The Charmingly Simple Model – adding environmental forcing

John Pope, Henrik Gislason,

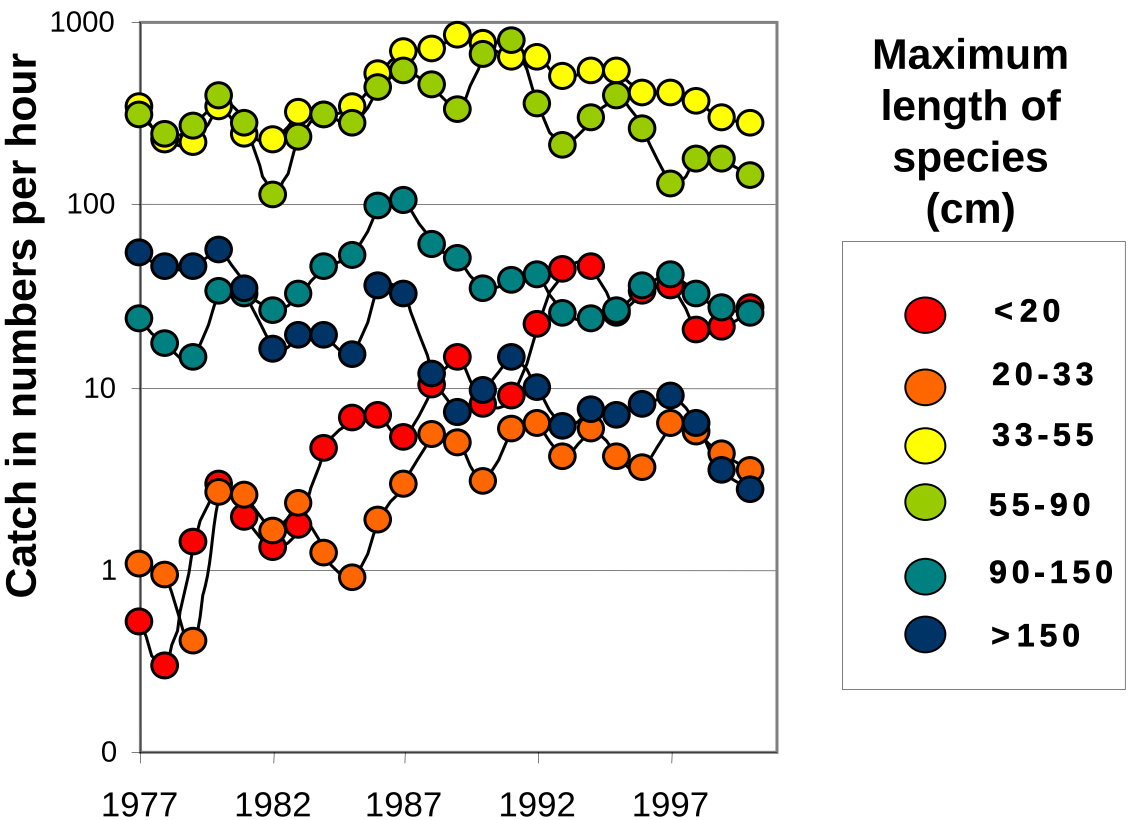
Jake Rice & Niels Daan

Fitting GLMs to MSVPA Suitabilities

Diet link of each age of each predator to each age of each prey (multiple years)

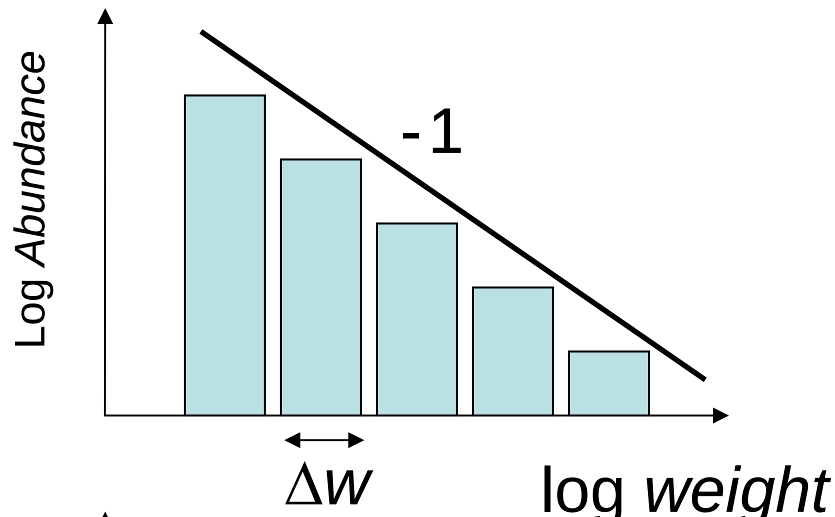
- SUBSTANTIAL Variance explained by overall SIZE OF Predator covariary
- LITTLE variance explained by
  - Main Effects of Species of Predator, Species of Prey, Year
  - Interactions of the Main Effects
  - Separate Slopes for each predator

