Towards end-to-end modeling for investigating the effects of climate and fishing in the Strait of Georgia ecosystem, Canada

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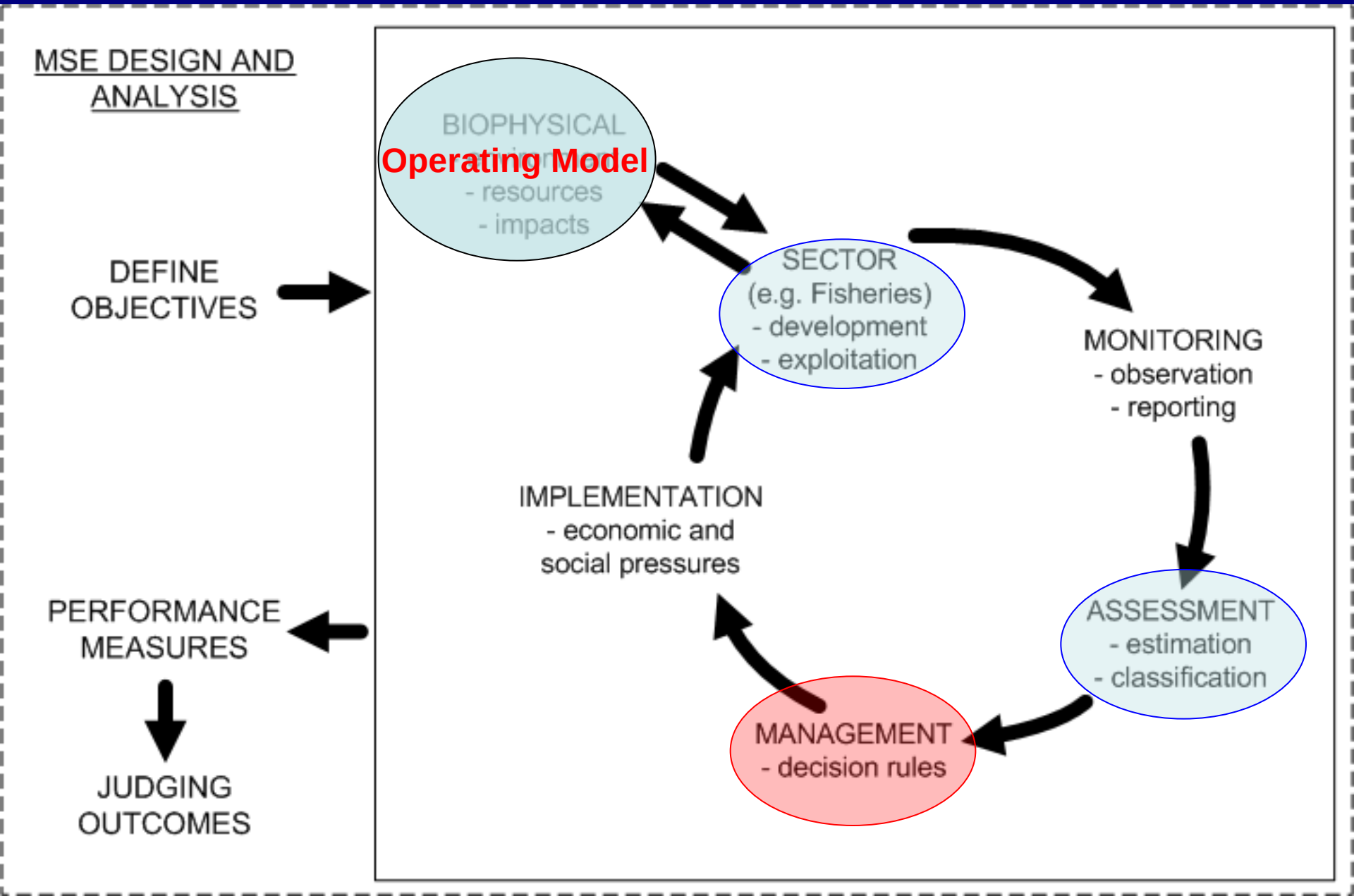
Work in progress

Funded by Fisheries and Oceans Canada under Ecosystem Research Initiative for the Pacific Region

