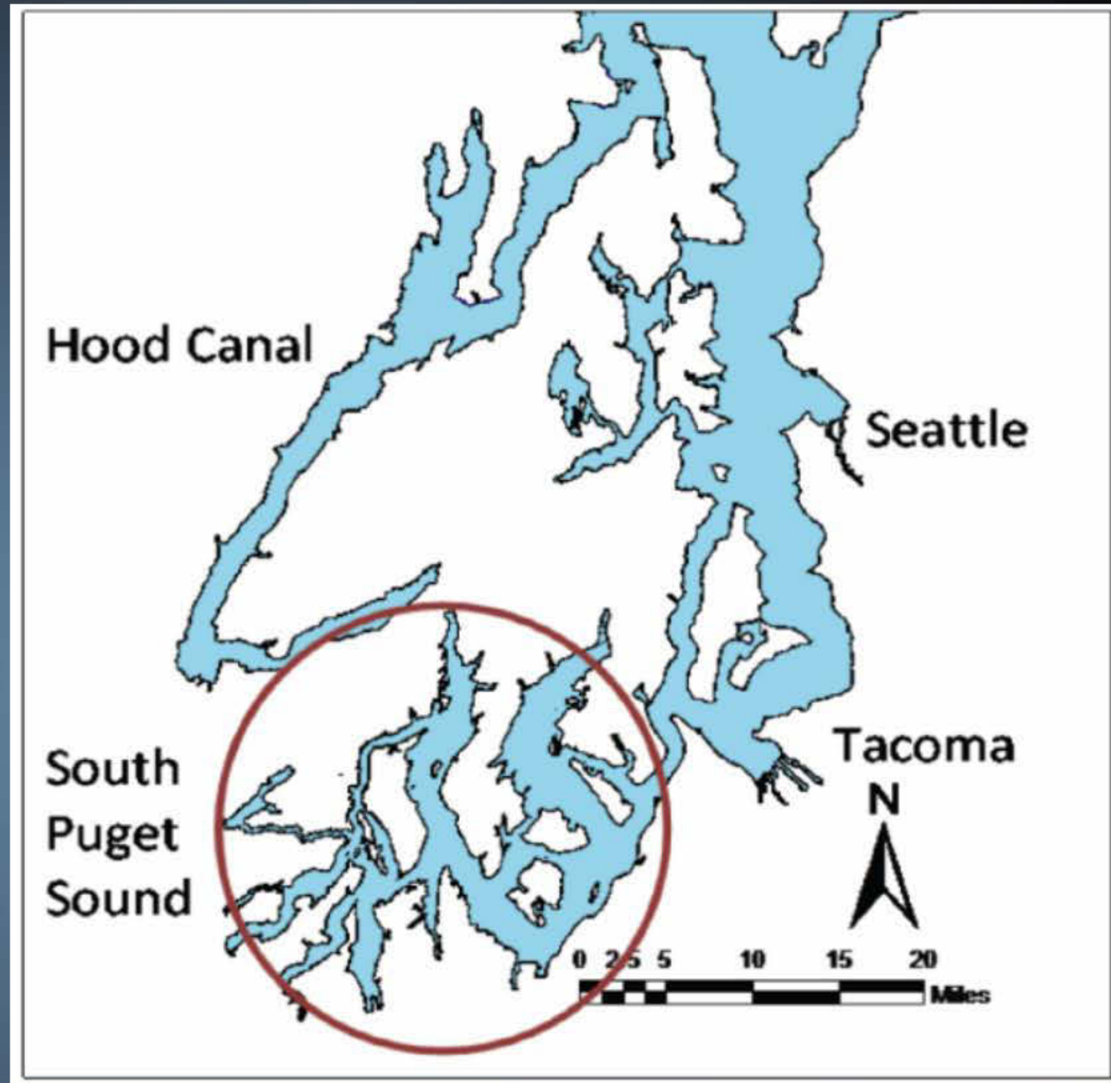
Ecological Carrying Capacity for South Puget Sound

Sea Grant Funded Research From a Shellfish Farming and Fisheries Perspective

Shellfish & the Environment
December 8, 2014



The south Puget Sound study area for this research project is circled

Pacific Shellfish Institute
SHELLFISH RESEARCH AND INFORMATION SERVICES

Carrying Capacity: Definition

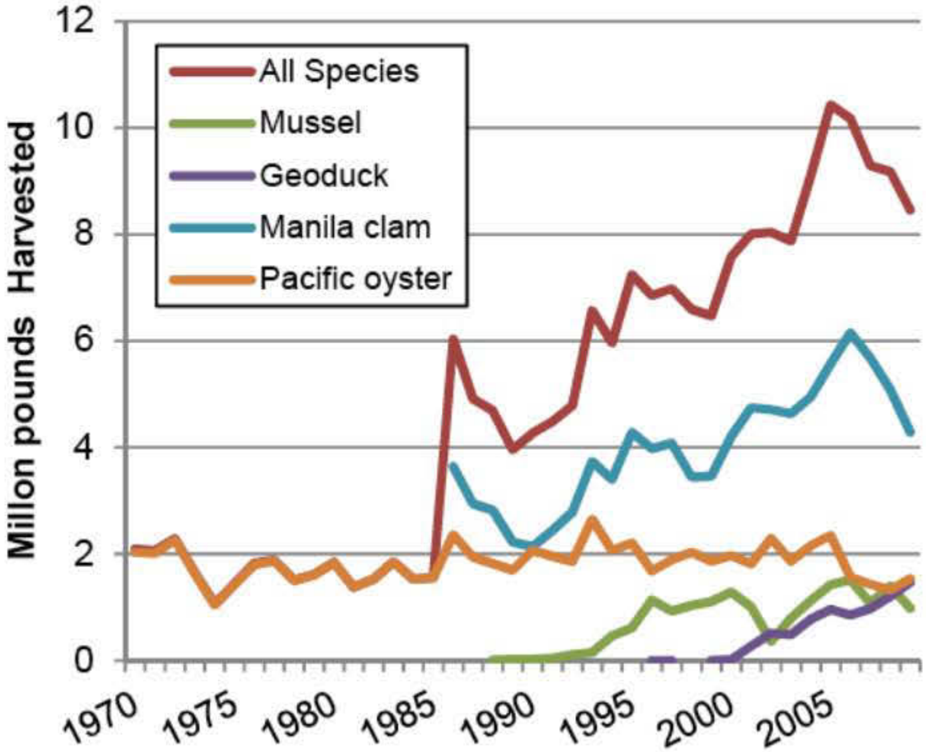
"The maximum production a species or population can maintain in relation to available resources" and "does not cause unacceptable change in the ecosystem"

