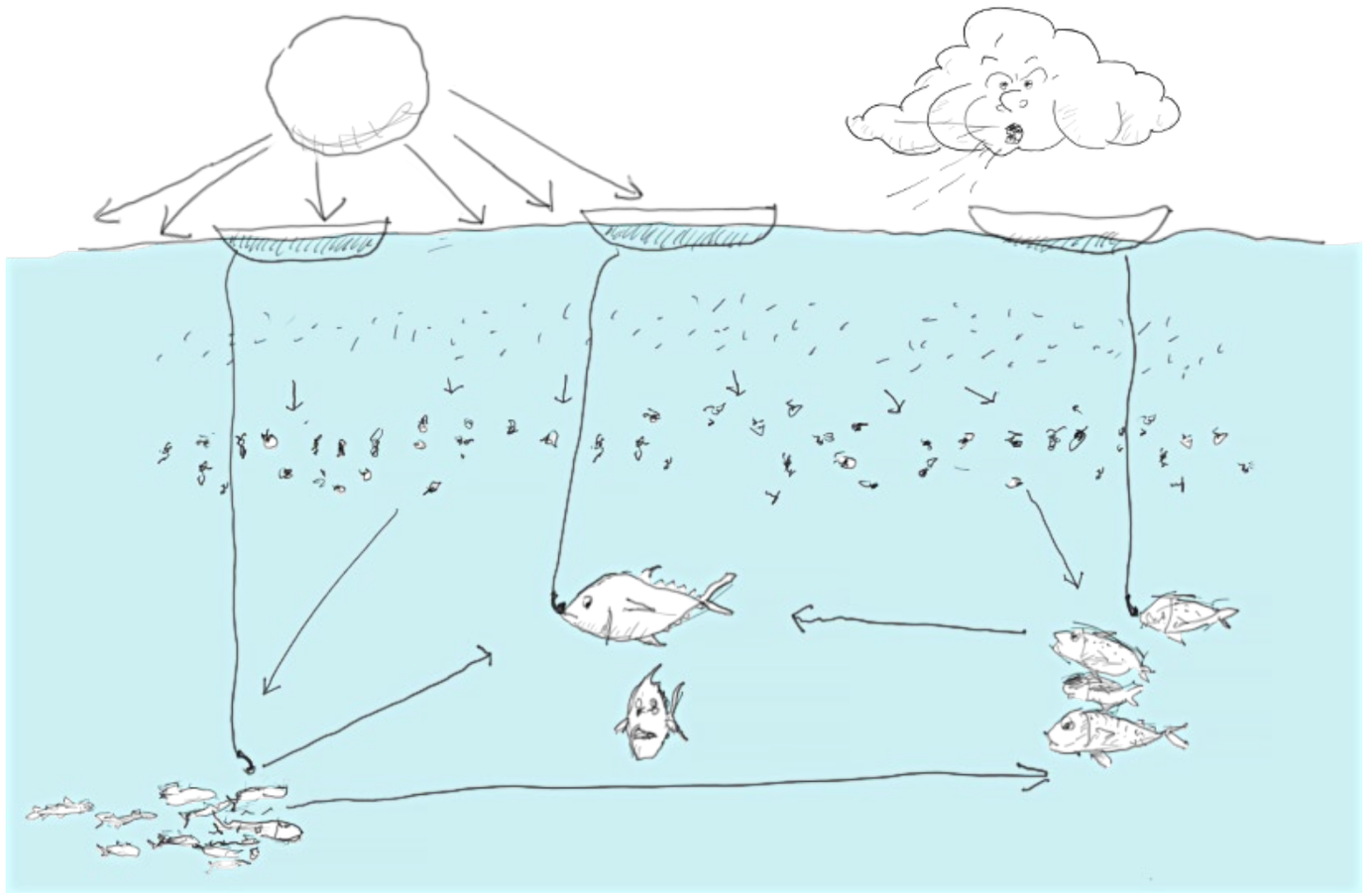
$11.3 billion



THE LENFEST STUDY USED ECOSYSTEM MODELS

- Most fish were represented with biomass dynamics:
  - Production = f(biomass, feeding conditions)

- We've learned from model comparisons that such model implementations tend to overestimate fisheries impacts



Smith et al. 2011, Forrest et al. 2015, Hilborn et al.[5] *2017*

Fisheries Research 2017. 191: 211-221

When does fishing forage species affect their predators?