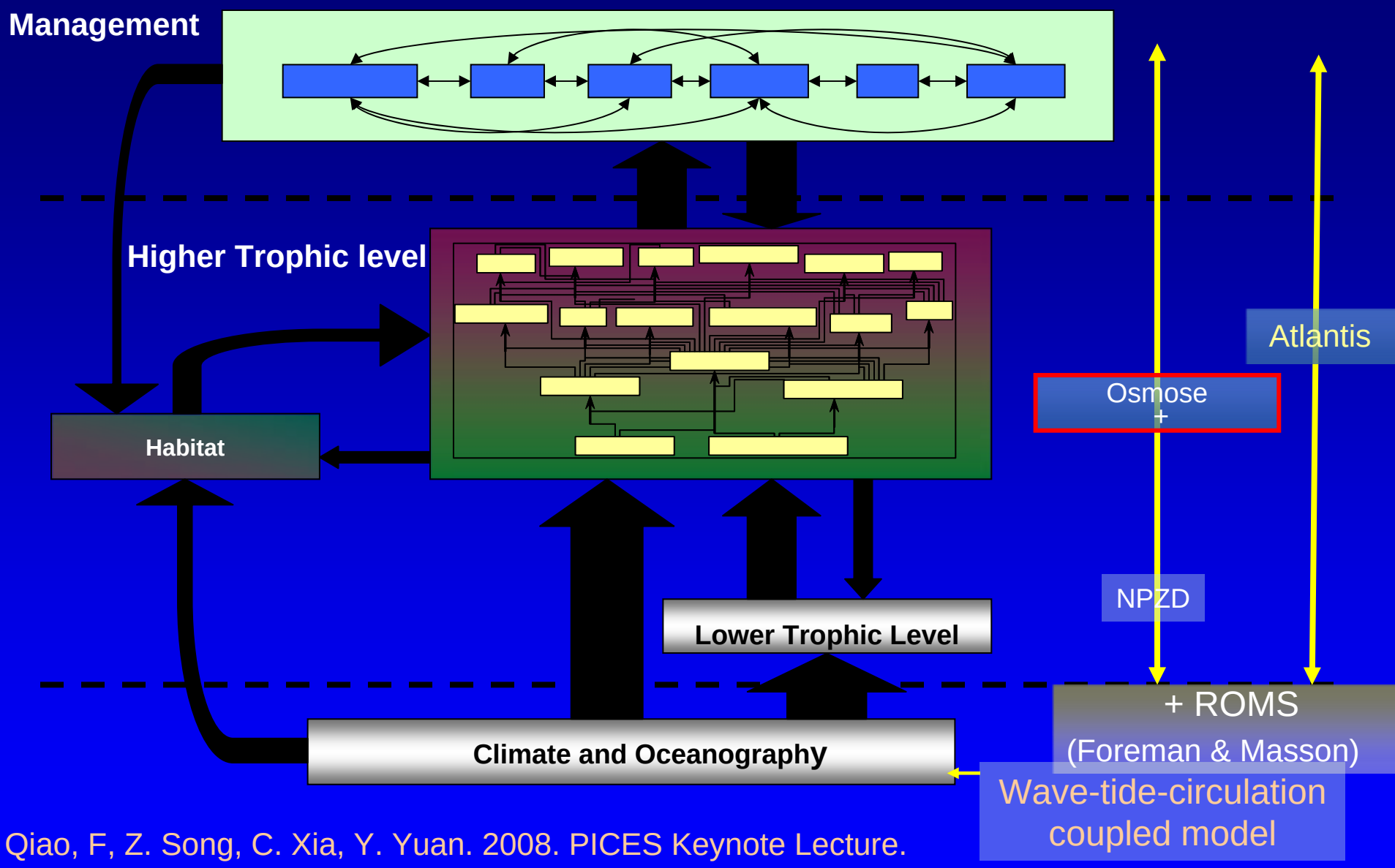
Fisheries and Oceans Canada

IRD Institut de recherche pour le développement

Management Strategy Evaluation (MSE)



End-to-end modelling



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OSMOSE (Object-oriented Simulator of Marine ecOSystems Exploitation)

-----Individual-based model (IBM), multi-species, structured by size.

Class SYSTEM

- abundance, biomass
- species richness **S**
- carrying capacity
- size spectrum
- **S species**

Class SPECIES

- abundance, biomass
- growth parameters
- reproduction parameters
- distribution area/age
- fishing mortality/age
- **(longevity+1) cohorts**

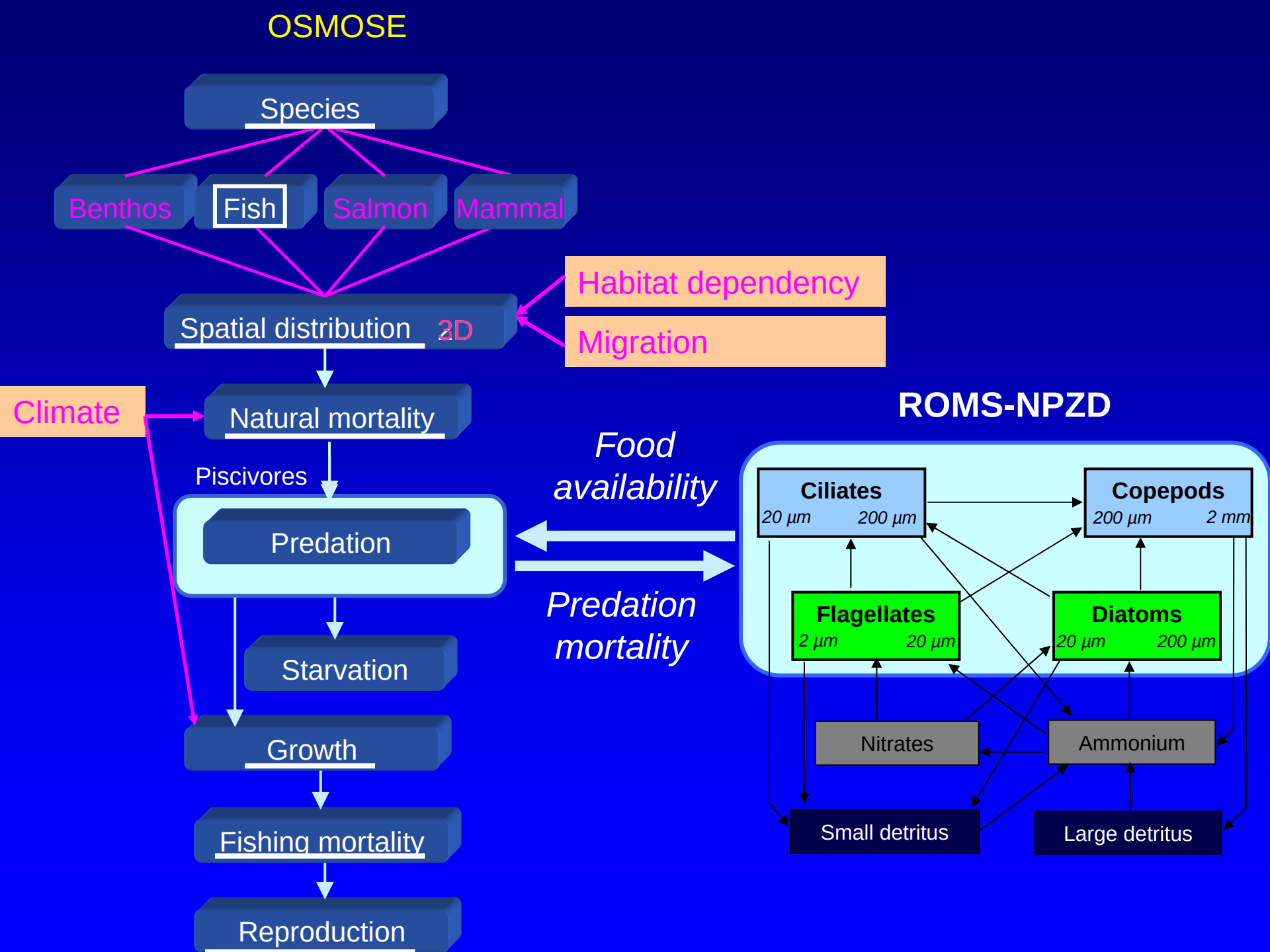
Class COHORT

- species
- abund., biomass
- **n schools**

Class SCHOOL

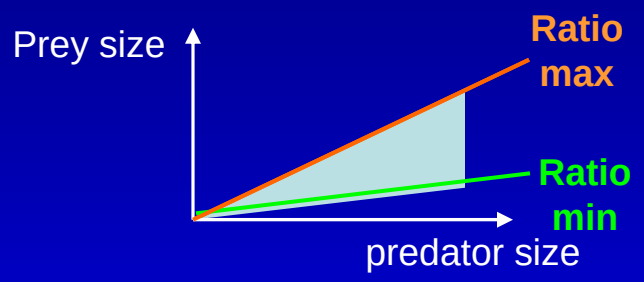
- species, age
- abundance, biomass
- spatial coordinates
- length, weight
- predation efficiency