Changes in the number caught per hour of large and small species



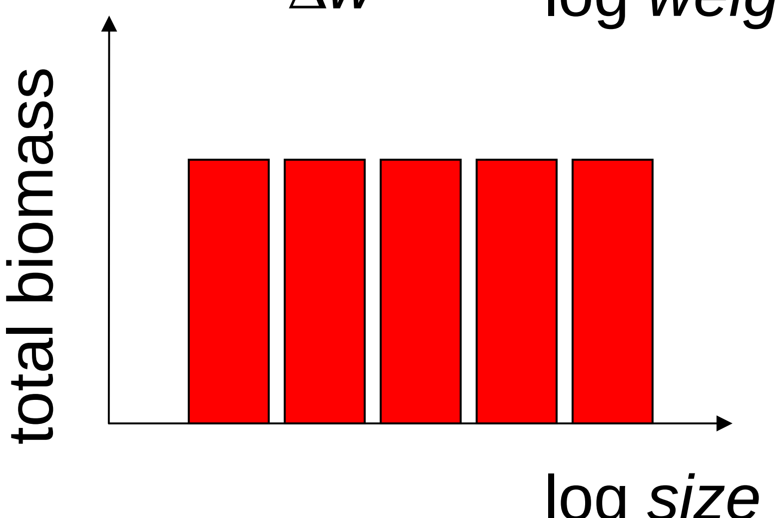
Daan, Gislason, Rice & Pope (2005)

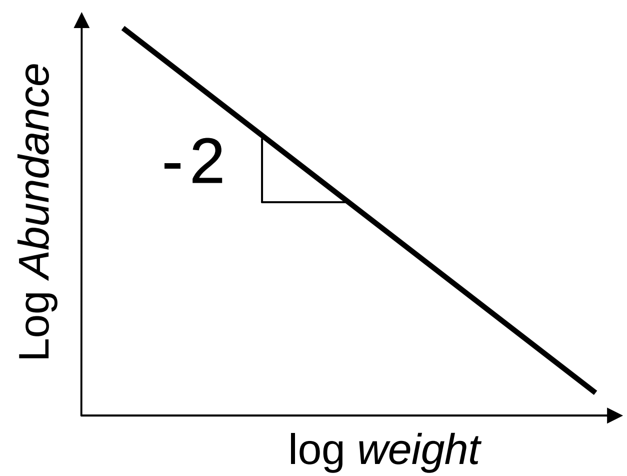
What is a size spectrum really?



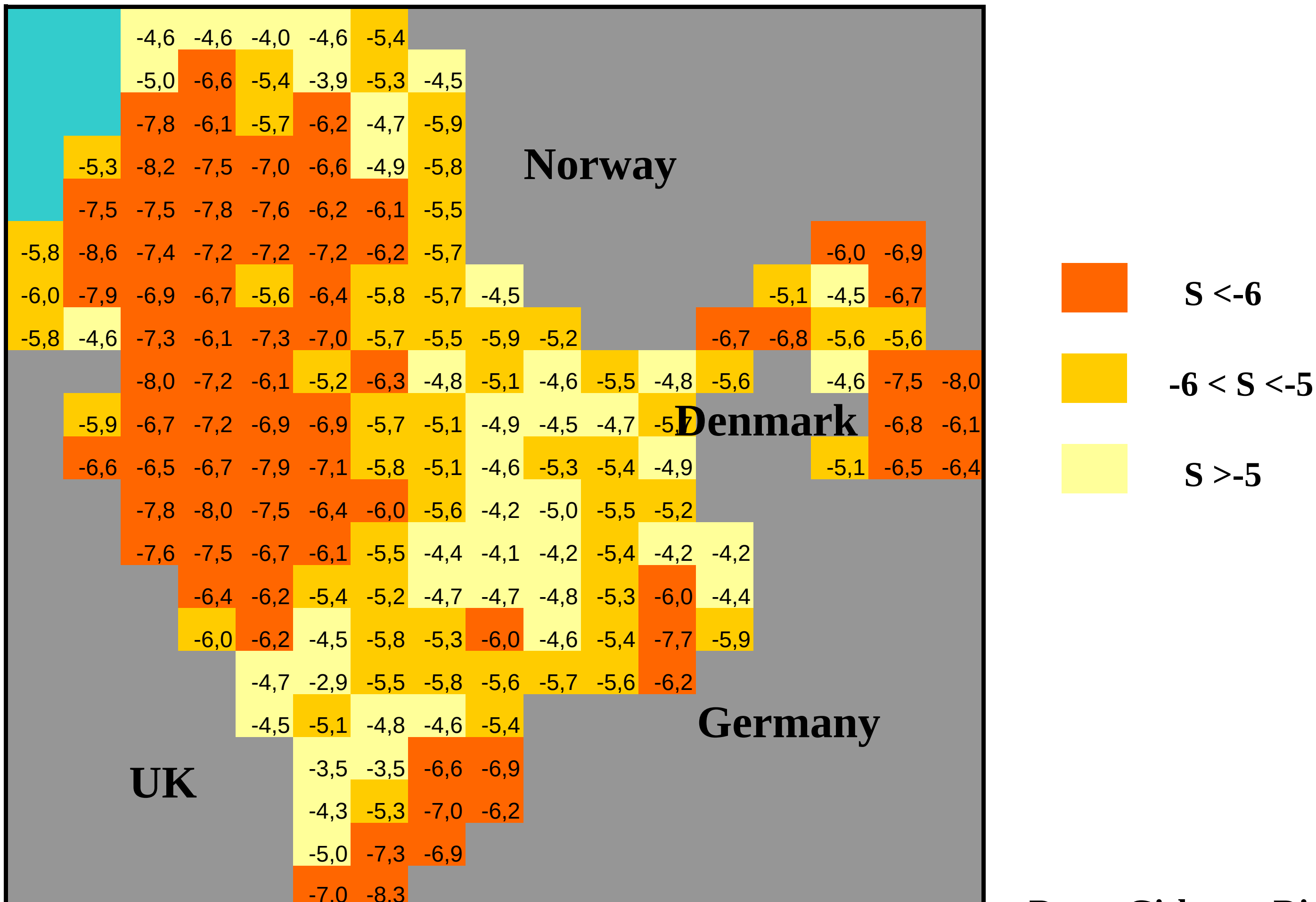
Power law scaling:

$$N = \kappa w^{-\lambda}$$





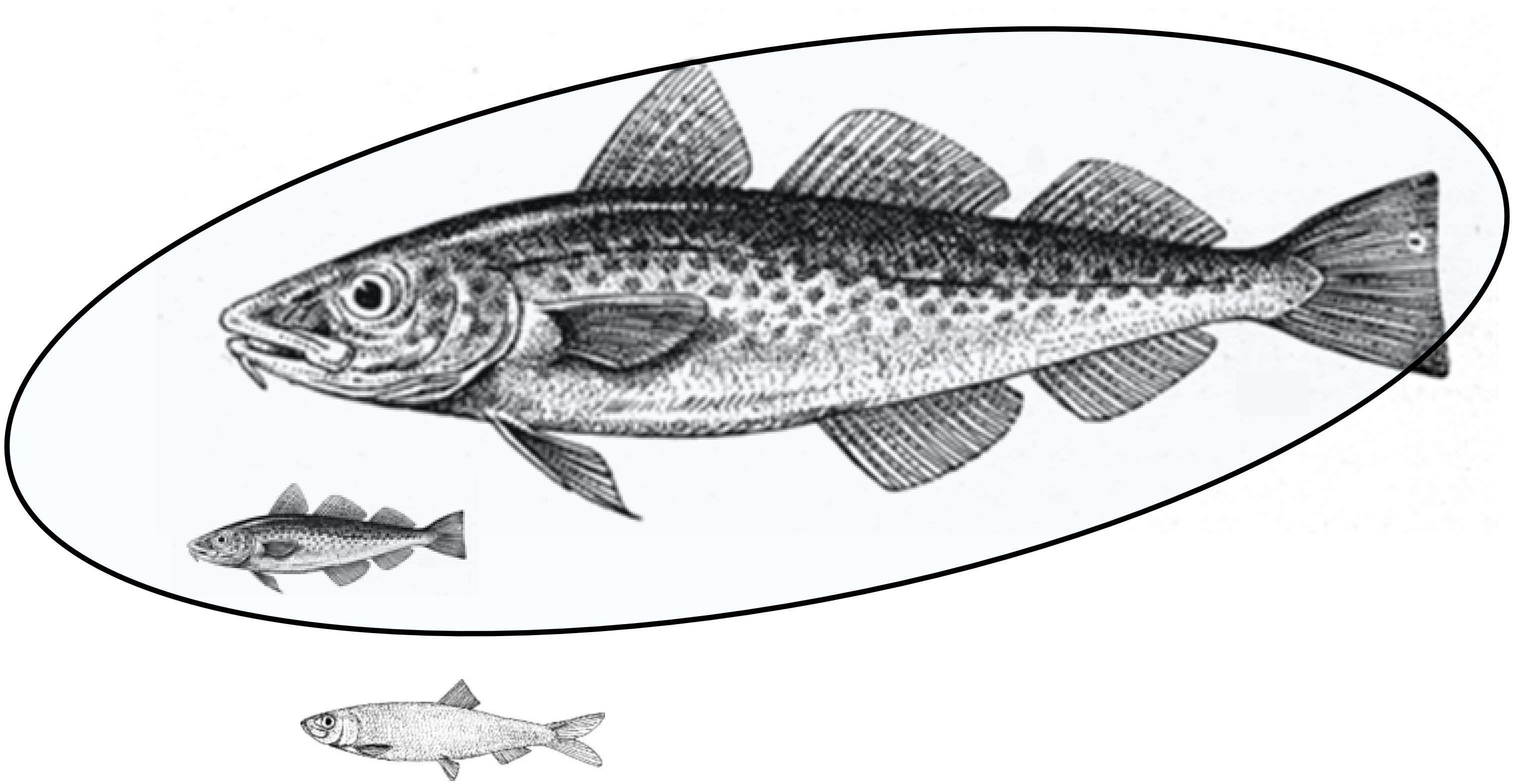
Slope of the size spectrum of fish in the North sea, 1980-1999