Ray Hilborn[a,*], Ricardo O. Amoroso[a], Eugenia Bogazzi[a], Olaf P. Jensen[b], Ana M. Parma[c], Cody Szuwalski[d], Carl J. Walters[e]

Predators may be less affected by catch of small fish than previously thought, new study says

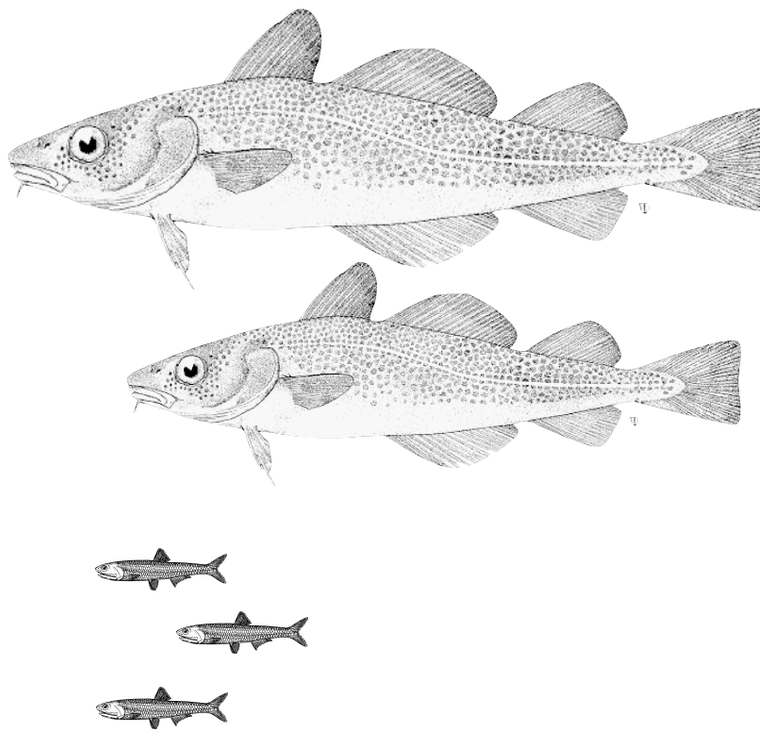
Monday, April 3, 2017

National Coalition for Fishing Communities

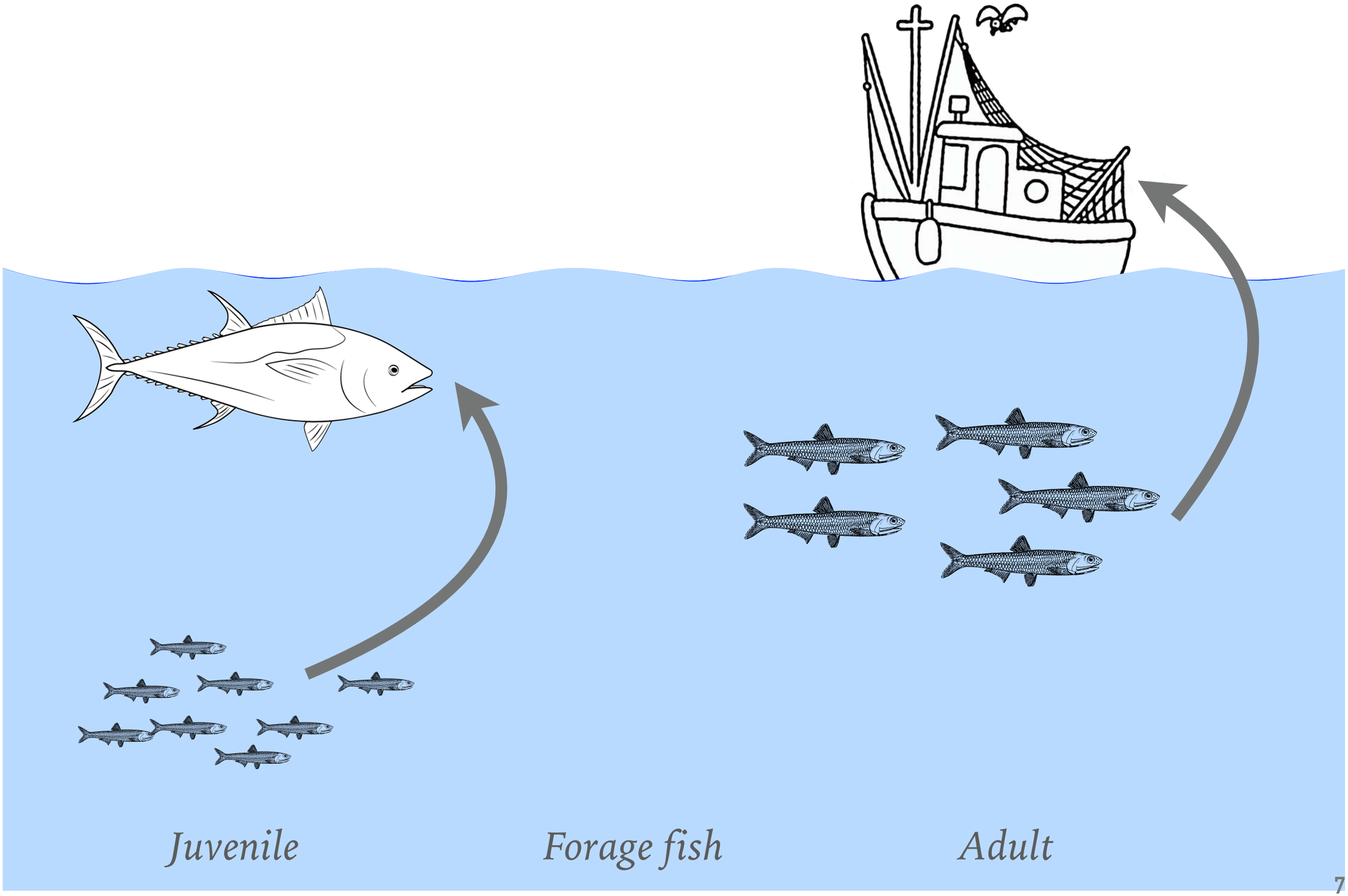
IFFO THE MARINE INGREDIENTS ORGANISATION

