

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

Caihong Fu¹, Yunne Shin², Morgane Trevers²
Ian Perry¹, Angelica Peña¹

1 Fisheries and Oceans Canada

2 Institute de recherché pour le développement, France

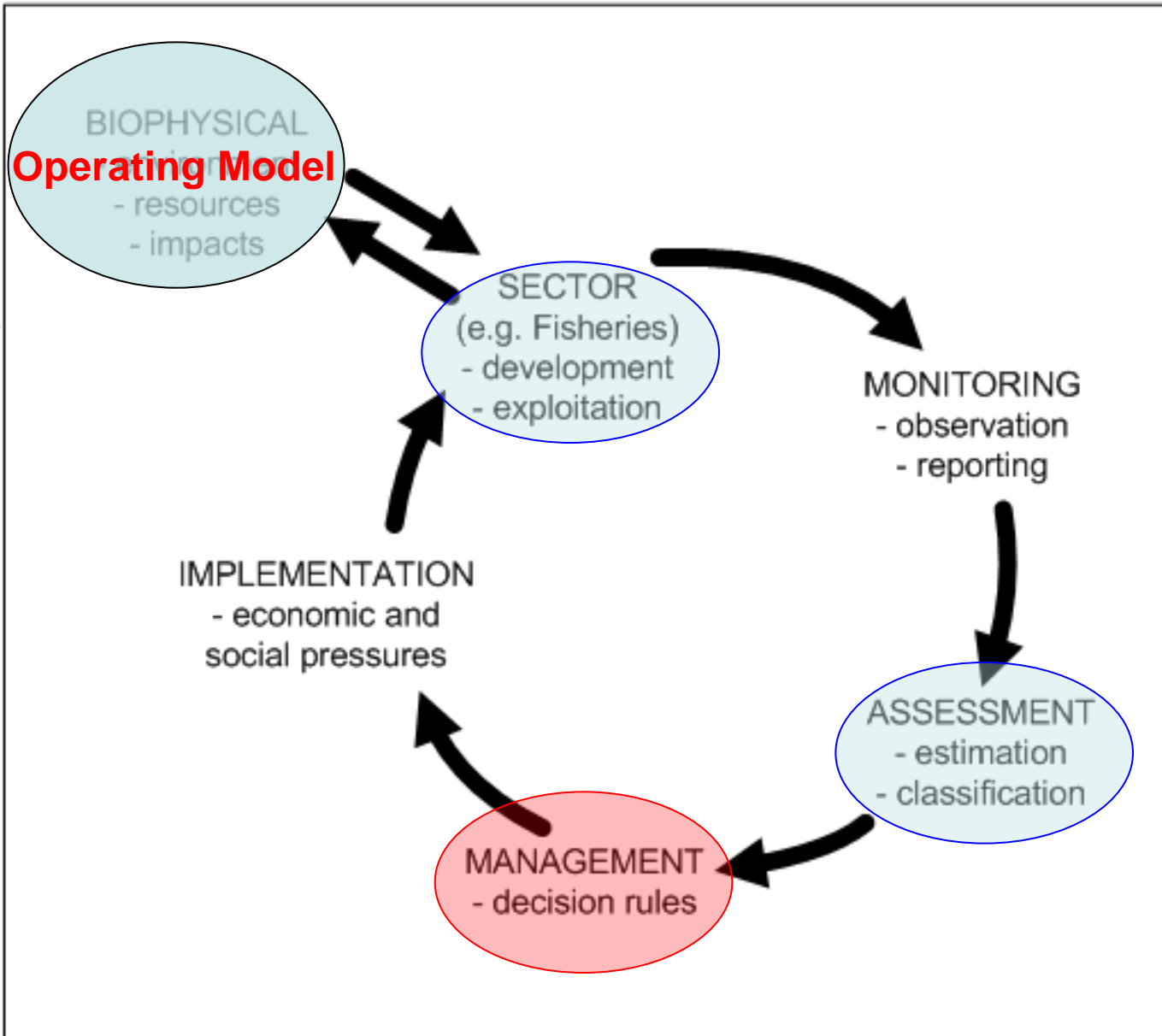
Work in progress

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

Management Strategy Evaluation (MSE)