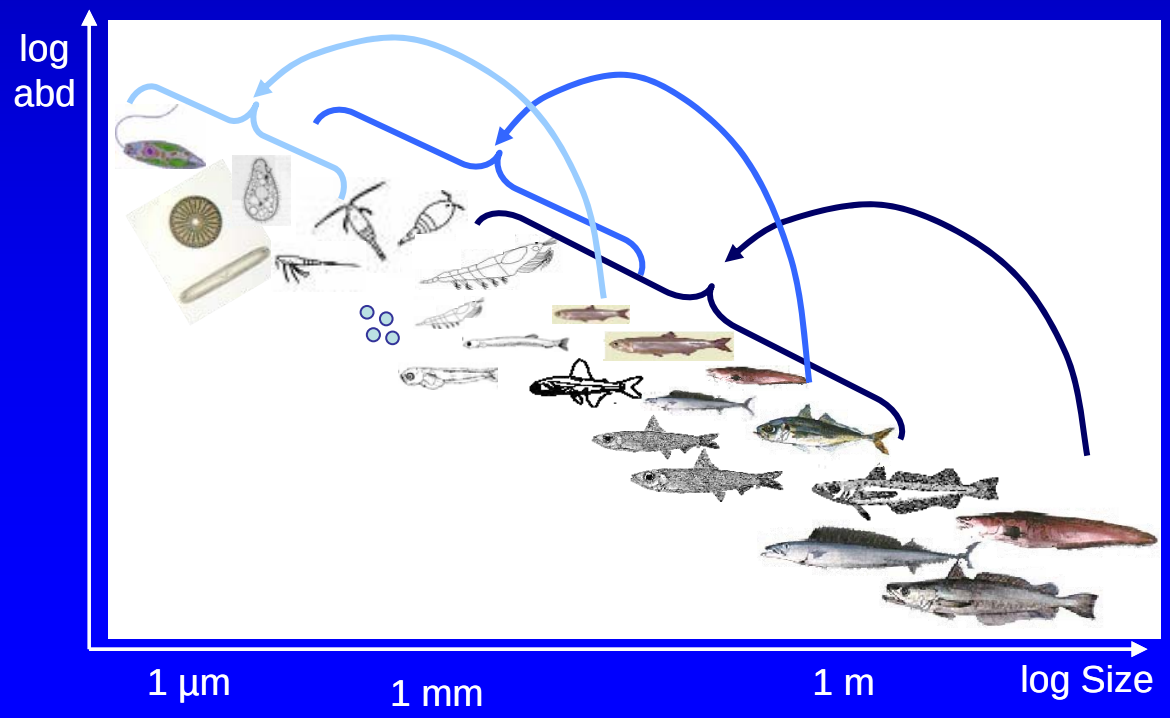
(Shin & Cury 2001, Aquat. Living Resour. 14: 65-80.)


OSMOSE
Species
Benthos
Fish
Salmon
Mammal
Habitat dependency
Spatial distribution
3D
Migration
Climate
Natural mortality
Piscivores
Predation
Starvation
Growth
Fishing mortality
Reproduction
Food availability
Predation mortality
ROMS-NPZD
Ciliates
20 µm
200 µm
Copepods
200 µm
2 mm
Flagellates
2 µm
20 µm
Diatoms
20 µm
200 µm
Nitrates
Ammonium
Small detritus
Large detritus

Size-based predation

1- Thresholds for predator/prey size ratio
2- Maximum ingestion rate
3- Spatial-temporal co-occurance