Previous studies overlooked key factors in recommending lower catch of forage fish

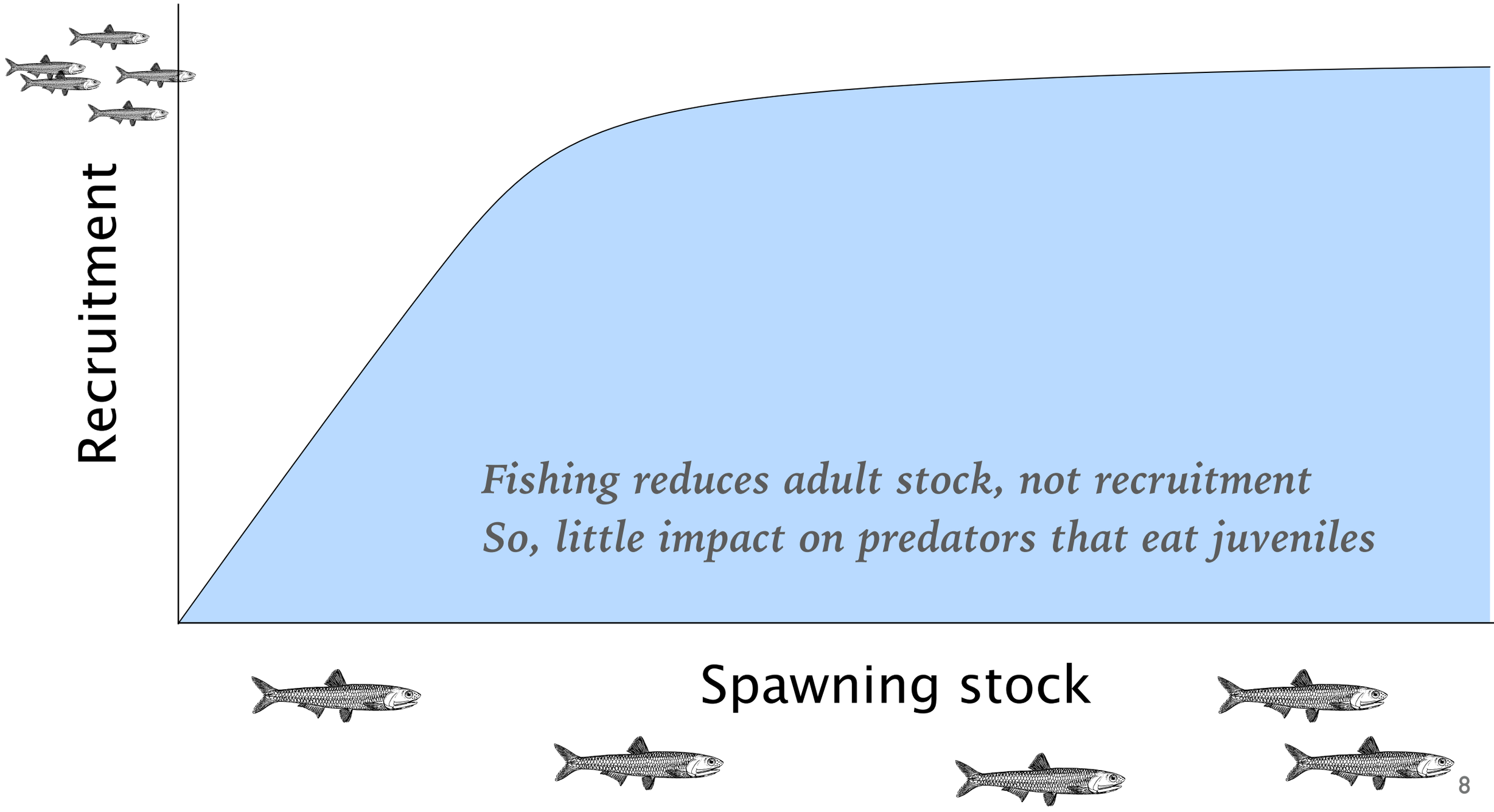
WASHINGTON (NCFC) – April 3, 2017 – New research published today in the journal *Fisheries Research* finds that fishing of forage species likely has a lower impact on predators than previously thought, challenging previous studies that argued forage fish are more valuable left in the ocean.