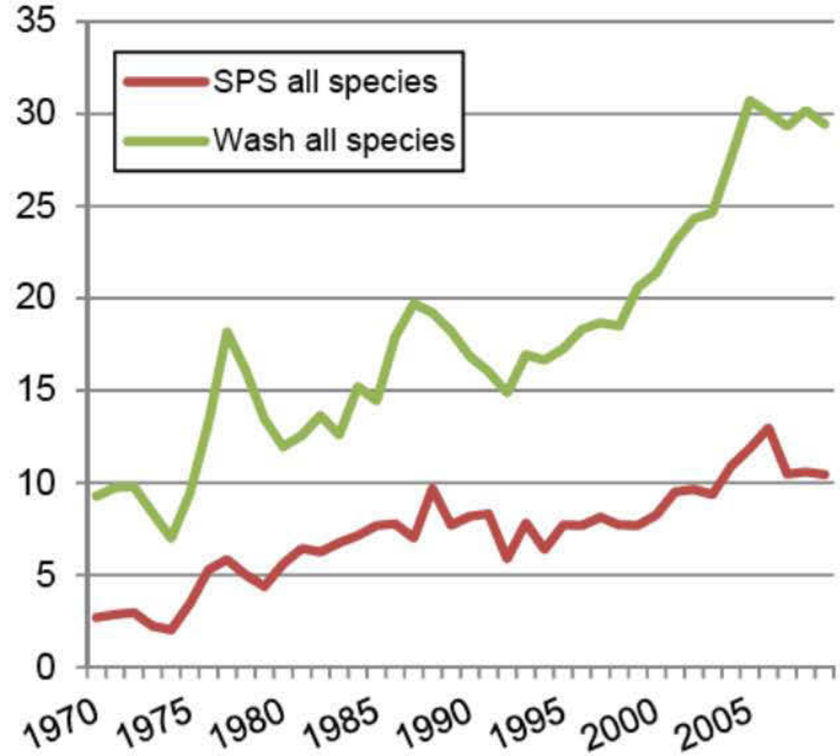
Similar to, but broader in scope to:
"Maximum and optimum sustainable yield"

Carrying Capacity

Early models focused on production carrying capacity (maximum sustained yield) and failed to evaluate the impacts of aquaculture on aquatic food webs or consider the social acceptance of aquaculture activities (optimum sustained yield).

The Expansion of Shellfish Production





Washington State is the largest producer of hatchery-reared and farmed shellfish in the U.S, accounting for 25% of the total domestic production by weight, with an annual farmgate value exceeding $107 million. South Puget Sound produces one third to one-half of Washington's shellfish production.

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Overall Goals for This Project

- To apply an expanded definition of carrying capacity to include interrelated and co-dependent elements of 1) physical, 2) production, 3) ecological and 4) social carrying capacities.
- To assess the bivalve shellfish ecological & social carrying capacity of south Puget Sound
  - Provide tools & information
- To develop recommendations for multi-use spatial or geographic planning
  - Include sustainable shellfish aquaculture

The Research Elements

- Production Carrying Capacity Model
  - Farm Aquaculture Resource Management (FARM)
- Ecological Carrying Capacity Models
  - EcoWin
  - EcoPath with EcoSim
  - ASSETS eutrophication model
- Social Carrying Capacity
  - A public perception survey (combined with EcoSim)

Research Elements
with emphasis on items in red

- Production Carrying Capacity Model
  - Farm Aquaculture Resource Management (FARM)
- Ecological Carrying Capacity Models
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  - EcoPath with EcoSim
  - ASSETS eutrophication model
- Social Carrying Capacity
  - Public perception survey (& EcoSim)

The FARM Model

"Farm Aquaculture Resource Management"

- Production carrying capacity at the farm level
- Analyses of culture location and species in SPS
- Optimization of culture practice
- Timing and sizes for seeding and harvesting
- Environmental assessment of farm-related effects

Described in: Ferreira, Hawkins and Bricker, 2007 – Aquaculture, 264(1-4):160-174