MSE DESIGN AND ANALYSIS

DEFINE OBJECTIVES



IMPLEMENTATION
- economic and social pressures

MONITORING
- observation
- reporting

ASSESSMENT
- estimation
- classification

MANAGEMENT
- decision rules

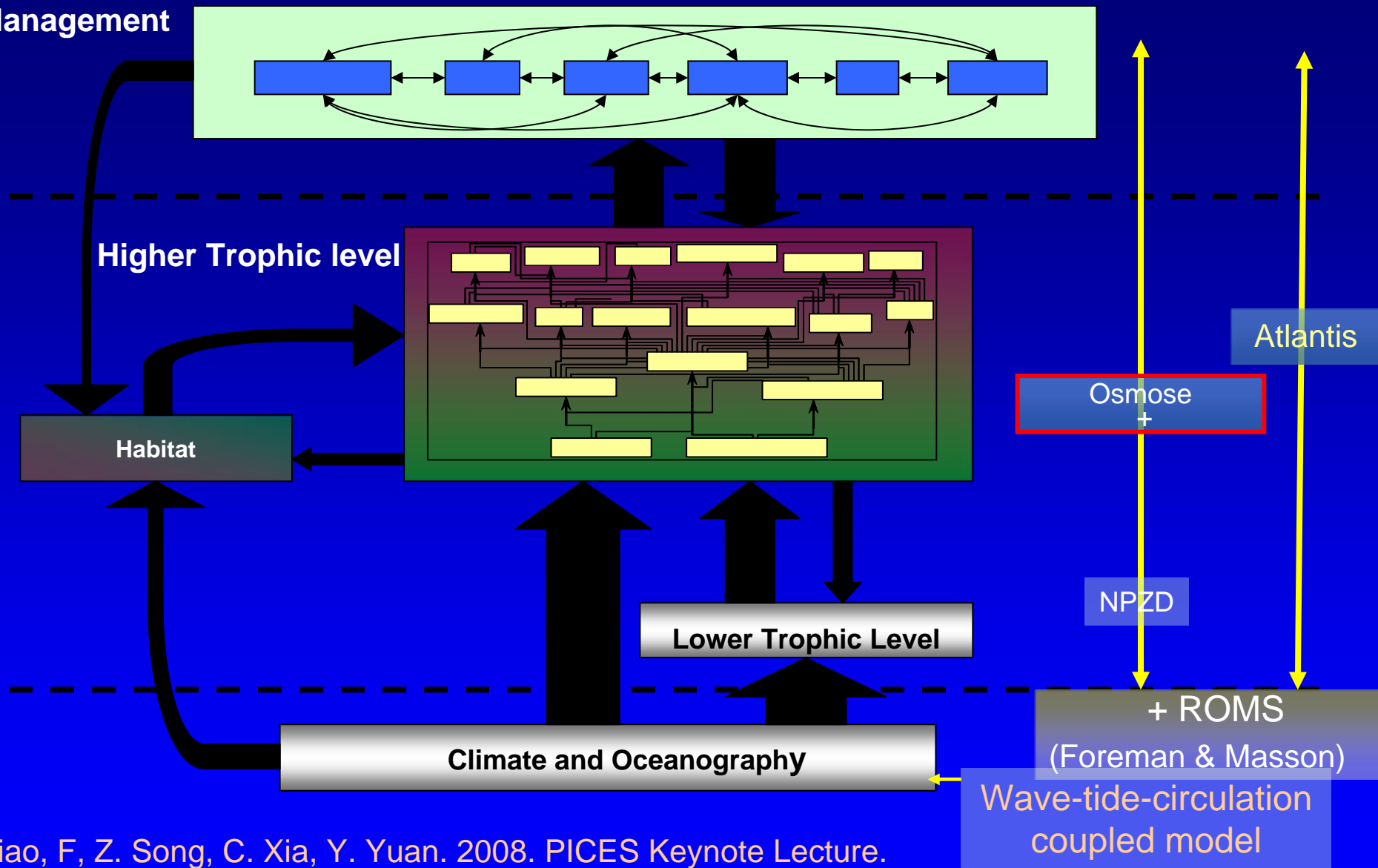
PERFORMANCE MEASURES



JUDGING OUTCOMES



End-to-end modelling



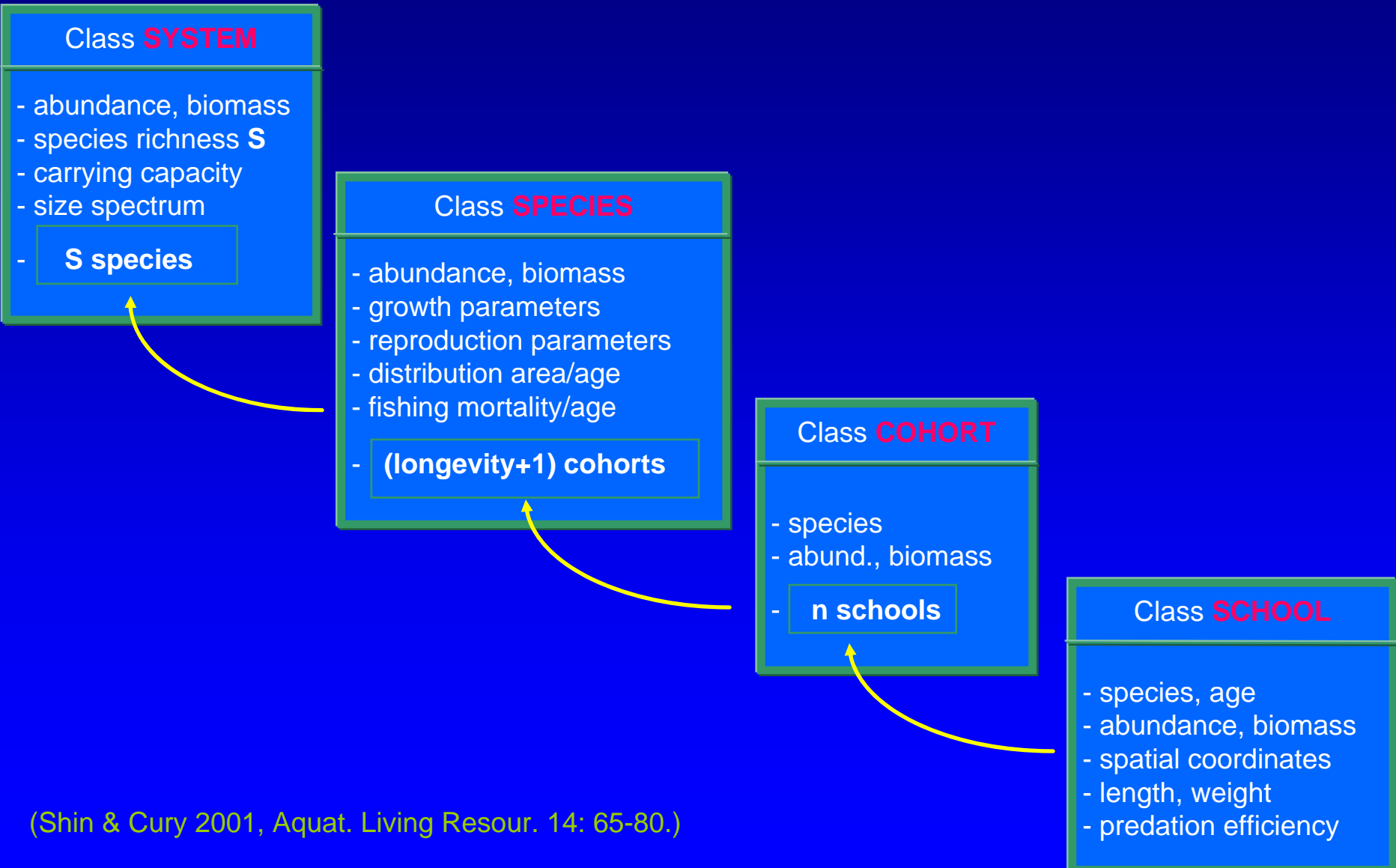
Qiao, F., Z. Song, C. Xia, Y. Yuan. 2008. PICES Keynote Lecture.