HILBORN: FISH AND FORAGE FISHERIES DON'T COMPETE . . .

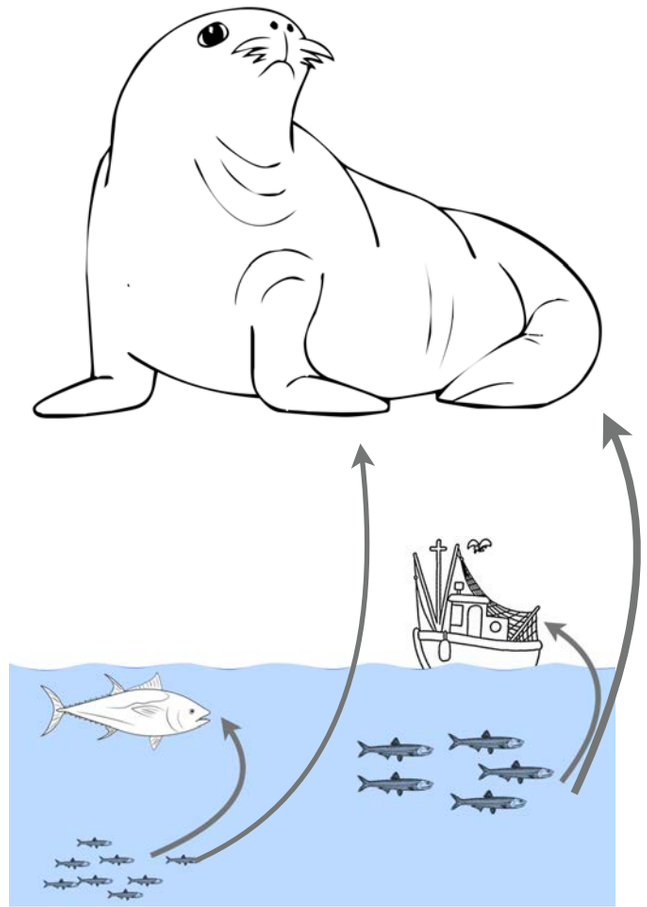


AND FISH HAVE STOCK-RECRUITMENT RELATIONSHIPS



BUT,

- Predators eat juveniles and fisheries catch adults is a best case scenario
- It may hold for many predatory fish
- but marine mammals and birds often eat adult forage fish
- Trade-offs between forage fisheries and marine mammals and birds more pronounced
- Trade-offs can be two-ways, it also means that predators often are first at the table



AND!

Fishing amplifies forage fish population collapses

Timothy E. Essington[a,1], Pamela E. Moriarty[a], Halley E. Froehlich[a], Emma E. Hodgson[a], Laura E. Koehn[a], Kiva L. Oken[b], Margaret C. Siple[a], and Christine C. Stawitz[b]

Forage fish support the largest fisheries in the world but also play key roles in marine food webs by transferring energy from plankton to upper trophic-level predators, such as large fish, seabirds, and marine mammals. Fishing can, thereby, have far reaching consequences on marine food webs unless safeguards are in place to avoid depleting forage fish to dangerously low levels, where dependent predators are most vulnerable.