→ Modelled food webs are variable in structure

→ Opportunistic predation

↓

Predation efficiency ξ

Fish life cycle

Spatial distribution

↓

Natural mortality

Piscivores ↓

Predation

ξ ↓

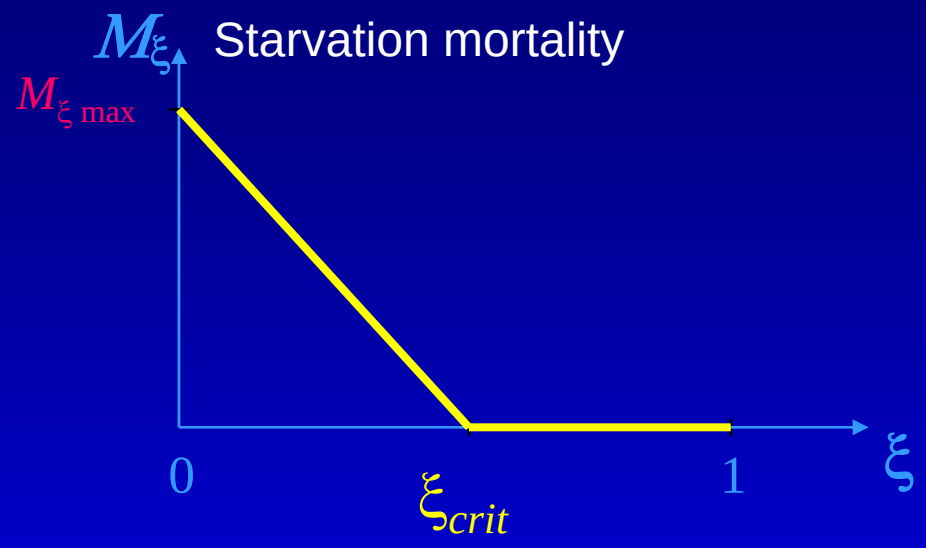
Starvation

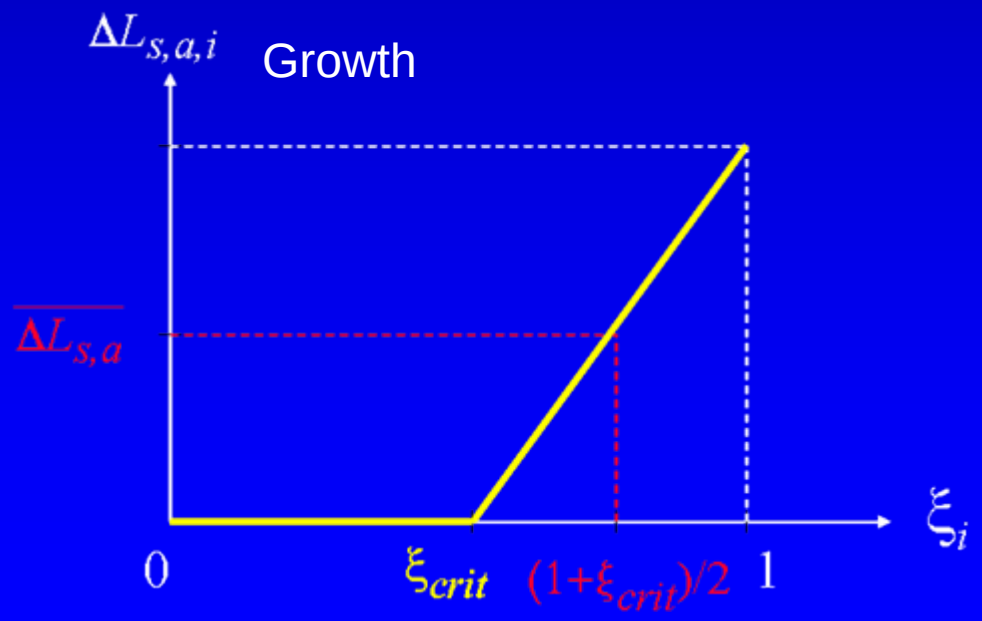
ξ

Growth

ξ= Predation efficiency

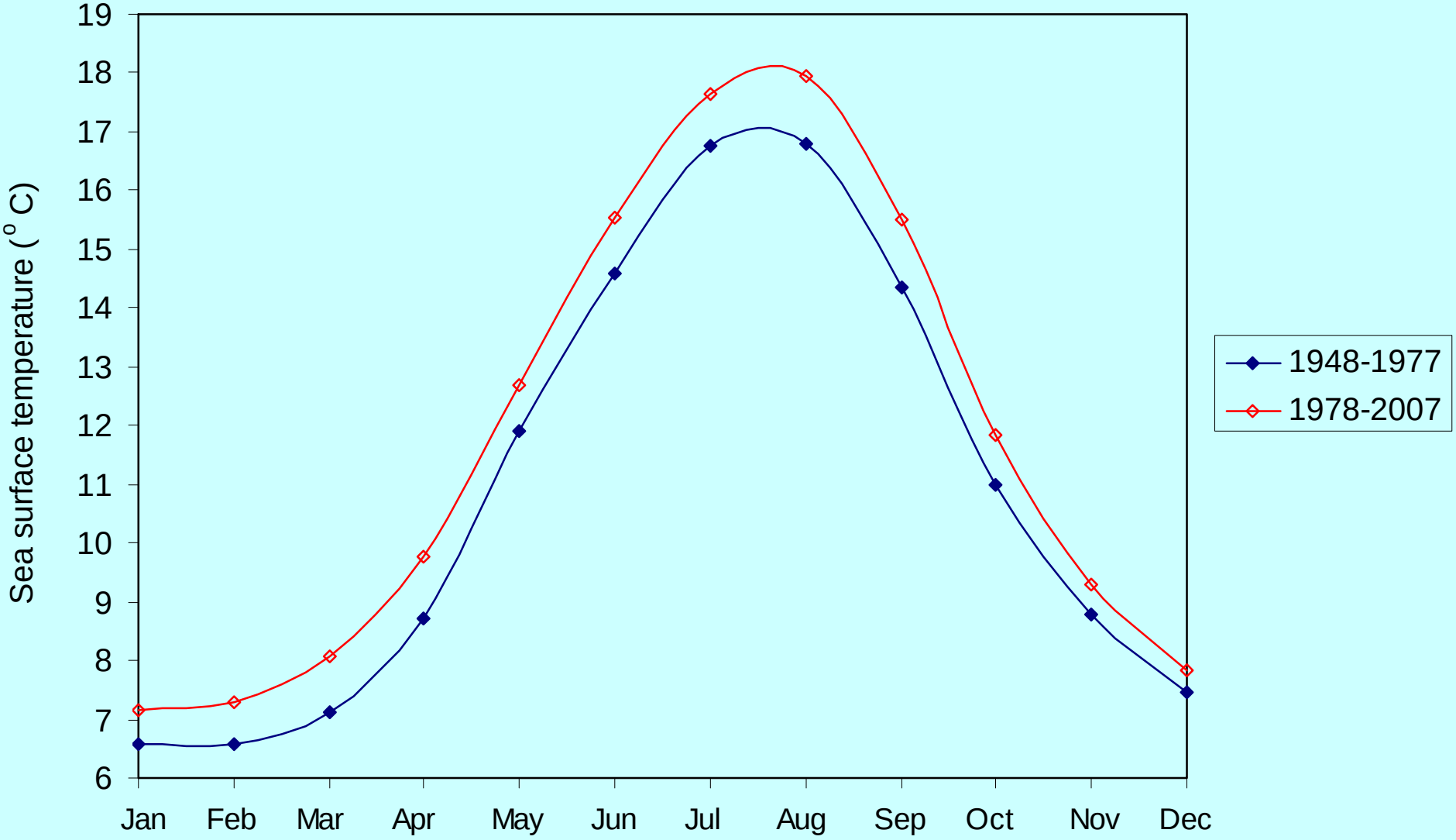
$$\xi_{crit} = \frac{\text{ration for maintenance}}{\text{maximal ration}}$$





Microsoft MapPoint
Cordova
Mount St. Elias 18,008 ft
YUKON TERR.
NORTHWEST TERRITORIES
Whitehorse
Mount Fairweather 4663 m (15,299 ft)
Juneau
Sitka
Gulf of Alaska
Thompson
MANITOBA
CANADA
ALBERTA
SASK.
ALAS.
Prince George
Prince Rupert
Edmonton
Saskatoon
BRITISH COLUMBIA
Regina
Calgary
Mount Waddington 4016 m (13,176 ft)
N. DAK.
Vancouver
MONTANA
Bismarck
Strait of Georgia
Seattle
Spokane
Great Falls
S. DAK.
WASHINGTON
Helena
Billings
Portland
Walla Walla
Grand Teton 13,771 ft
Boise
WYOMING
NEBR.
Eugene
PACIFIC OCEAN
UNITED STATES
GREAT
Denver
Colorado Springs
Sacramento
Reno
BASIN
Santa Fe
San Francisco
Fresno
Las Vegas
NEW MEXICO
Bakersfield
Los Angeles
Phoenix
©2008 Microsoft Corp.
160°
155°
150°
135°
130°
125°
120°
115°
110°
55°
95°
50°
45°
100°
40°
35°

Water temperature changes in the Strait of Georgia



Changes in fish community in the Strait of Georgia

- **Pacific hake dominates the resident fish biomass.**
- **Pacific herring are at high abundance.**
- **Harbour seal biomass has tripled.**
- **Groundfish species such as Pacific cod are nearly absent**

Research questions

- What has driven these changes in the strait, climate change? fishing?...
- What will the strait be like in the future?
- How can we manage marine resources under changing environment?