Travers, M., Shin, Y.-J., Jennings, S., Cury, P. 2007. Progress in Oceanography, 75: 751-770.

Fulton, E.A., Smith, A.D.M and Johnson, C.R., 2004. Ecological Modelling, 174: 267-307.

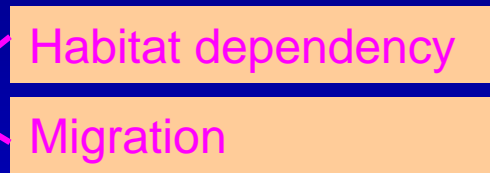
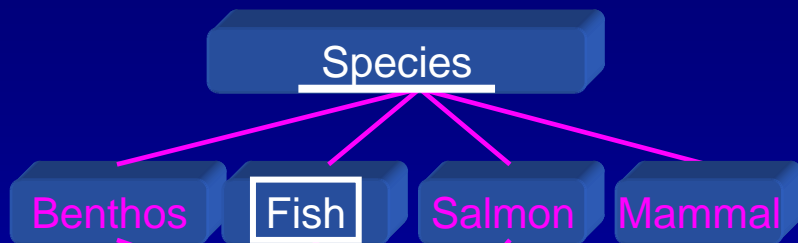
OSMOSE (Object-oriented Simulator of Marine ecOSystems Exploitation)

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

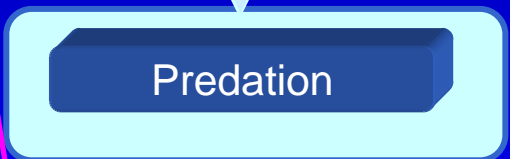


(Shin & Cury 2001, Aquat. Living Resour. 14: 65-80.)