PNAS 2015
112: 6648-52

Ecological Modelling 2016. 337: 272-280

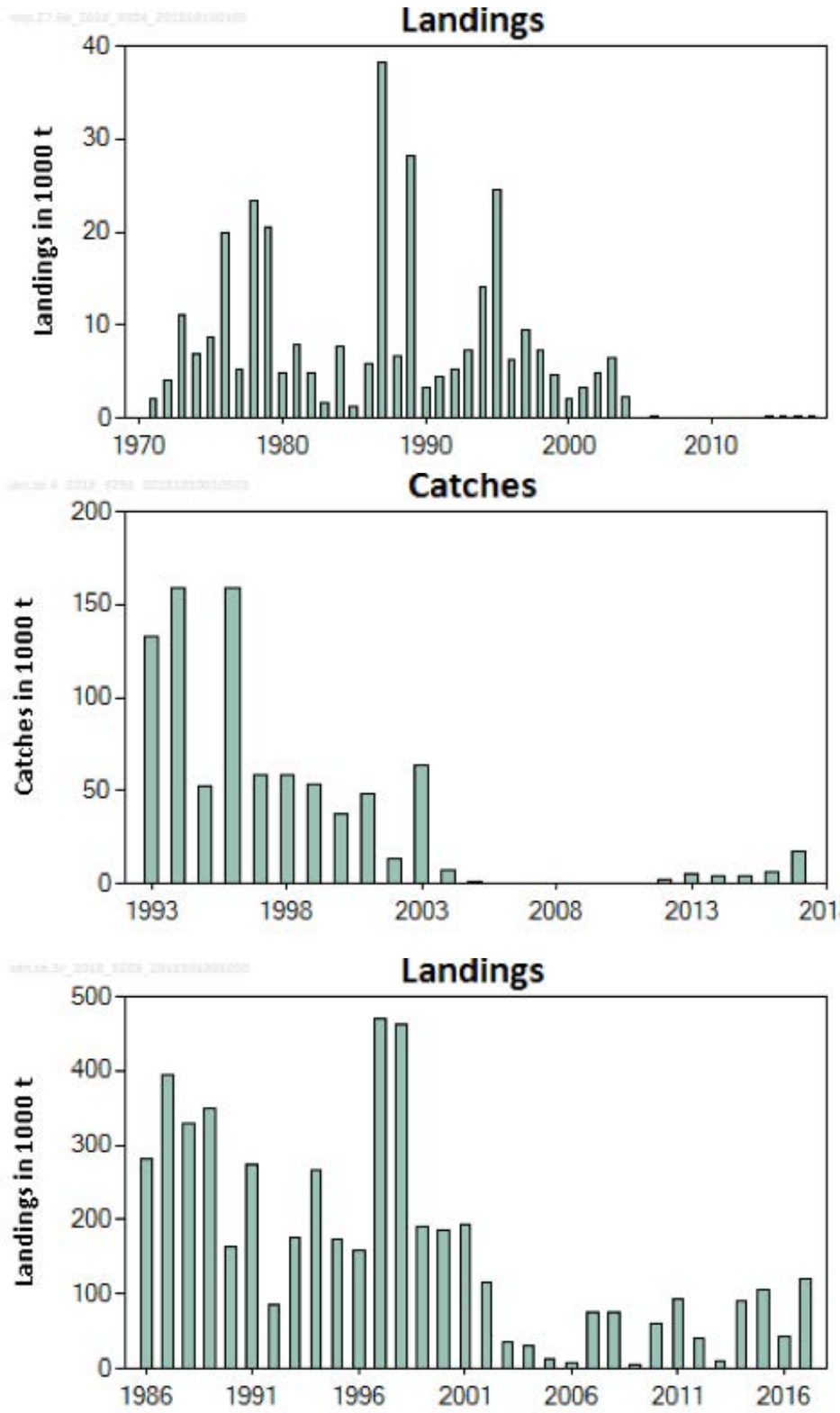
Predictions from simple predator-prey theory about impacts of harvesting forage fishes

Carl Walters[a,*], Villy Christensen[a], Beth Fulton[b], Anthony D.M. Smith[b], Ray Hilborn[c]

Showed that even small environmental changes can increase risk of depensatory impact on forage fish w increased fishing, and increased risk and severity of collapses

FORAGE FISH COLLAPSES

- Collapses, once they happen, can be more severe than simple models predict
- Recovery slow in coming
- Why?



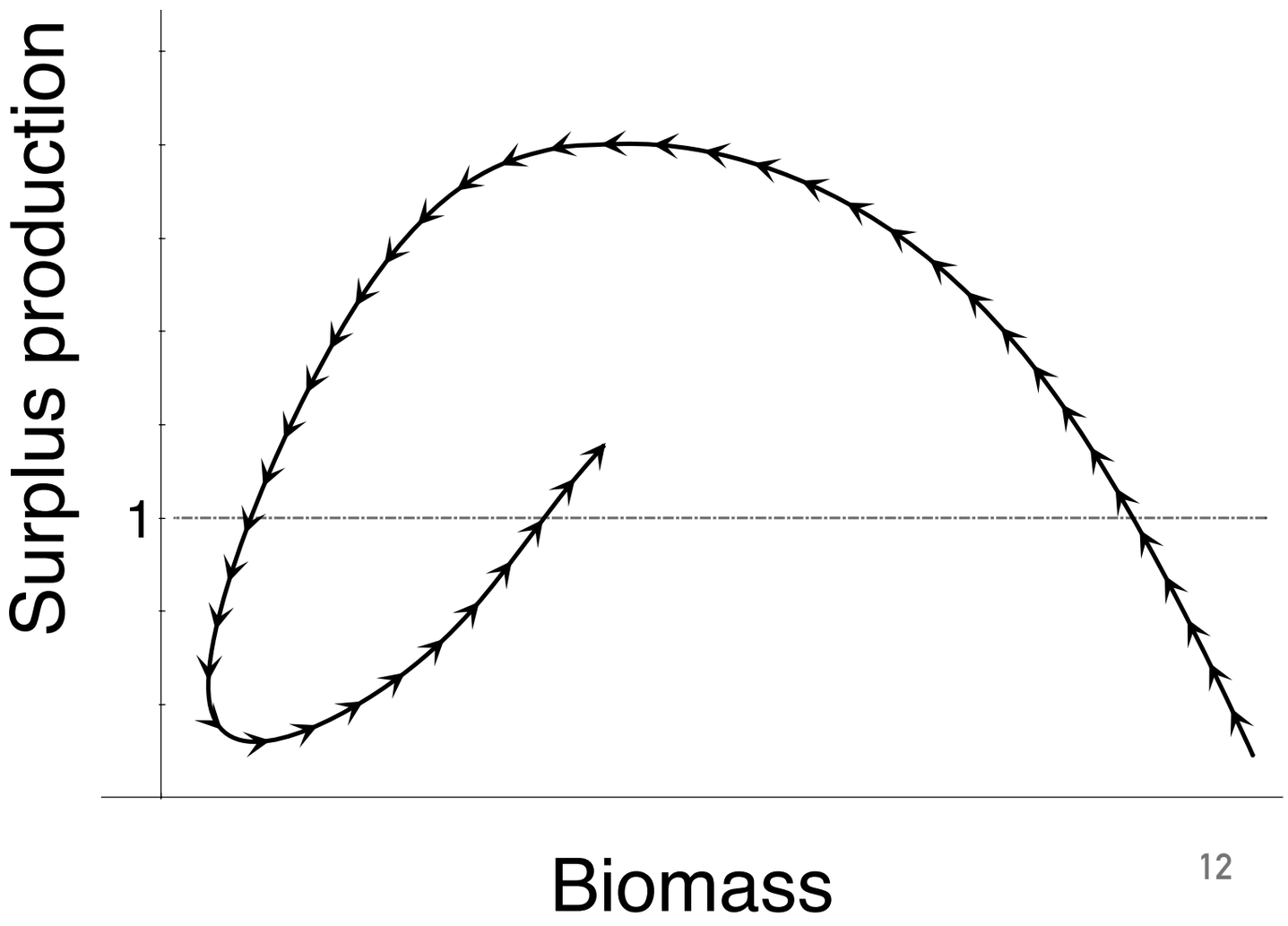
AN INDICATOR OF COLLAPSE: SURPLUS PRODUCTION