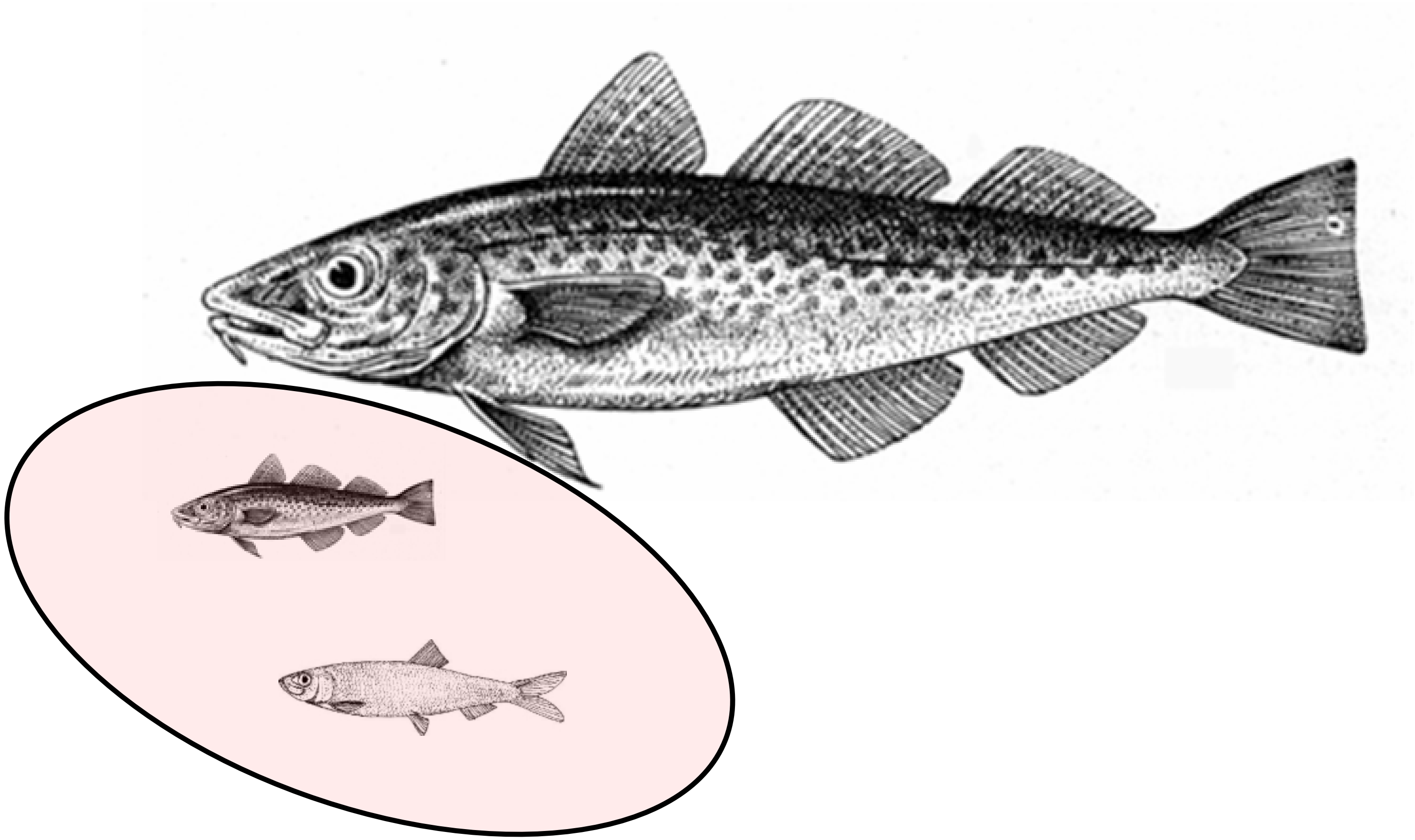
Data from the International Bottomtrawl Survey

Daan, Gislason, Rice & Pope (2005)

Which two fish are most similar?