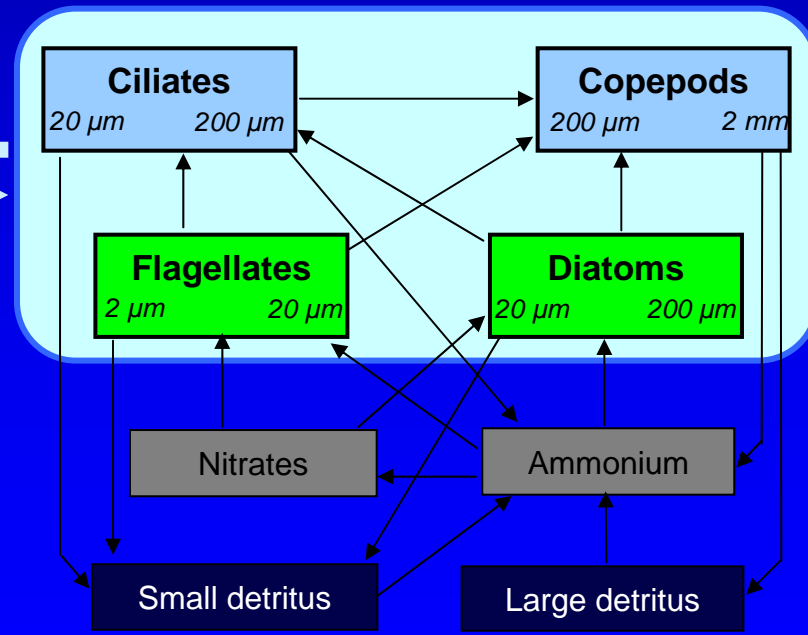
OSMOSE



Piscivores

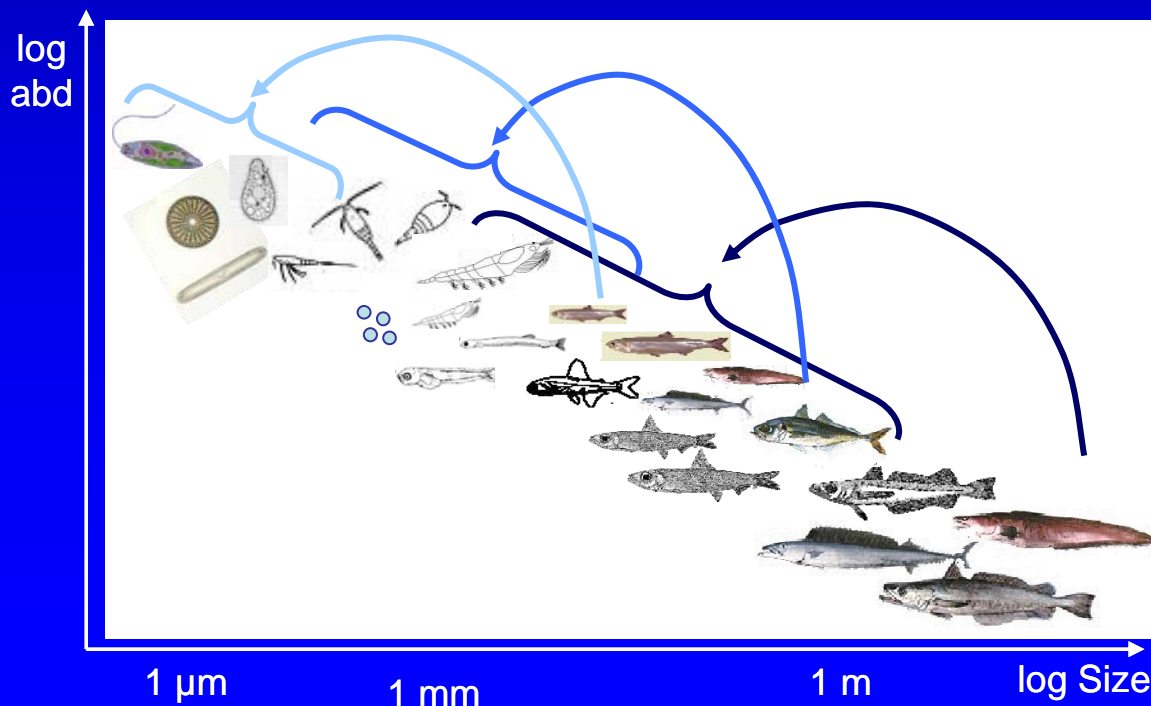
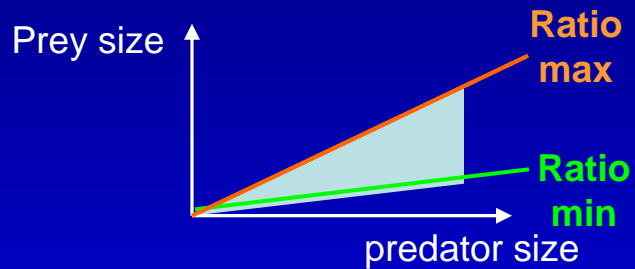