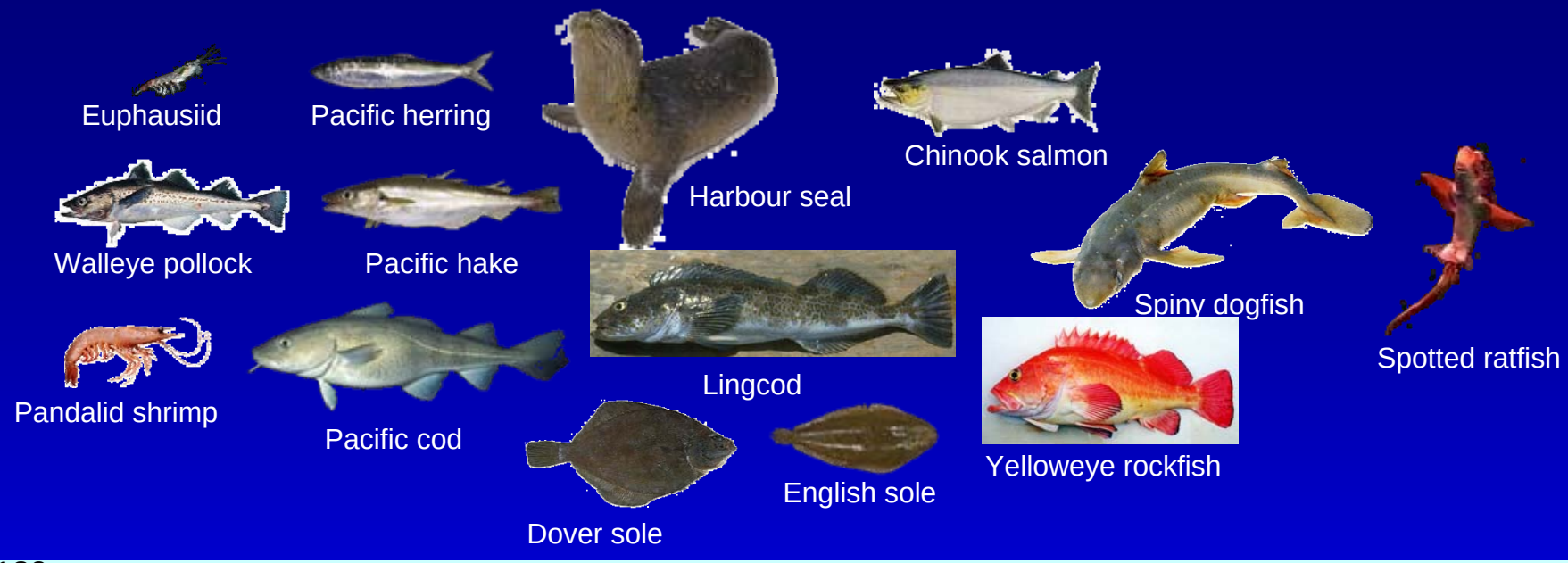
Application of OSMOSE to the Strait of Georgia

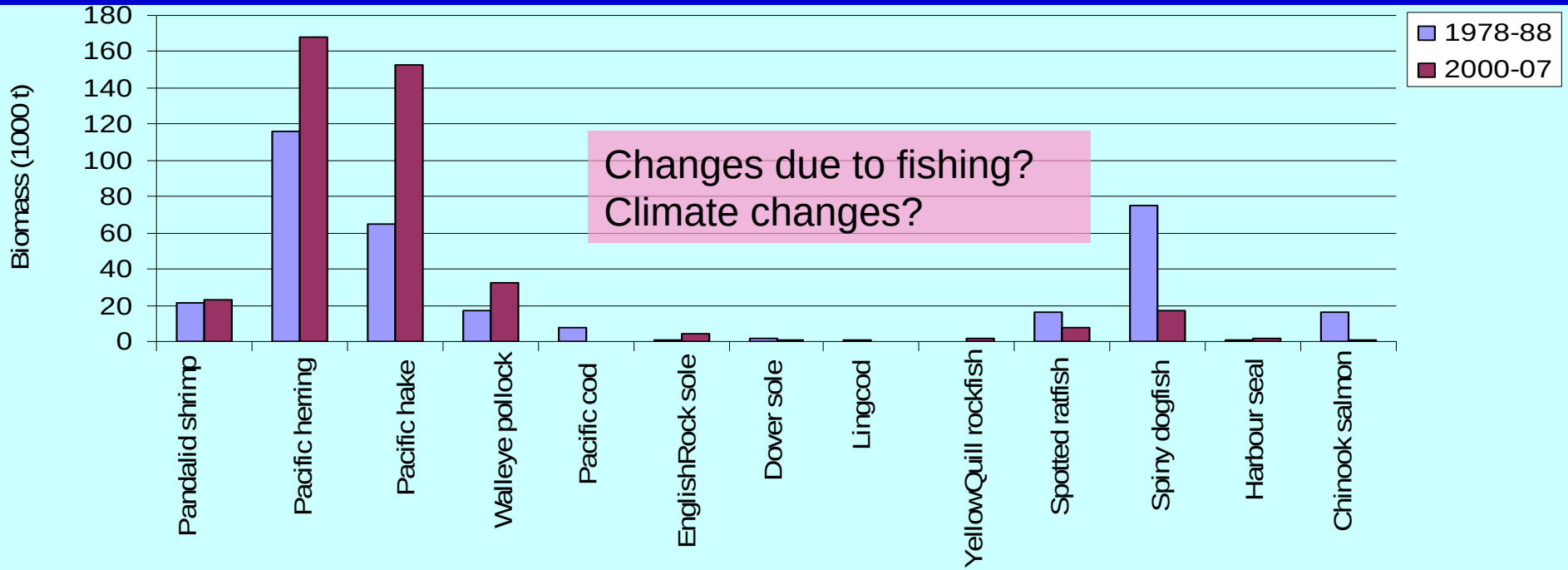
Selecting 14 key species in the model

Criteria:

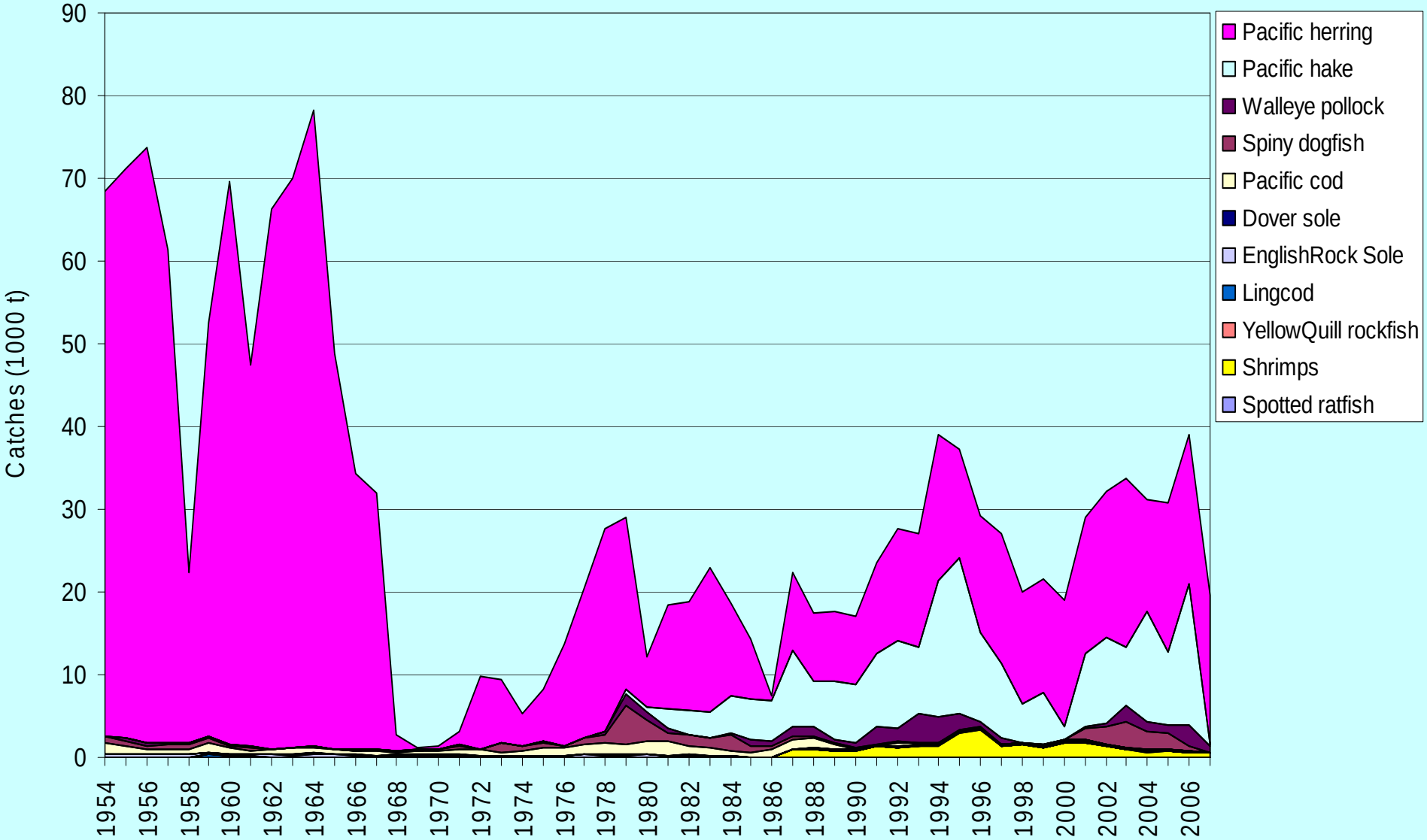
- ✓ commercial interest (>90%)
- ✓ importance in biomass (>70%)
- ✓ perceived ecological significance

Key species from the Strait of Georgia





Commercial catches from the Strait of Georgia



Inputs for OSMOSE model

1. Habitat maps
2. Water temperature over time and optimal level for larval survival and growth
3. Migration patterns
4. Fishing and reproduction seasonality
5. Spatial distributions of OSMOSE species (grids of 4km x 4km)
6. Biological parameters

	Growth					Reproduction		Survival			
Species	$L_\infty(cm)$	$k(year^{-1})$	$t_0(year)$	$a(g \cdot cm^{-3})$	b	$\varphi(eggs \cdot g^{-1})$	$A_{mat}(year)$	$A_{max}(year)$	$A_{rec}(year)$	$M(year^{-1})$	$F(year^{-1})$
Euphausiids	1.84	1.680	-0.200	0.0091	2.920	24469	1	2	1	1.151	0.004
Pandalid shrimp	15.50	0.924	0.232	0.0006	3.069	345	2	4	2	0.576	0.100
Pacific herring	26.30	0.360	-0.030	0.0070	3.000	200	3	10	3	0.230	0.200
Pacific hake	44.50	0.457	-0.173	0.0007	2.997	108	4	12	4	0.192	0.100
Walleye pollock	44.50	0.918	0.575	0.0053	2.441	938	4	8	3	0.288	0.100
Pacific cod	87.50	0.387	-0.010	0.0074	3.096	564	3	8	3	0.288	0.288
EnglishRock sole	37.55	0.311	-0.279	0.0071	3.125	1231	4	21	4	0.110	0.110
Dover sole	50.17	0.081	-4.688	0.0041	3.250	97	9	50	7	0.046	0.046
Lingcod	90.50	0.215	-1.150	0.0004	3.217	26	5	17	4	0.135	0.096
YellowQuill rockfish	64.53	0.040	-15.472	0.0114	3.126	4116	16	106	17	0.022	0.022
Spotted ratfish	79.00	0.196	0.000	0.0067	3.013	2 (per ♀)	5	15	3	0.154	0.001
Spiny dogfish	105.52	0.055	-4.279	0.0025	3.060	7.2 (per ♀)	12	85	10	0.027	0.021
Harbour seal	150.22	0.632	-1.523	0.0113	3.116	1 (per ♀)	4	25	1	0.092	0.092
Chinook salmon	64.0	0.800	-0.300	0.0100	3.000	2	3	5	2	0.461	0.461

Calibration targets

Species	Biomass (tonnes) (1978 – 1988)	Biomass (tonnes) (2000 – 2007)
Euphausiids	227874.04	227874.04
Pandalid shrimp	21451.76	22803.11
Pacific herring	116232.27	168386.36
Pacific hake	64478.10	153034.49
Walleye pollock	17011.65	32280.82
Pacific cod	7471.33	74.70
EnglishRock sole	1094.27	4285.48
Dover sole	1935.35	1161.45
Lingcod	881.92	133.78
YellowQuill rockfish	403.17	1397.84
Spotted ratfish	16581.09	7620.18
Spiny dogfish	75075.71	17188.48
Harbour seal	637.25	2040.00
Chinook salmon	16425.17	653.26