Details and a sample model are at -- http://www.farmscale.org

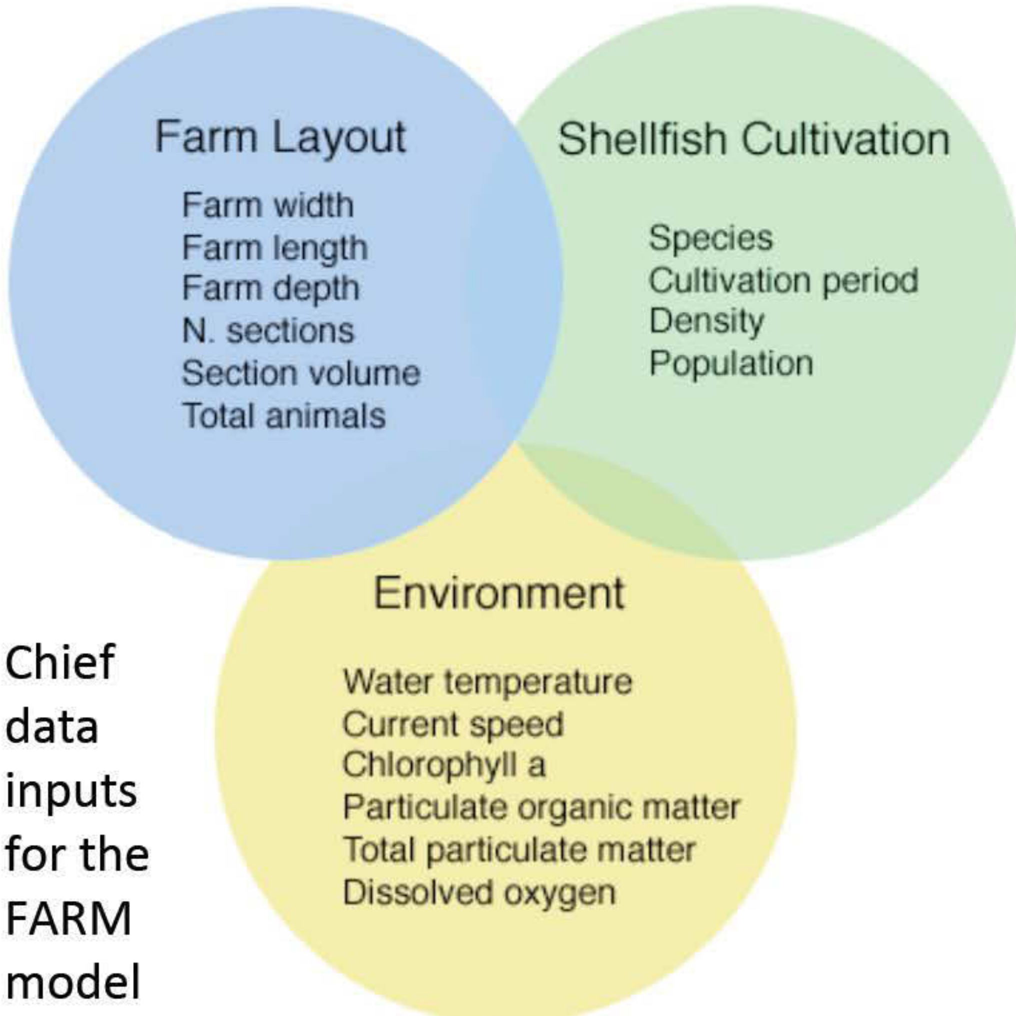
The FARM Model

"Farm Aquaculture Resource Management"

The model is applied to bottom or near-bottom culture, including intertidal areas. It is used to examine the outcomes of different cultivation strategies at a local scale for estimating the role of shellfish farms in nutrient removal, and to provide input data for the potential valuation of nutrient credit from shellfish aquaculture.

Calibrated and validated models are under development for four cultivated SPS species: geoduck, Pacific oyster, Manila clam, and Mediterranean mussel.

Model Components



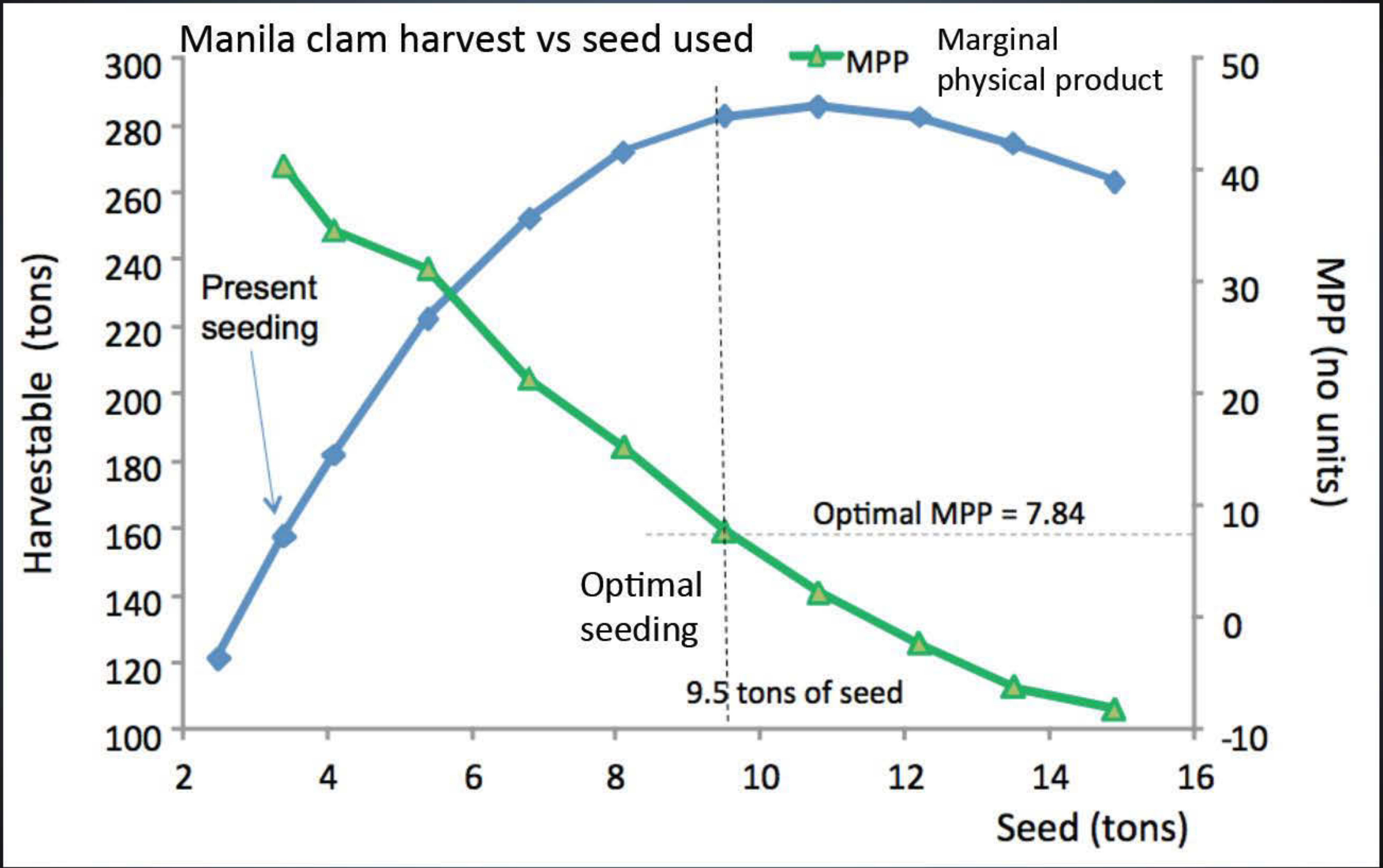
Chief data inputs for the FARM model

Model Outputs

Weight (g)
Length (cm)
Harvest (Tons)
Chlorophyll
POM
TPM
Dissolved oxygen (DO)