ROMS-NPZD



Size-based predation

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

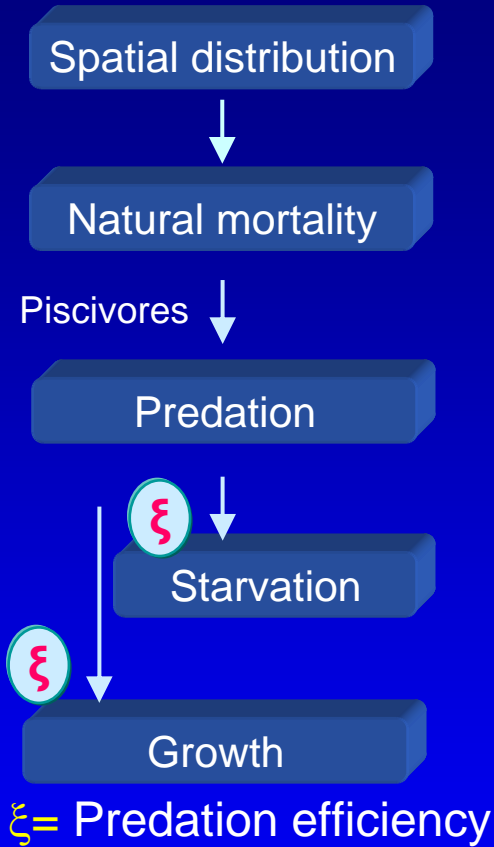


→ Modelled food webs are variable in structure

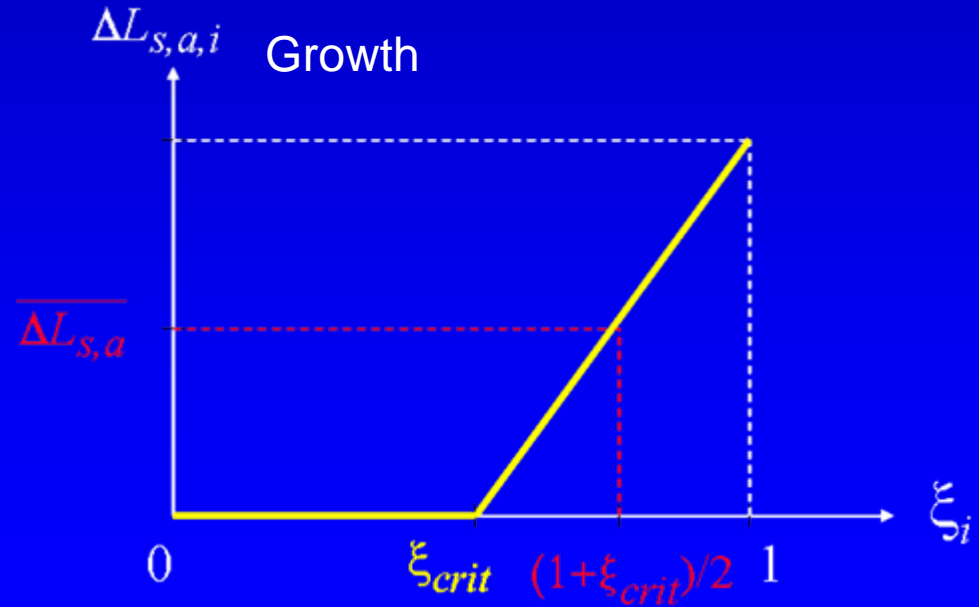
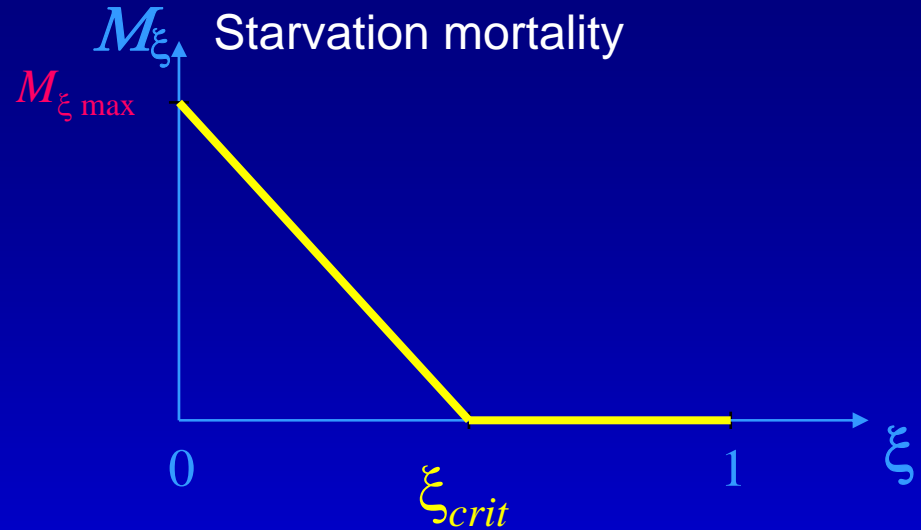
→ Opportunistic predation

Predation efficiency ϵ

Fish life cycle



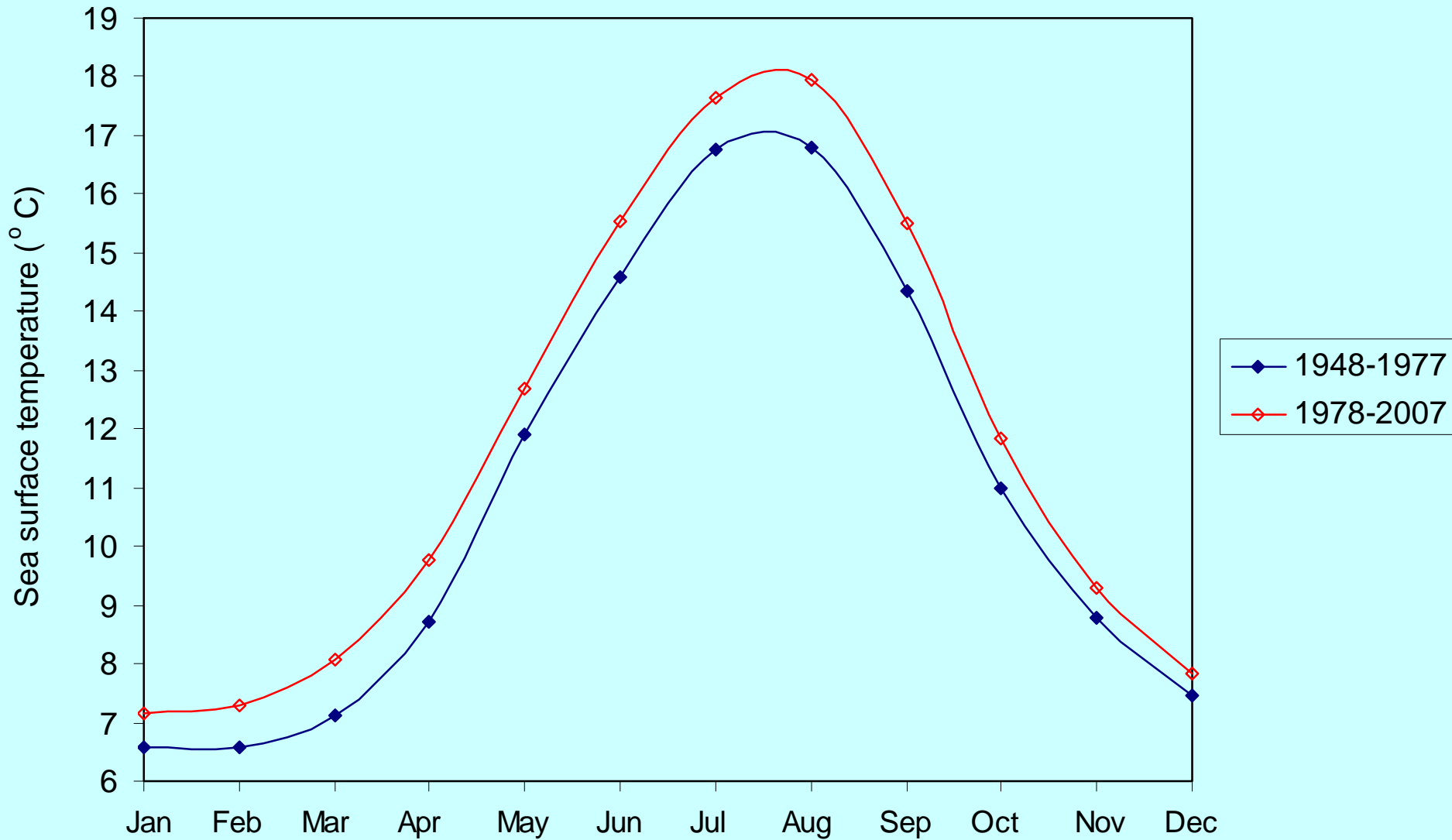
$$\xi_{crit} = \frac{\text{ration for maintenance}}{\text{maximal ration}}$$





Strait of Georgia

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?