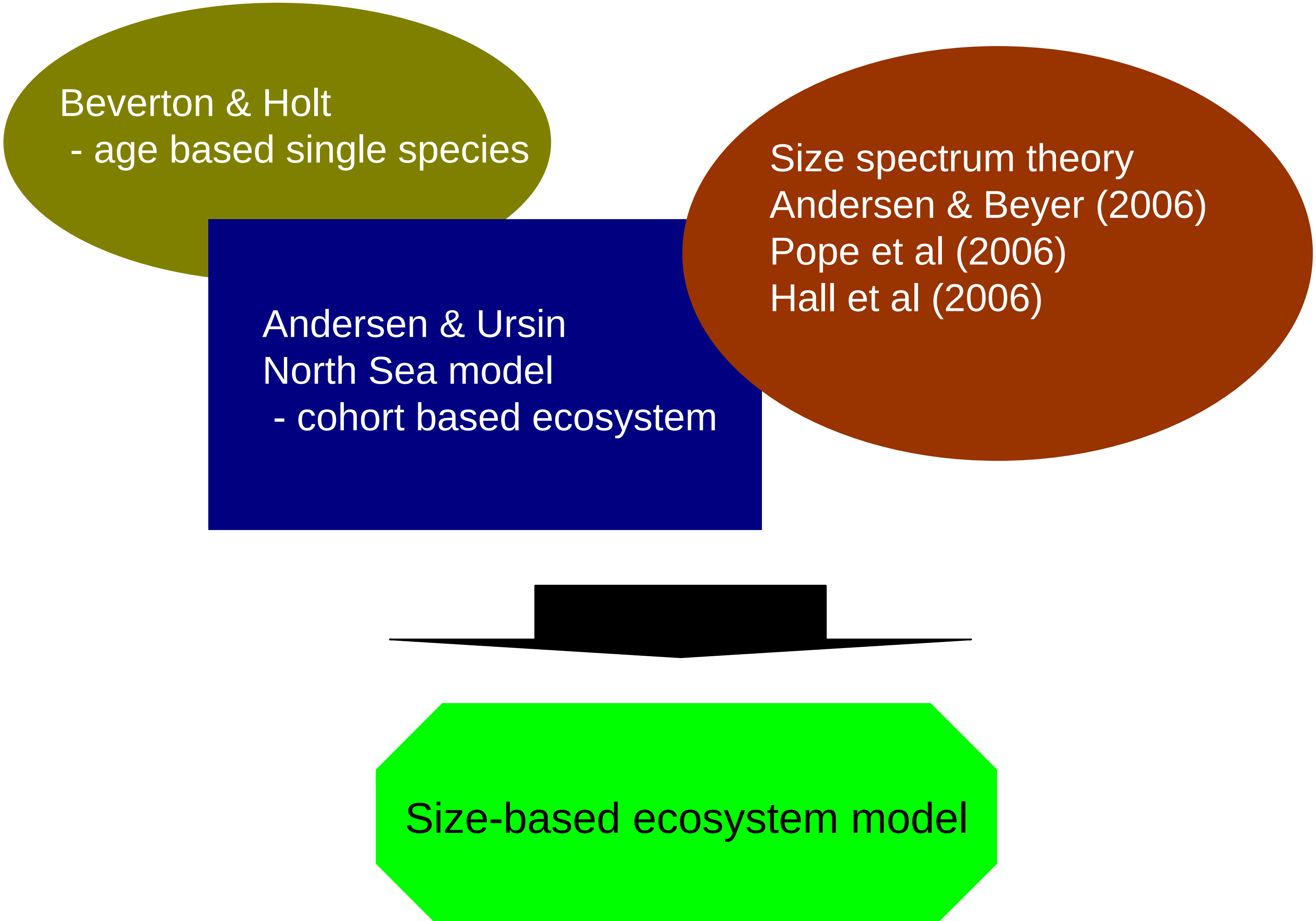


Which two fish are ecologically most similar?



Size is more important than species

Ingredients…



Strategy of model

- Modelling FISH COMMUNITY from smallest estimated by surveys to largest
- Based on ALLOMETIC SCALING RELATIONSHIPS (Charnov etc)
- Assumes trophodynamic relationships closer to size-based than species based
- Does not pretend to model lower trophic levels
- Allocate $L_{infinity}$ for community members and let allometric functions assign values for each "species" – total of 15 parameters for 12 species

Key Equations

- VonBertalanffy growth (2 parameters)
  - Jones length-based cohort analysis
- Size selectivity of fishery (4 parameters)
  - Logistic selectivity (3); *Scenario dependent mean F
- Anderson-Ursin Predation Mortality (4 p)
  - Mean & variance of size ratio, power, constant
- Maturity at proportion of L (1 parameter)
- *Power S-R function (3 parameters)
- *Scaling M/k ratio with size (1 parameter)

Variables for Scenarios

Scenario		Key	Density Dependence High	Low	V.low
• M/K ratio	τ	0.8	0.8	0.9	1.
• Stock Recruitment					
– power ssb	ϕ	0.45	0.25	0.75	0.95
– power Linf	φ	-3.55	-3.90	-3.10	-2.66
• const	ρ	18.0	20.3	14.7	12.4

Constraints

- **F ~ mean F** on fully recruited size classes of all species in the North Sea (.7) with 50% selection at 30% of L∞.
- **A size spectrum slope** ~ 0.1 **per** cm that was linear over the 20cm to 100cm length range (**R^2 > 0.95**).
- **M2** such that a plot against weight (Wt) was as close as possible to the fitted relationship in MSWG reports
- **A total fish biomass** of about 7 million t with both catch and fish consumption being about 3 million.
- **Catch fish** with L_∞ of 10 and 20cm about half of the total