Seed
Total physical product (TPP)
Average physical product (APP
Total revenue (TR)
Total cost (TC)
Profit

FARM Production Analysis Example



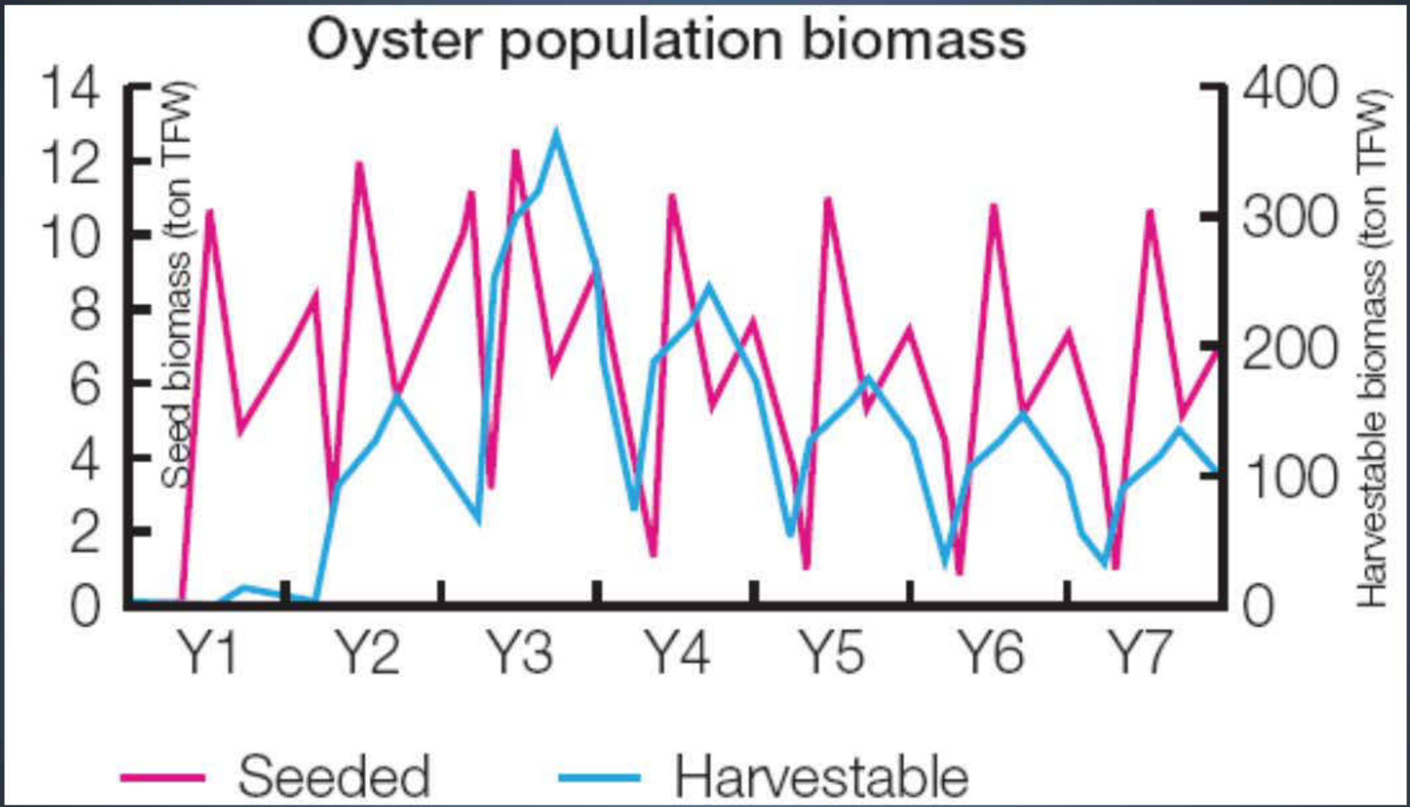
EcoWin

Multiple Farm Modeling in SPS by mid 2015

- Employs outputs from the FARM medels
- Simulates hydrodynamics, water chemistry, and aquaculture production for multiple farms
- Allows 10+ yr simulation
- Uses available Washington Dept. of Ecology data/ models

Further information is available at:
http://ecowin2000.com

EcoWin modeling example



Simulation of seeding and harvest for Pacific oysters in Northern Ireland (courtesy SMILE project -- sustainable mariculture in Northern Irish Lough Ecosystems)

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Ecopath and Ecosim

measuring interactions beyond shellfish cultivation

Ecopath – a snapshot of resources in an ecosystem and their interactions

- trophically linked species or species groups
- models constructed with data or estimates of
  - biomasses,
  - food consumption/production, and
  - mortality rates

data requirements are relatively simple, and data is often already available from stock assessment, ecological studies, or literature: biomass estimates, total mortality estimates, consumption estimates, diet compositions, and fishery catches.

Further information at: www.ecopath.org

Ecopath and Ecosim

Ecosim - a time dynamic (years) simulation

For policy issues Ecosim can be set to explore or simulate:

- Aquaculture profits
- Social benefits
- Restoration of species
- Ecosystem structure or 'health'

Ecosim is a dynamic simulation at the ecosystem level, with key initial parameters inherited from a base Ecopath model.

Ecopath & Ecosim Applications

30+ years in development.

100's of worldwide models, and 1000's of users; but complicated and demanding of a firm understanding by the user

Some examples –

Rhode Island: response to rapid increase in aquaculture and concerns of wild clam harvesters.