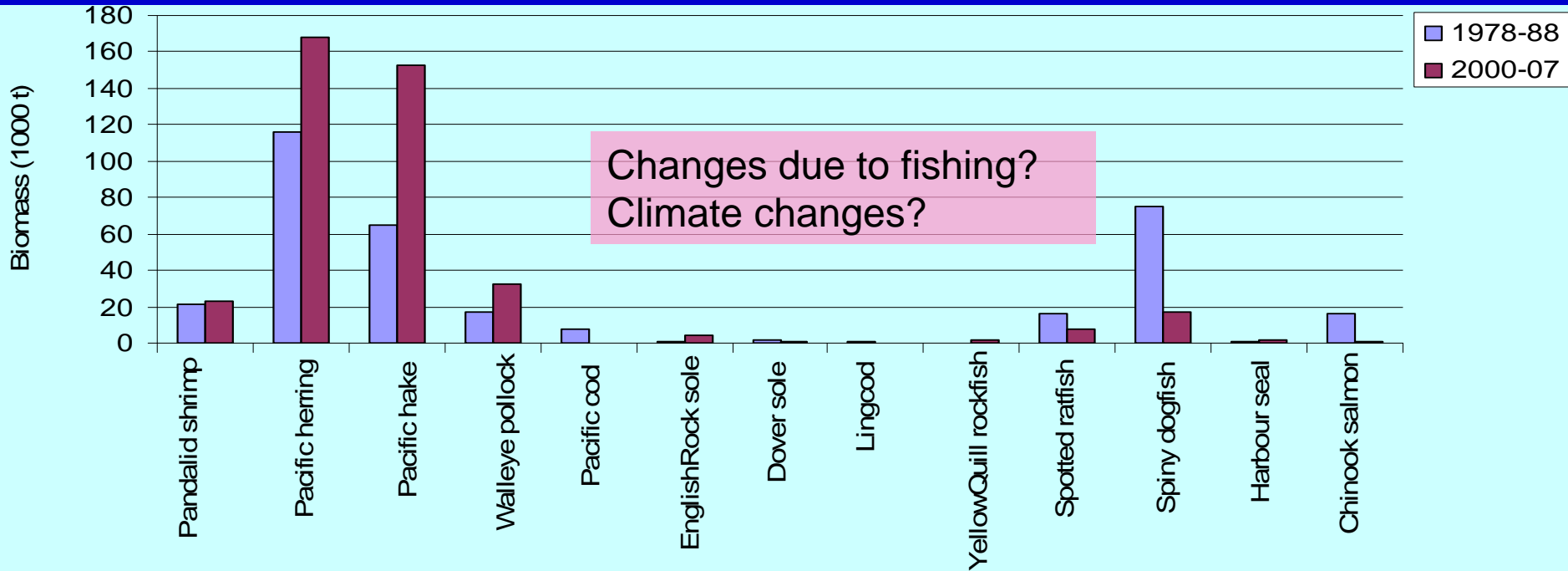
Application of OSMOSE to the Strait of Georgia

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



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

Species	Growth					Reproduction		Survival			
	$L_{\infty}(cm)$	$k(year^{-1})$	$t_0(year)$	$a(g \cdot cm^{-3})$	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

(1978 – 1988) (2000 – 2007)

Species	Biomass (tonnes)	Biomass (tonnes)
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