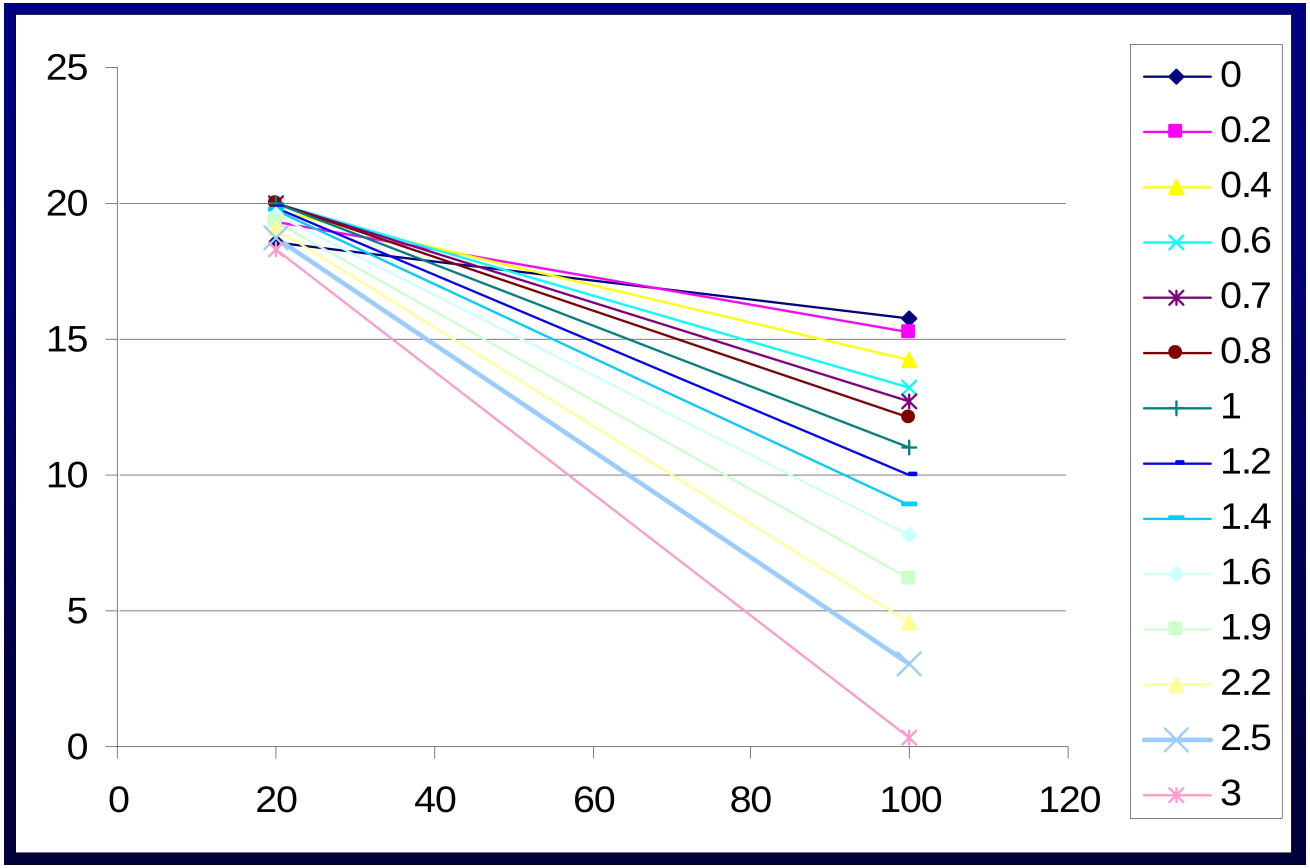
All these have documentation in literature

Fits to constraints

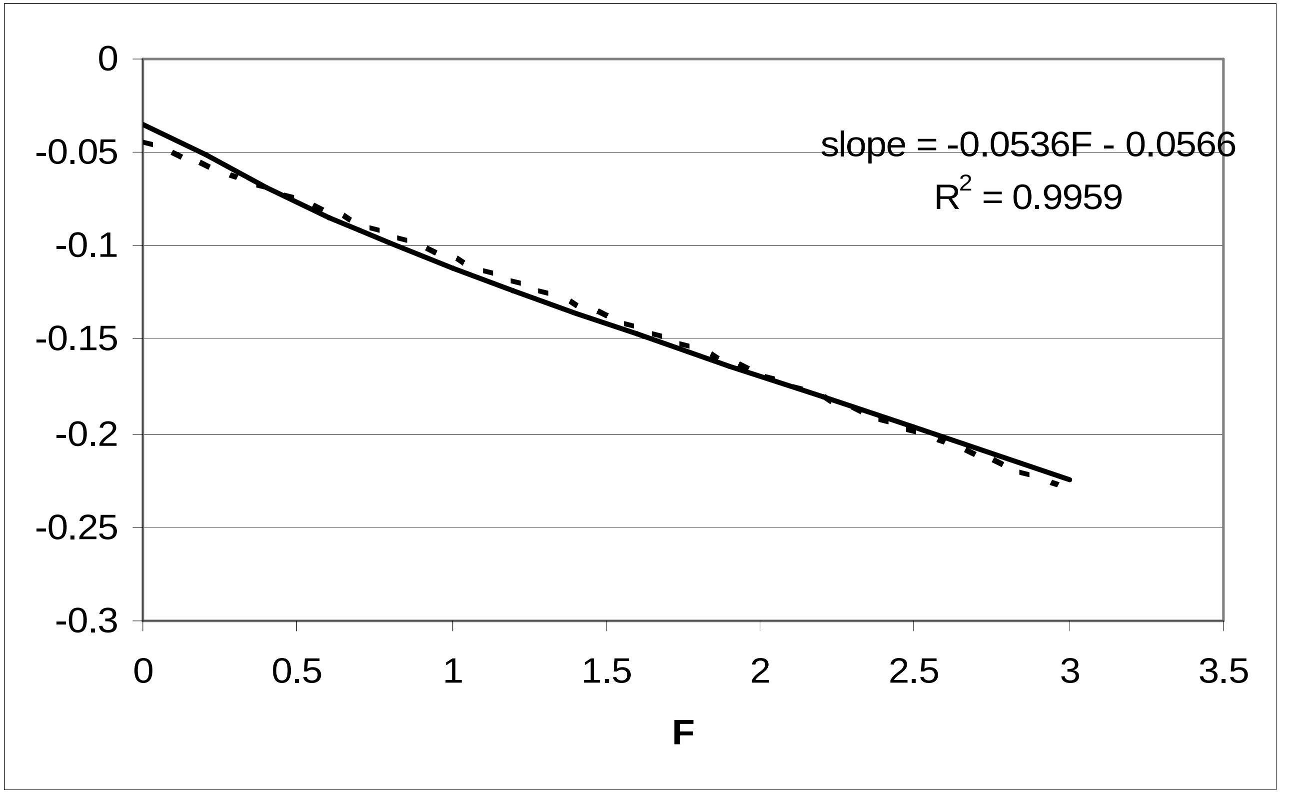
	Target	Key run	Scenarios 2	Scenarios 3	Scenarios 4
Size Spectra R^2					
	>0.95	0.997	0.997	0.994	0.961
M2's (year-1) & ln(M2) on Ln(Wt) regression					
Max M2	1.50	1.61	1.74	1.37	1.41
Catch, consumption and biomass (million t)					
<30cm L∞ groups	1.50	1.54	1.45	1.74	1.64
Total catch	3.00	2.97	2.98	3.14	3.13
Total eaten	3.50	3.50	3.46	3.48	4.00
Total biomass	**7.00**	**5.04**	**5.14**	**5.60**	**6.07**