Byron et al. (2011a, b and c)

Modeling Carrying Capacity of Cultured Shellfish in Rhode Island, USA Using Ecopath

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(CIIP)

Marine Policy 35 (2011) 363–370

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Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Integrating science into management: Ecological carrying capacity of bivalve shellfish aquaculture

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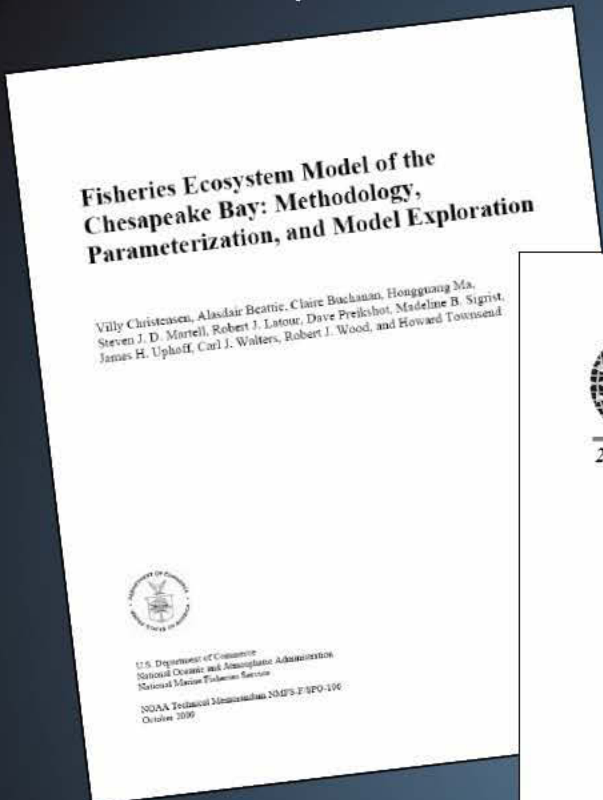
ABSTRACT

Ecosystem-based management (EBM), despite the best efforts of managers, researchers, and policy makers, often falls short of its intended purpose resulting in inadequate protection of resources. Coastal habitats are particularly vulnerable to poor management due to high use and potential for user conflict. EBM can be improved when it is informed by ecological science and considers the socio-economic needs of the community. Communication between scientists and stakeholders can help to prevent adverse outcomes while enhancing protection and sustainability of the coastal environment. In the research presented here, a framework is used to guide and enhance communication between scientists and stakeholders for sustainable management of resources and equity of all users. The outcome of this applied framework is a long-term plan to guide the management of an oyster aquaculture industry using carrying capacity as an estimate for the basis of management decisions. Central to the framework is the Working Group on Aquaculture Regulations (WGAR), which represents a diverse group of stakeholders. The WGAR worked closely with ecological modelers over a two-year period using mass-balance modeling to calculate ecological carrying capacity for oyster aquaculture in two ecosystems: Narragansett Bay and a set of highly flushed temperate lagoons in Rhode Island, USA. Collaboration between scientists and the WGAR greatly improved the models and stakeholder understanding of the science and acceptance of the results. Aquaculture is increasing in coastal regions world-wide and this framework should be easily transferable to other areas suffering from similar user conflict issues.

More Examples

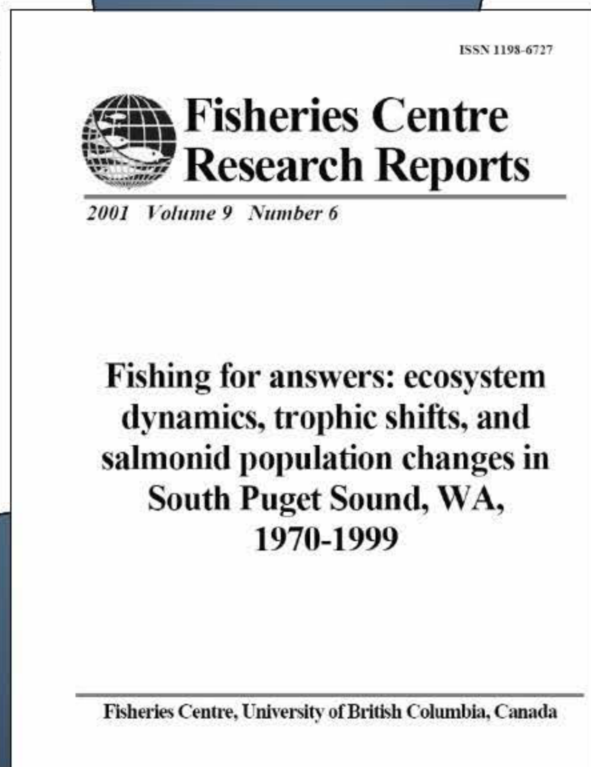


Fisheries Ecosystem Model of the Chesapeake Bay: Methodology, Parameterization, and Model Exploration

Villy Christensen, Alasdair Beattie, Claire Buchanan, Hongguang Ma, Steven J. D. Martell, Robert J. Latour, Dave Preikshot, Madeline B. Sigrist, James H. Uphoff, Carl J. Walters, Robert J. Wood, and Howard Townsend