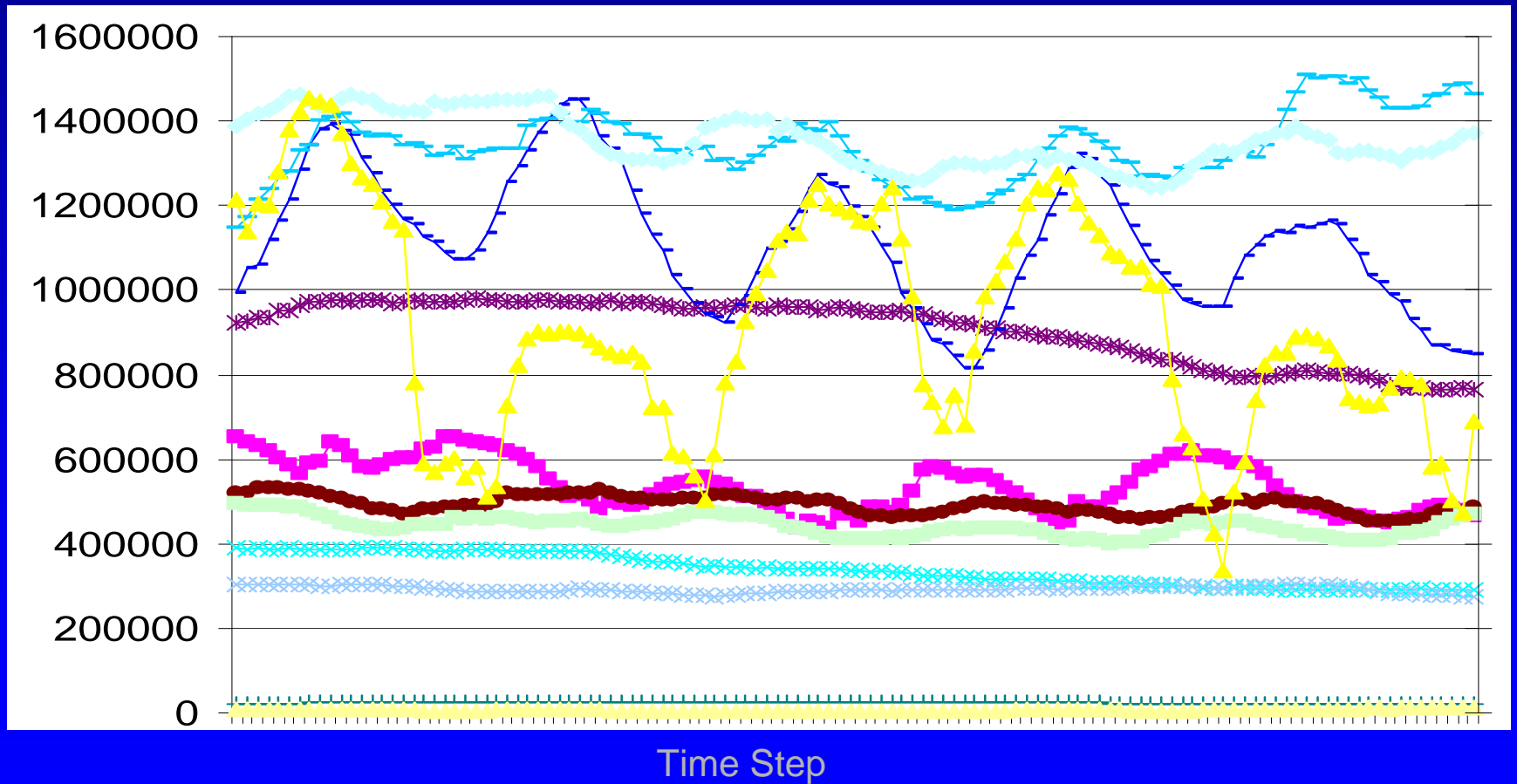
- Tuning parameters include larval mortality for each species and accessibility coefficient for each plankton compartment.
- Calibration is done by using a genetic algorithm specifically developed for OSMOSE (Shin *et al.* in review)

Questions to be addressed through OSMOSE simulations

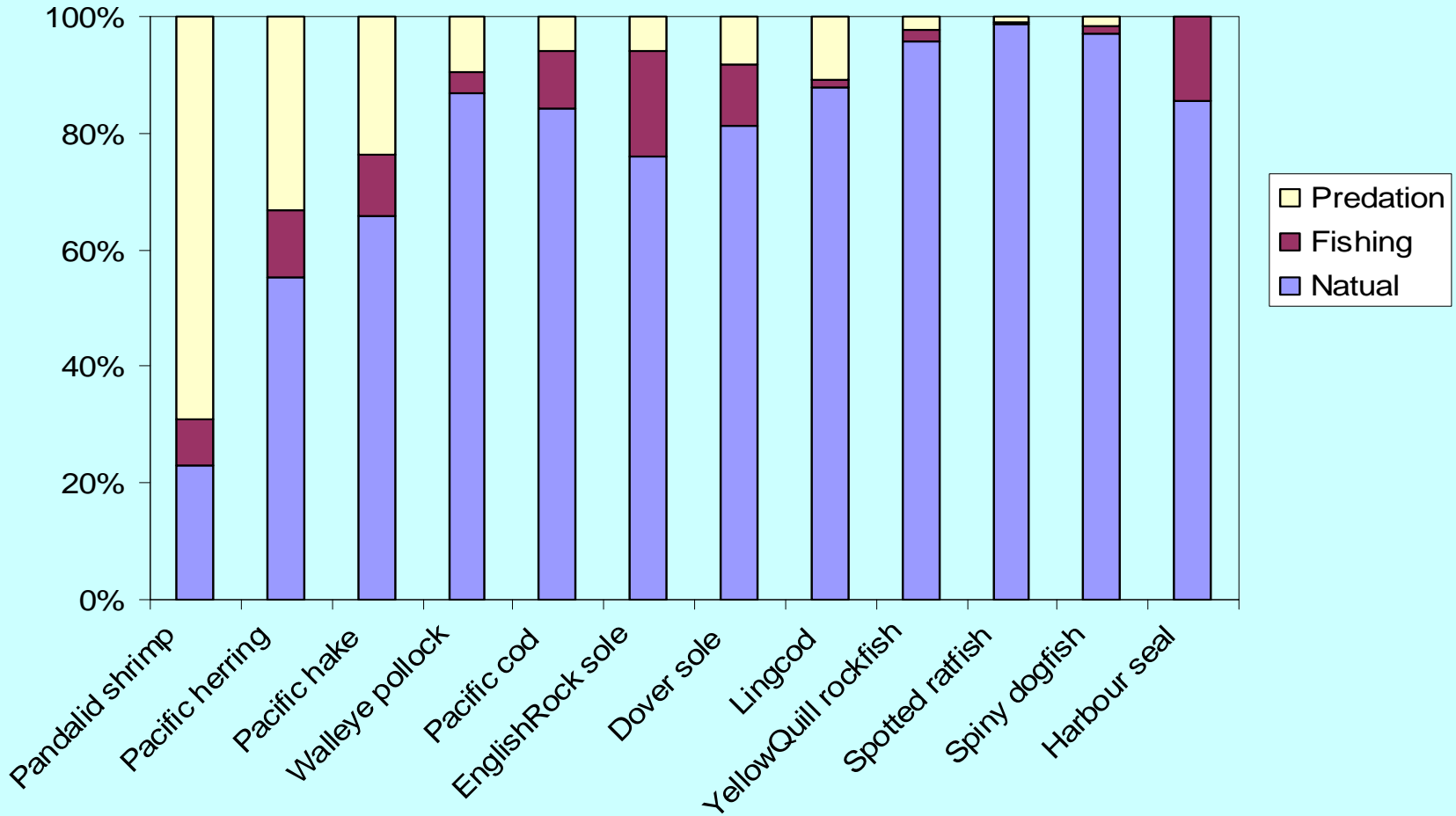
- What if water temperature increased by another degree
- What if herring were removed from the system
- What if harbour seals were removed
- What if Pacific cod were not fished but climate was not favorable
- What if Pacific cod were not fished but climate was favorable