What types of things can the model do?

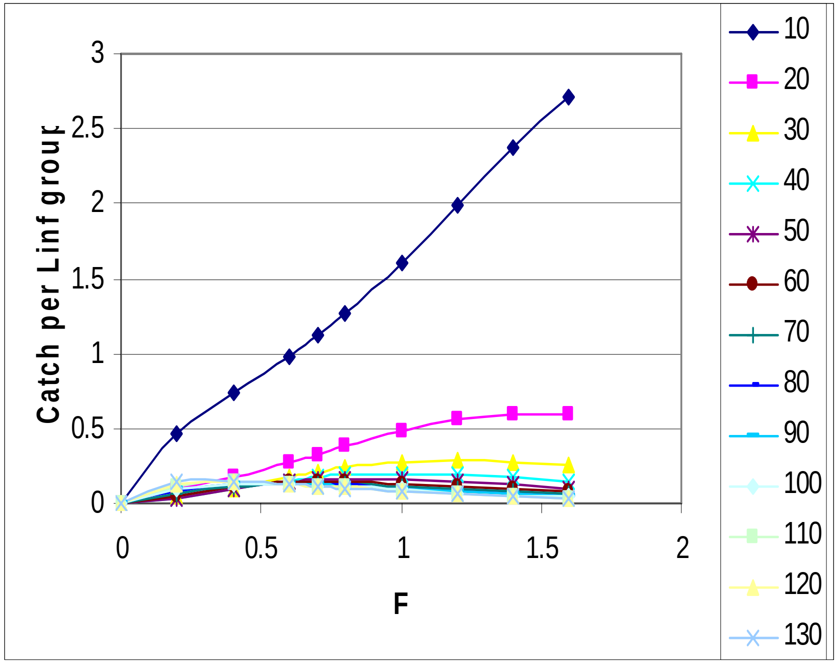
Slope as function of F

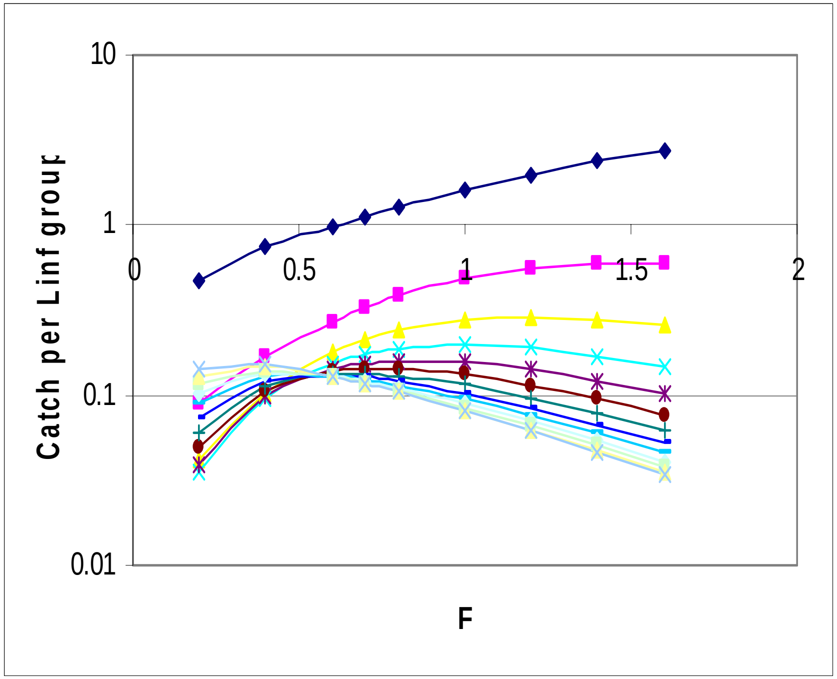