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-F/SPO-106
October 2009



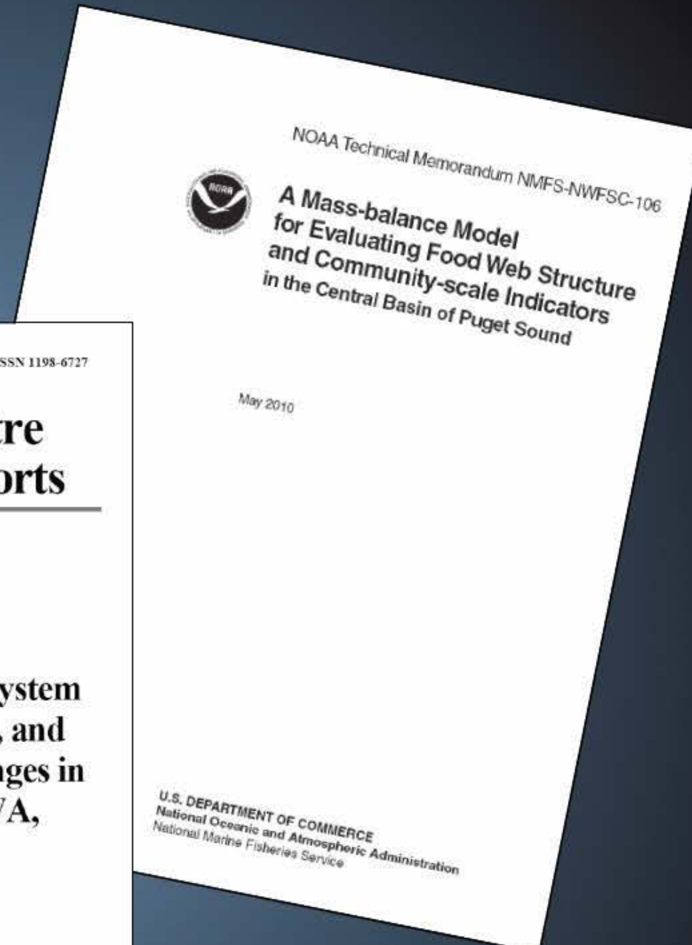
ISSN 1198-6727

Fisheries Centre Research Reports

2001 Volume 9 Number 6

Fishing for answers: ecosystem dynamics, trophic shifts, and salmonid population changes in South Puget Sound, WA, 1970-1999

Fisheries Centre, University of British Columbia, Canada



NOAA Technical Memorandum NMFS-NWFSC-106

A Mass-balance Model for Evaluating Food Web Structure and Community-scale Indicators in the Central Basin of Puget Sound