Examples of Output

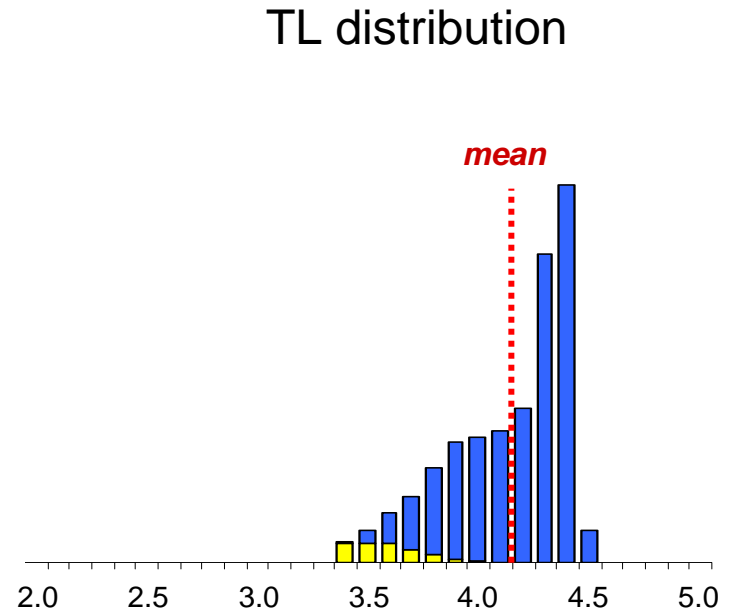
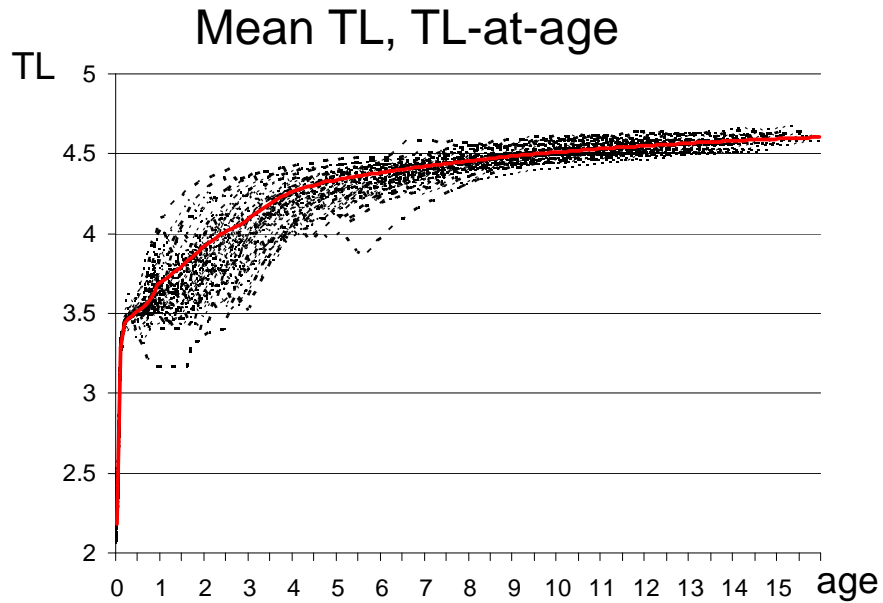
Population biomass



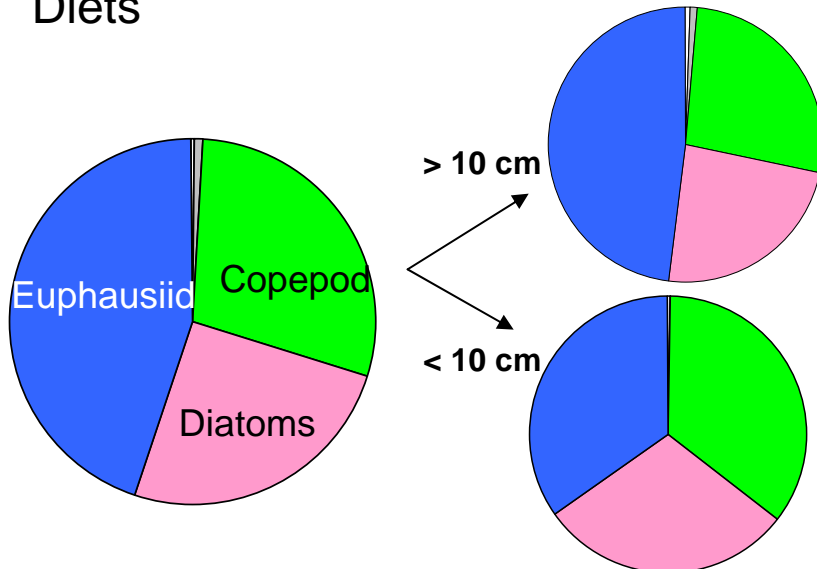
Biomass loss due to each cause



Trophodynamic indicators



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