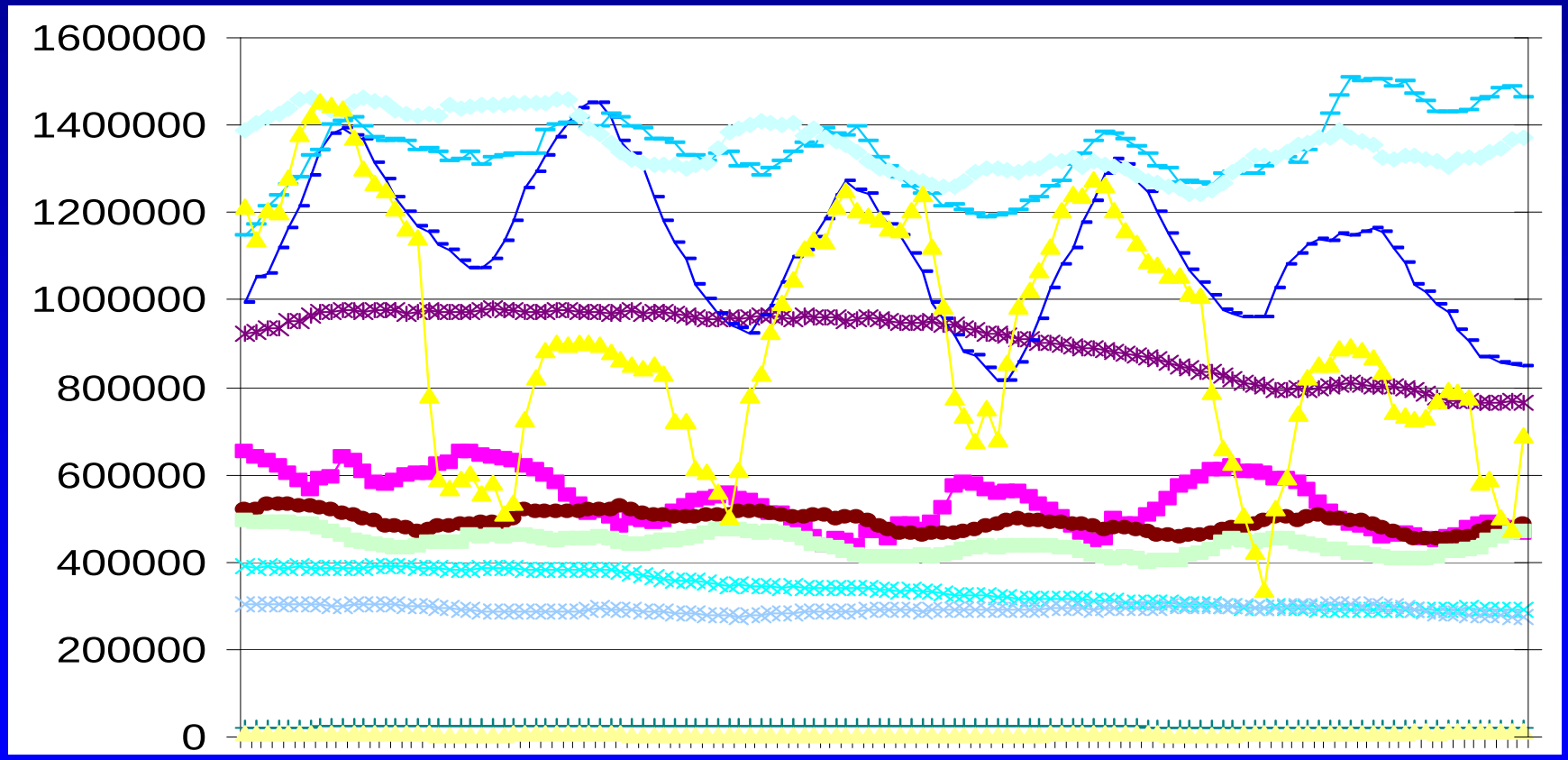
- Tuning parameters include larval mortality for each species and accessibility coefficient for each plankton compartment.
- Calibration is done by using a genetic algorithm specifically developed for OSMOSE (Shin *et al*. in review)

Questions to be addressed through OSMOSE simulations

- What if water temperature increased by another degree
- What if herring were removed from the system
- What if harbour seals were removed
- What if Pacific cod were not fished but climate was not favorable
- What if Pacific cod were not fished but climate was favorable