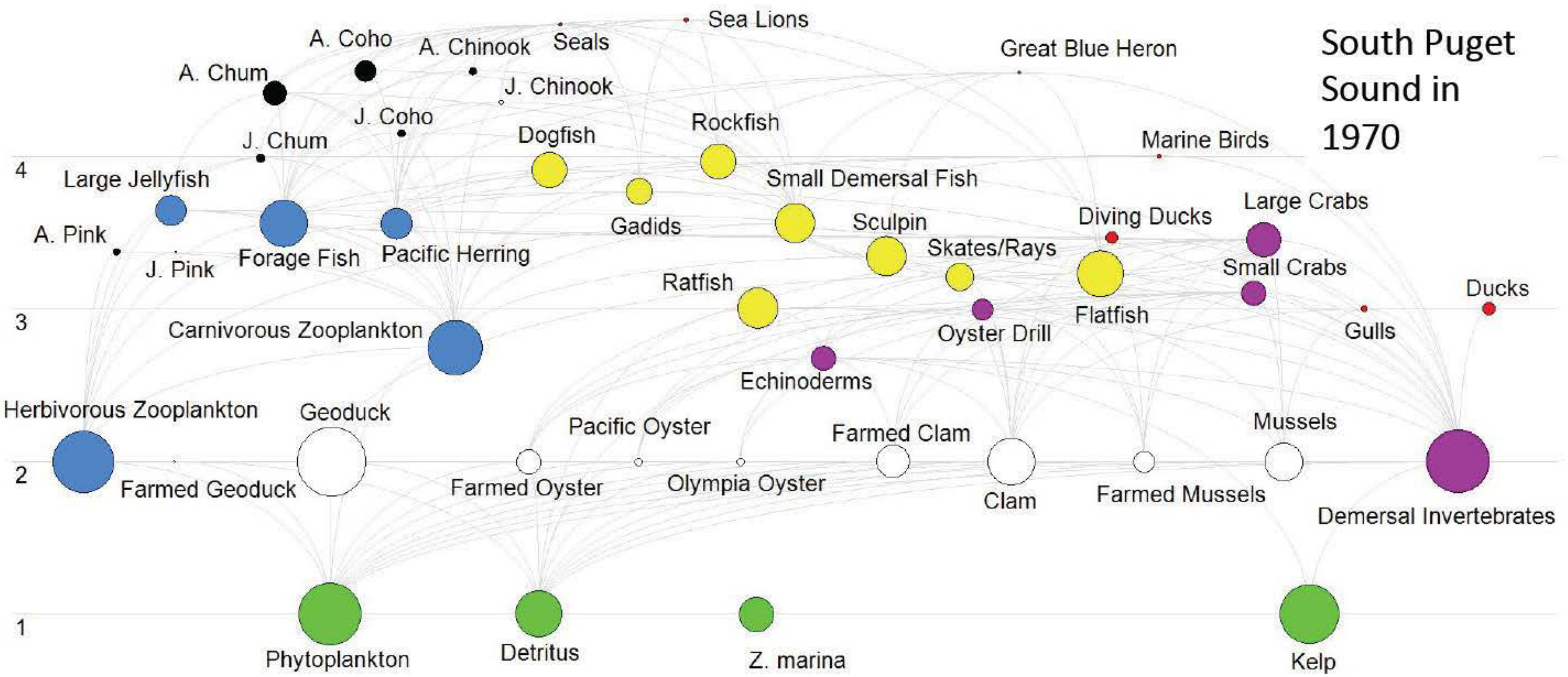
May 2010

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

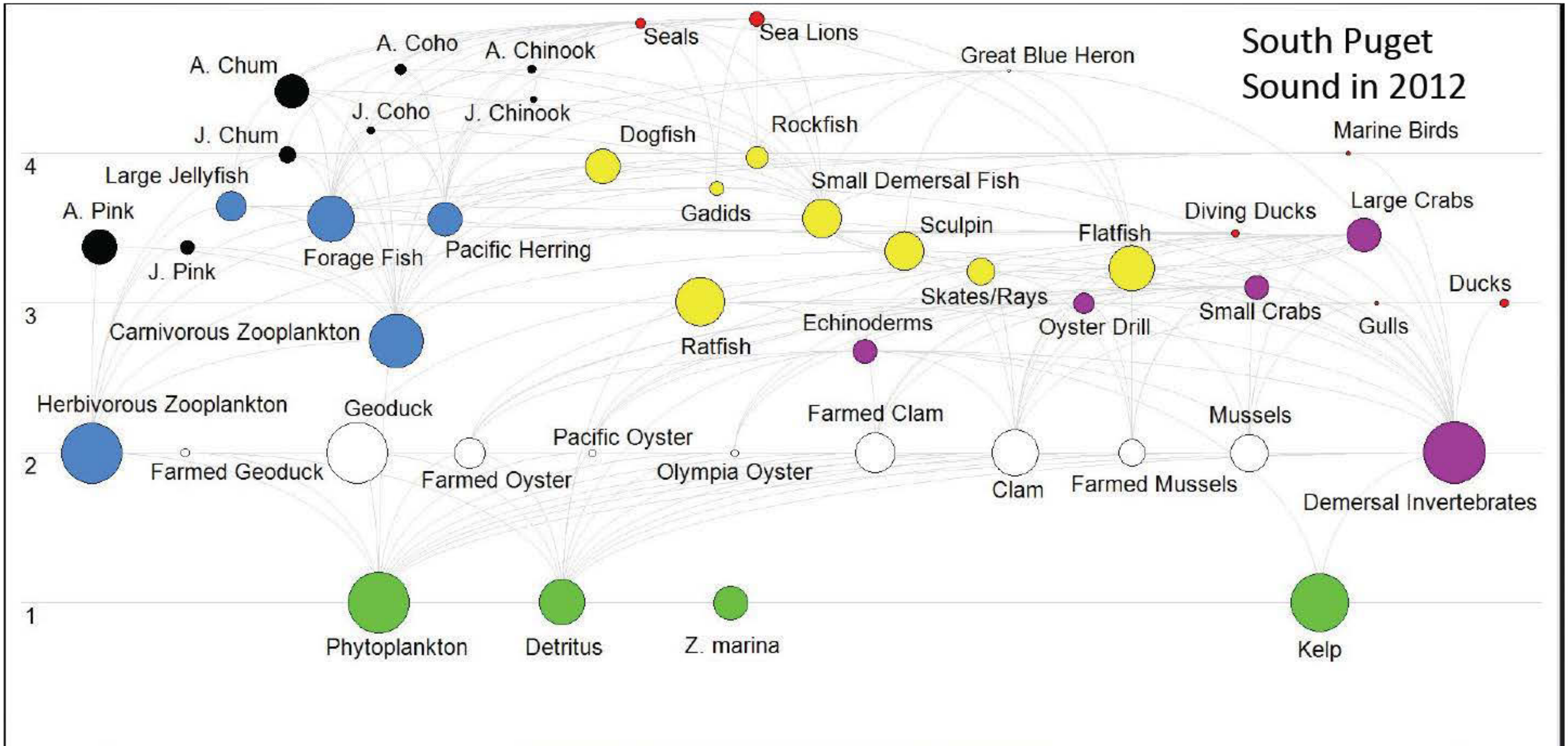
Project Ecopath Modeling in SPS

Currently Underway (late 2014)

- A multi-trophic look at the animals and plants in our south Puget Sound marine ecosystem, and
- A stakeholder-guided process to:
  - Gather the best data (population/biomass)
  - Ask the right questions (scenario development)



Graphic was generated from Ecopath modeling software. Numbers on the left are trophic level. Lines indicate biomass flowing from prey to predators. Groups are color coded as follows: *green - primary producers and detritus; white – bivalves; blue – zooplankton and planktivores; purple – benthic invertebrates; yellow – bottom and midwater fish; black – salmonids; red - mammals and birds*