- What leads to collapses?
- We evaluated 110 stocks,
  $SP_t = B_{t+1} - B_t + C_t$
- Most common shape was counter-clock wise hook
- Clock wise also happens
- Why slow recovery?

CJFAS 2008. 65: 2536-51

Surplus production dynamics in declining and recovering fish populations

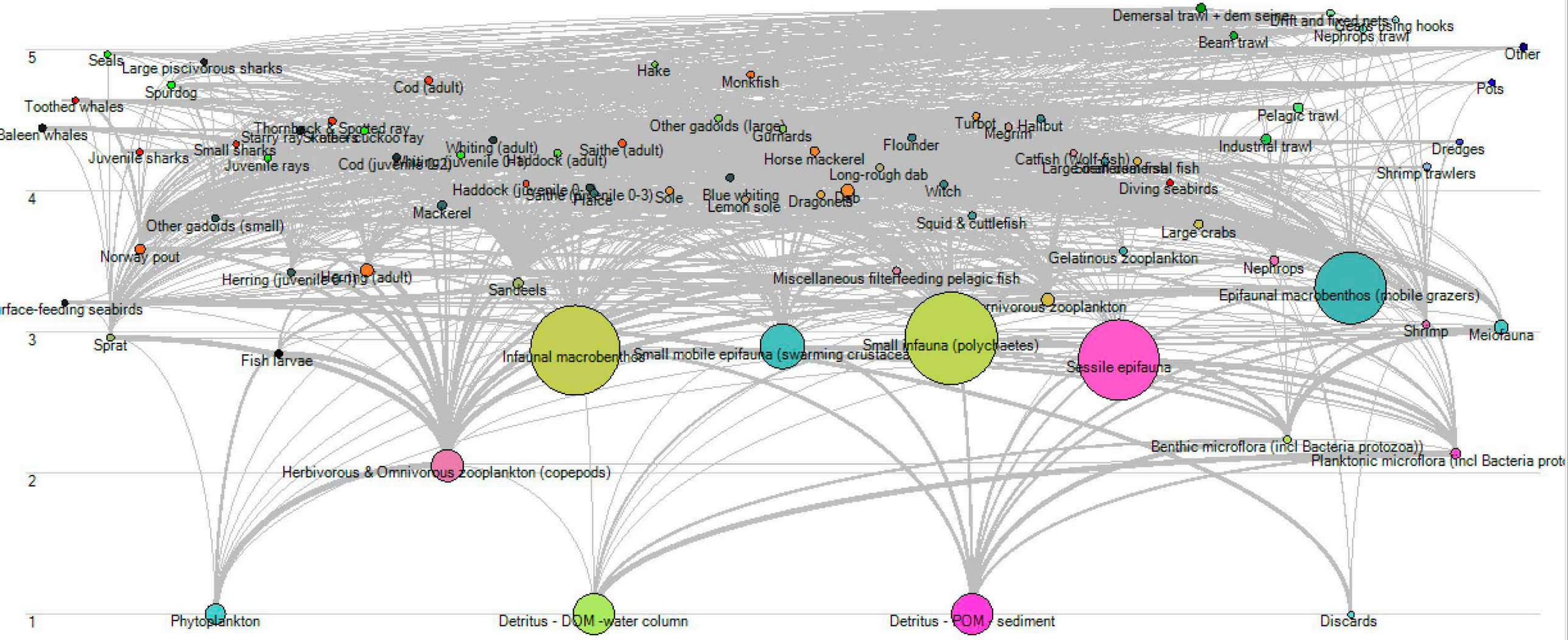
Carl J. Walters,[a] Ray Hilborn,[b] Villy Christensen[a]