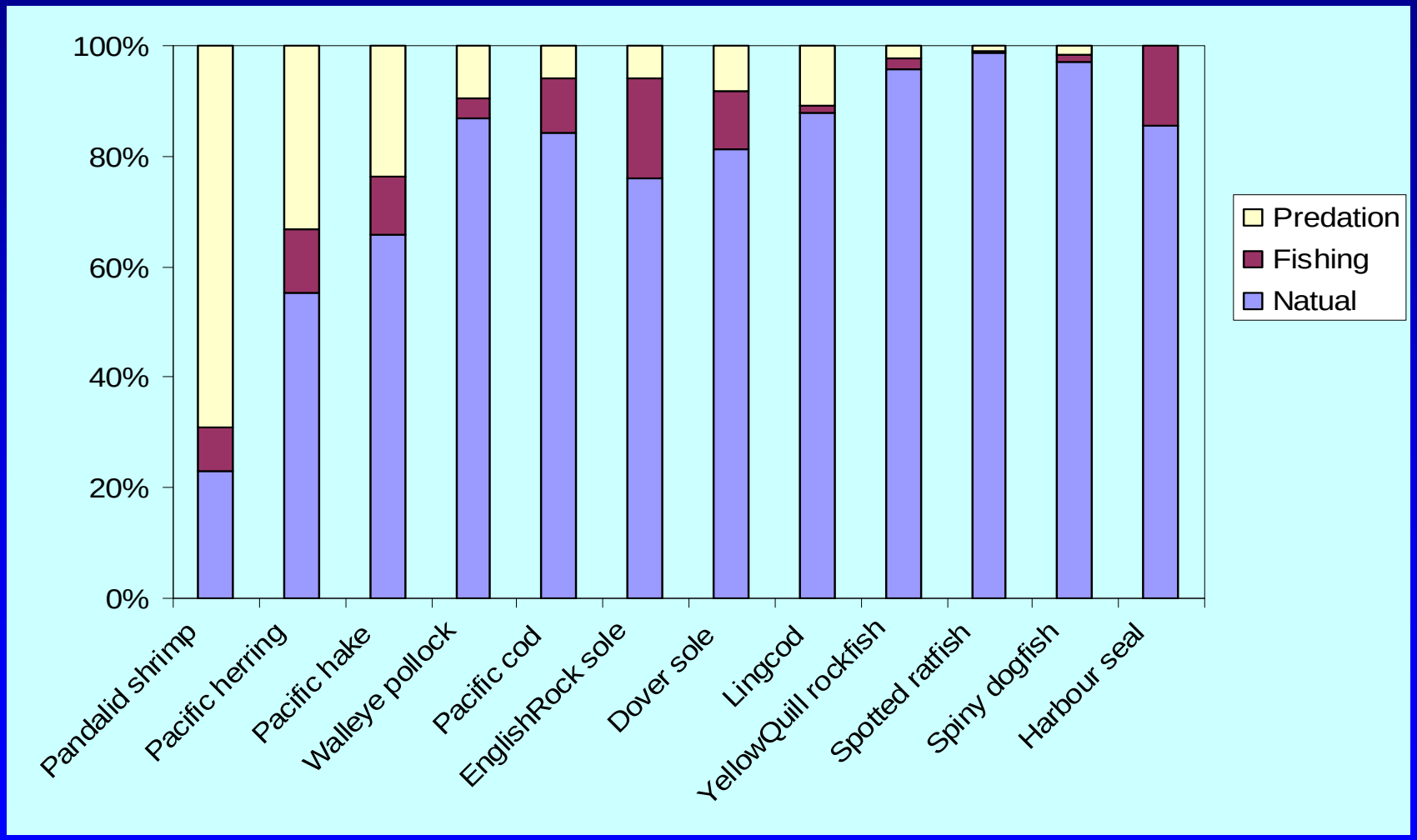
Examples of Output

Population biomass



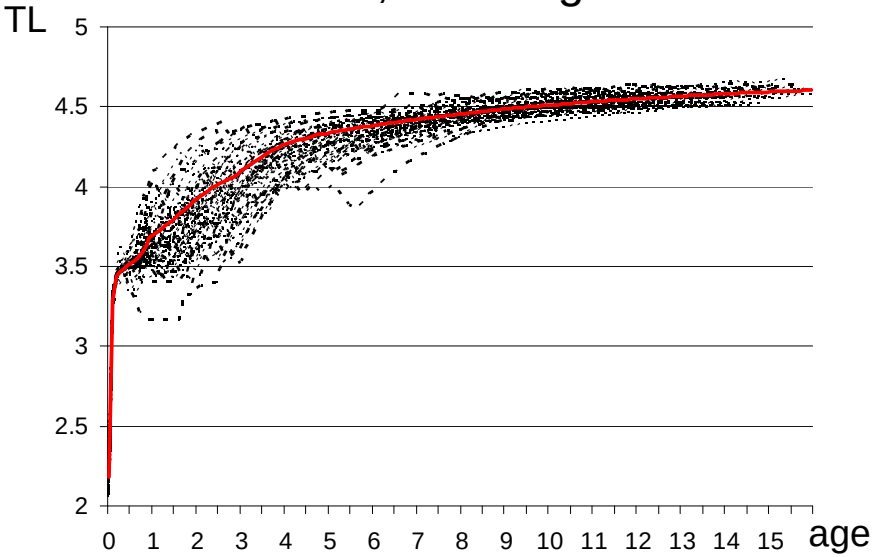
Time Step

Biomass loss due to each cause

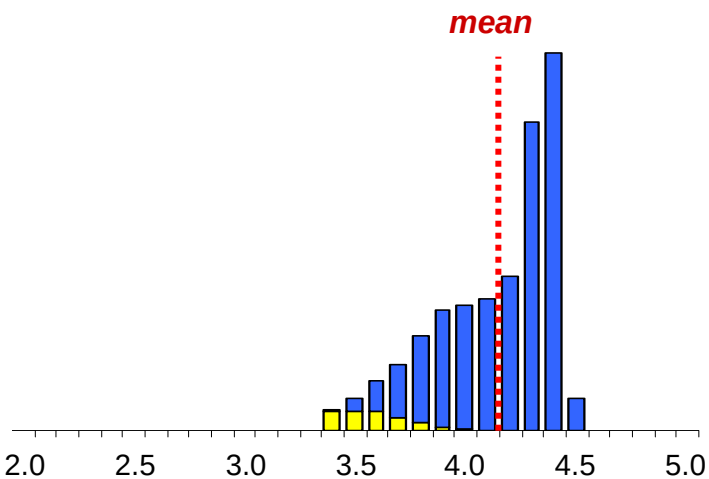


Trophodynamic indicators

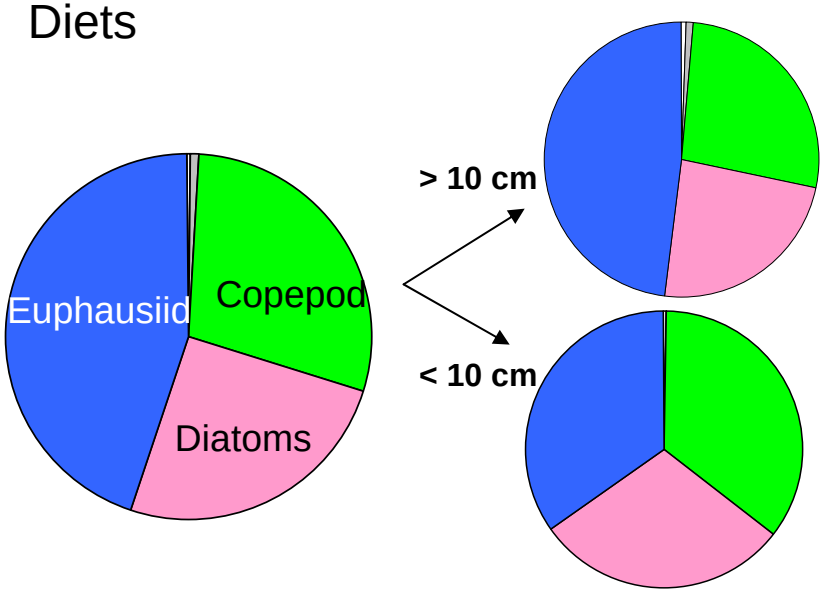
Mean TL, TL-at-age



TL distribution



Diets



Future Research

1. Tuning model using Genetic Algorithm and doing model sensitivity analyses
2. Coupling with ROMS-NPZD
3. Comparing OSMOSE and other models' output, such as Atlantis.
4. Conducting management strategy evaluation

THANKS FOR YOUR ATTENTION