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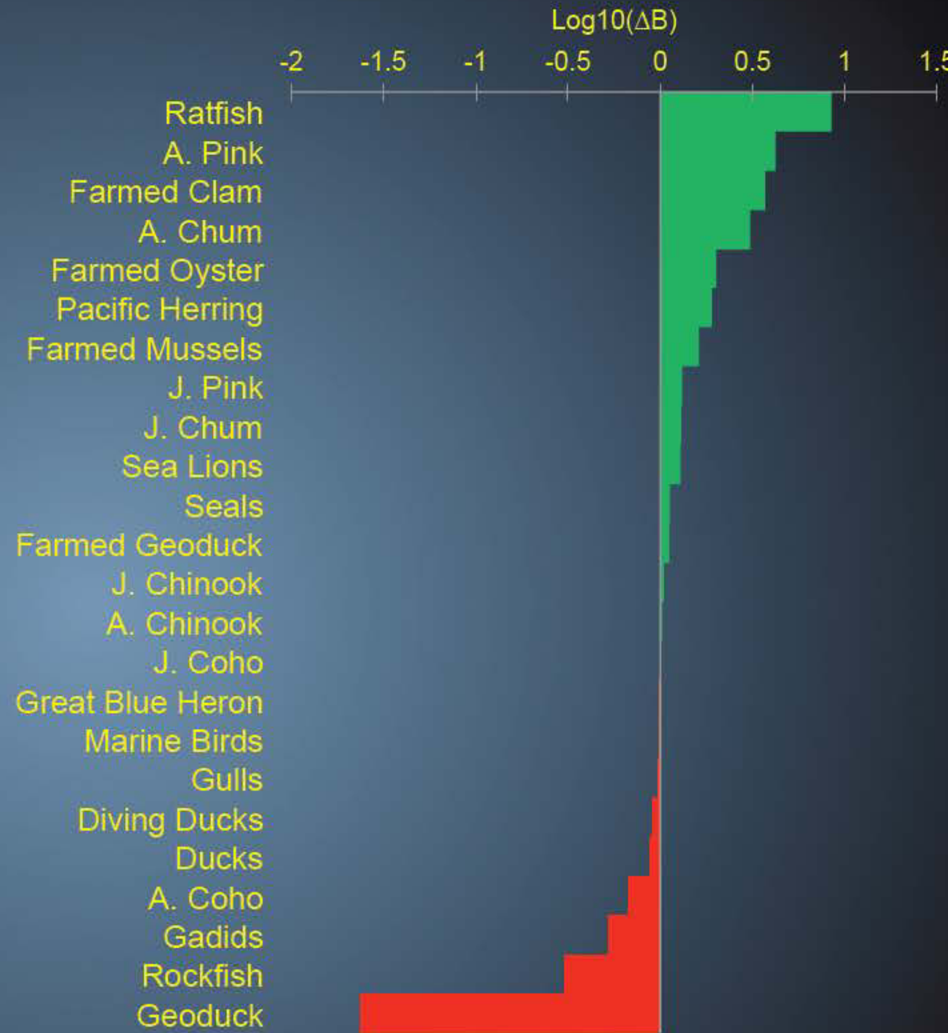
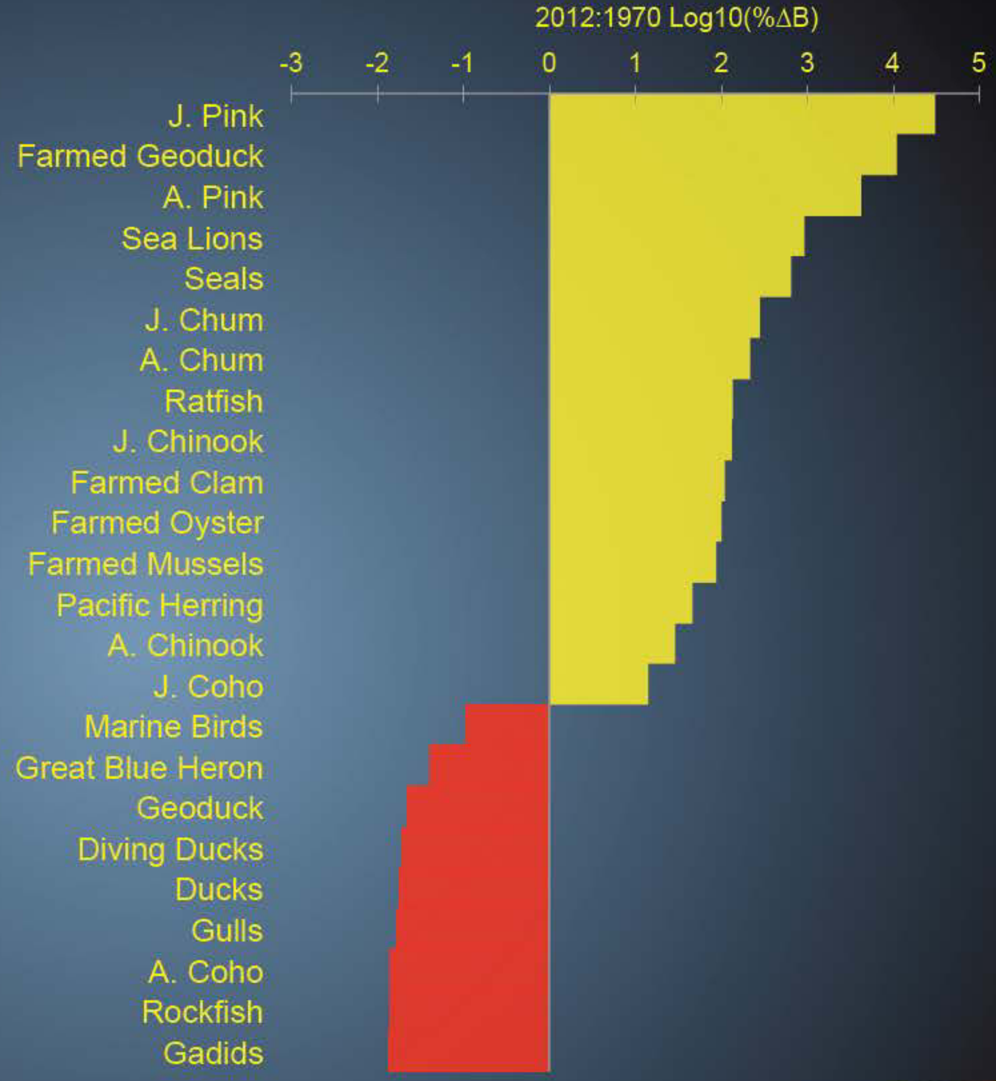
Ecopath Model Output for Major Animal Assemblages

- 2012 vs 1970 absolute change of biomasses
- Log scale: 1=10t/km^2 change
- Big increase for Ratfish, Adult Pink and Chum Salmon, and Farmed Bivalves
- Big decline for Wild Geoducks, Rockfish, and Gadids.



Ecopath Model Output for Major Animal Assemblages

- 2012 relative to 1970 % change in biomass
- Log scale: 3=100% change
- Big increase for Pink Salmon, Seals, Sea Lions, Ratfish, Farmed Bivalves
- Big decline for most bird groups, Coho salmon, Rockfish, and Gadids.



Selected Ecosim Simulations

- 50% increase and 25% decrease in annual average phytoplankton or macroalgae biomass
- 100% increase and 50% decrease in seagrass biomass
- Change in mediating factor to reflect a shift in shellfish growout practices
- Increase shellfish aquaculture production (all or some species) by various amounts (2x to 10x).
- 100% increase/50% decrease of jellyfish biomass
- Others may follow.

Anticipated Outcomes by Fall 2015

- Completed models – FARM, EcoWin, Ecopath, EcoSim and Assets
- Guidance regarding the potential applications of ecological models and scenario development
- Increased understanding of ecosystem interactions in south Puget Sound
- Improved understanding of trade-offs & environmental impacts of shellfish aquaculture
- Enhanced decision-maker capacity to plan for sustainable shellfish aquaculture

Project Work Group

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David Fyfe, NWIFC

Bill Dewey and Joth Davis, Taylor Shellfish

+ Our Stakeholder Volunteers

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