SMALL PELAGICS STICK TOGETHER: RANGE CONTRACTION

- Abundant forage fish populations often shows range expansion and contraction with population size changes – which may well be initiated by environmental conditions
- Range contraction leads to localized spawning concentrated in restricted areas
- Small habitat areas for juveniles leads to low recruitment
- Predators (and fisheries) may aggregate in these small habitat areas and cause depensatory mortality (and high CPUE)
- Making it hard to come back again from a collapse

COMPLICATION, FOOD WEB INTERACTIONS: A MESSY PICTURE



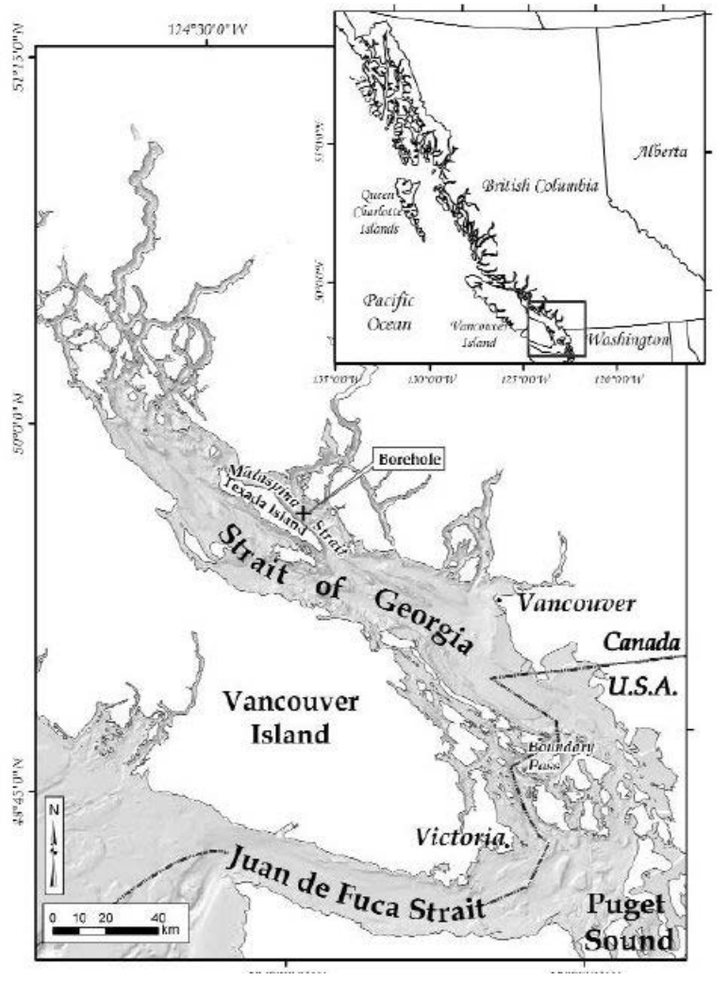
Mackinson et al, North Sea model key run, CEFAS,

THE CORE LESSON LEARNED

- Well-managed forage fisheries can co-exist with other fisheries
- It takes longer time to recover from collapses than predicted by simple models
- Fisheries' trade-offs may be limited as long as the forage fish are kept from collapses
- Trade-offs between forage fisheries and marine mammals and birds are often stronger

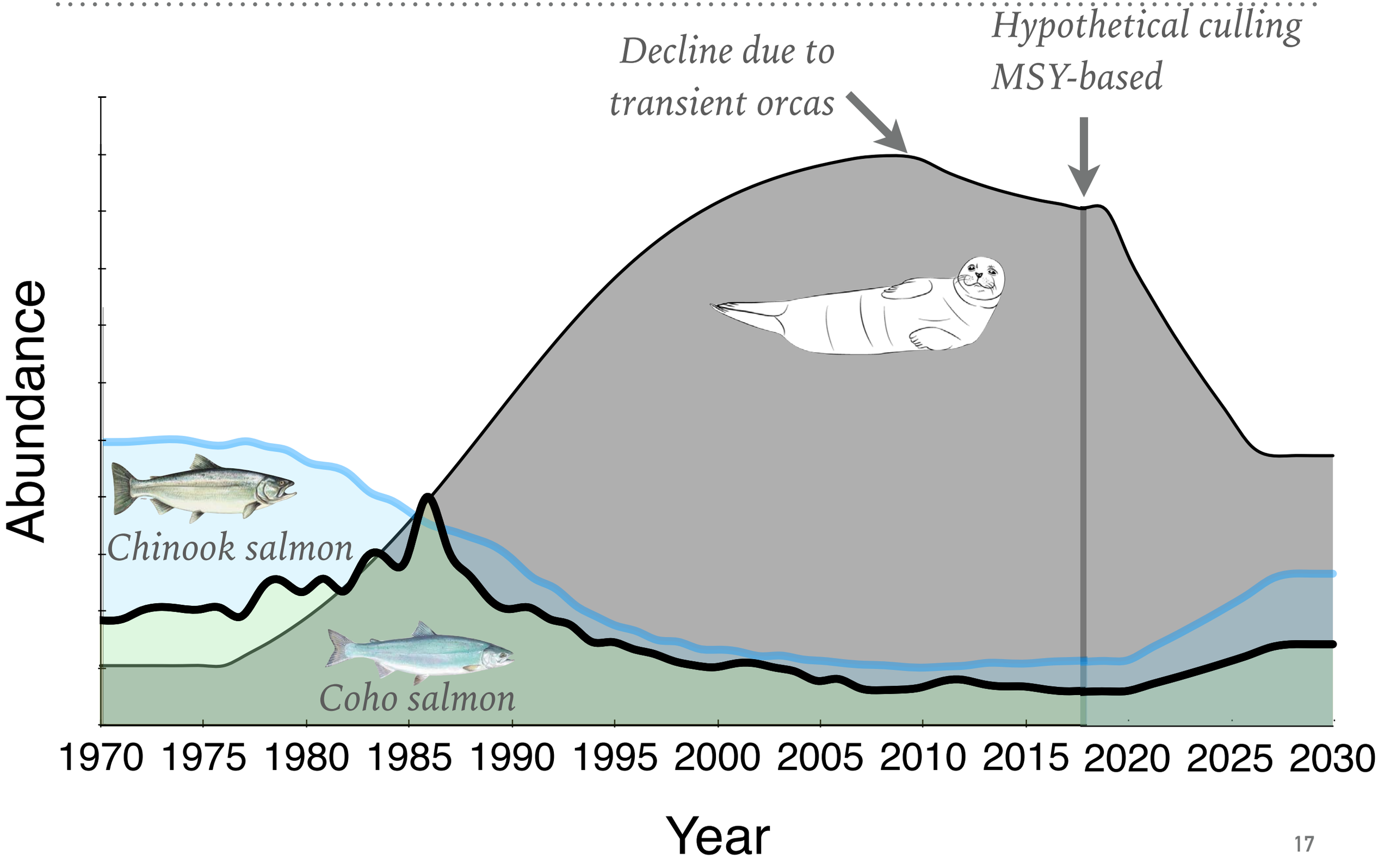
AN EXAMPLE: THE STRAIT OF GEORGIA WHERE SALMON RULES

- Chinook and coho 1st year marine survival has decreased strongly since the 1980s
- Salmon fisheries curtailed
- Resident orcas are listed as endangered with low abundance of Chinook salmon considered a major factor
- Harbour seals were culled till early 1970s
- Seals diet include a few % of Chinook and coho salmon smolts
- Population grew from 4,500 to 40,000



Vaughn Barrie et al. JGAC 2005

SALMON AND SEALS



OPTIMIZING FISHERIES YIELD

- We have complex ecosystem models that are ‘well-behaved', i.e. similar to single species models they have been fitted to time series data, and they make credible predictions about impact of fisheries
- They also have a fair approach for including environmental impacts and evaluating trade-offs
- We can optimize for, e.g., profit, revenue, and/or jobs in the fishing fleets or sector, biodiversity status, stock status (avoid collapses), …
- But,
  - we cannot define the objective function …

"OPTIMUM" FISHERIES YIELD?

- Who defines it?
- Depends on the governance system, but it's almost Mission Impossible
  - Policy-makers should not ignore that there are trade-offs
  - Scientists have responsibility to make the tradeoffs clear
    - It's not enough to say, "our models don't consider it"
- Same for spatial issues – e.g., range contraction, MPAs, and spatial management

WITH THANKS TO

- Carl Walters and Søren Anker Pedersen for discussions that led to this presentation

TODAY'S TALKS

15:35 Shifts in North Sea forage fish productivity and potential fisheries yield (Mikael van Deurs, DTU Aqua)

16:00 The North East Atlantic pelagic fisheries case study in ClimeFish (Kjell Rong Utne, IMR)

16:25 *Coffee break*

16:45 How much fish is eaten by marine mammals in the Barents Sea? (Daniel Howell, IMR)

17:10 The potential direct and indirect effects of grey seal on Baltic cod (Jane Behrens, DTU Aqua)

17:35 Are the growing marine mammal populations in West Greenland reducing the potential fisheries yields? (Jens Stubkjær, AMP)

17:50-18:30 Panel discussion:
How to optimize fisheries yields from changing ecosystems?