Regression of slope on F

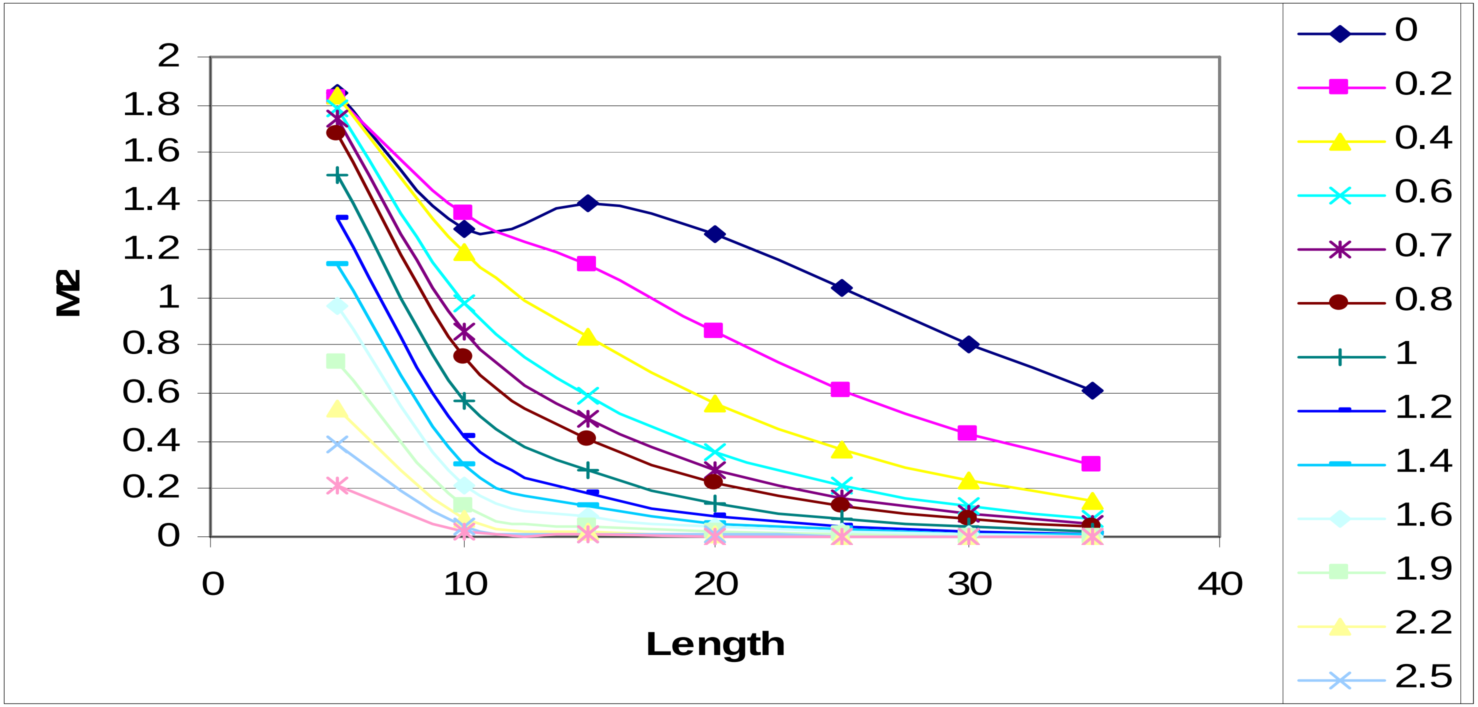


Yield by 10 cm size group

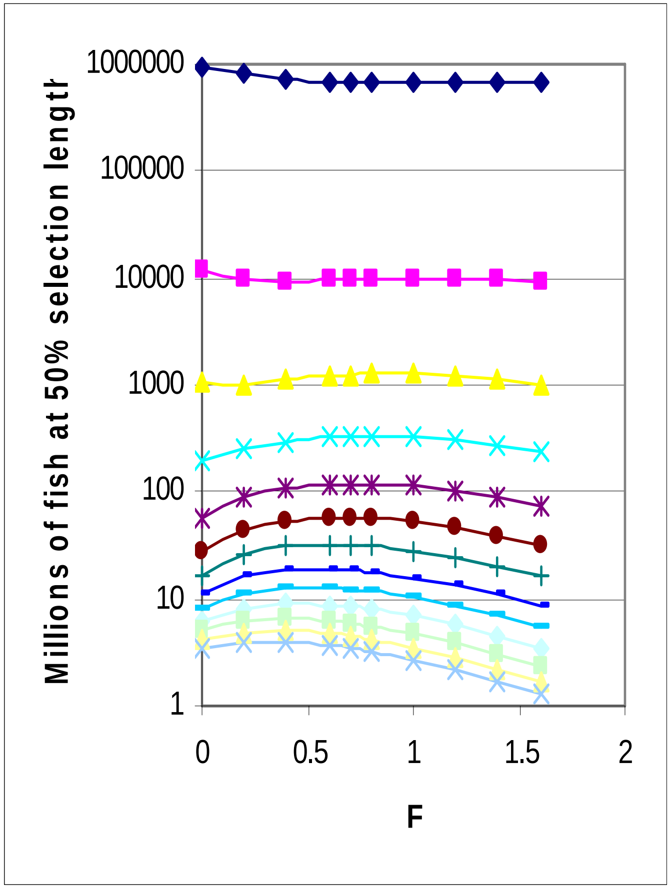


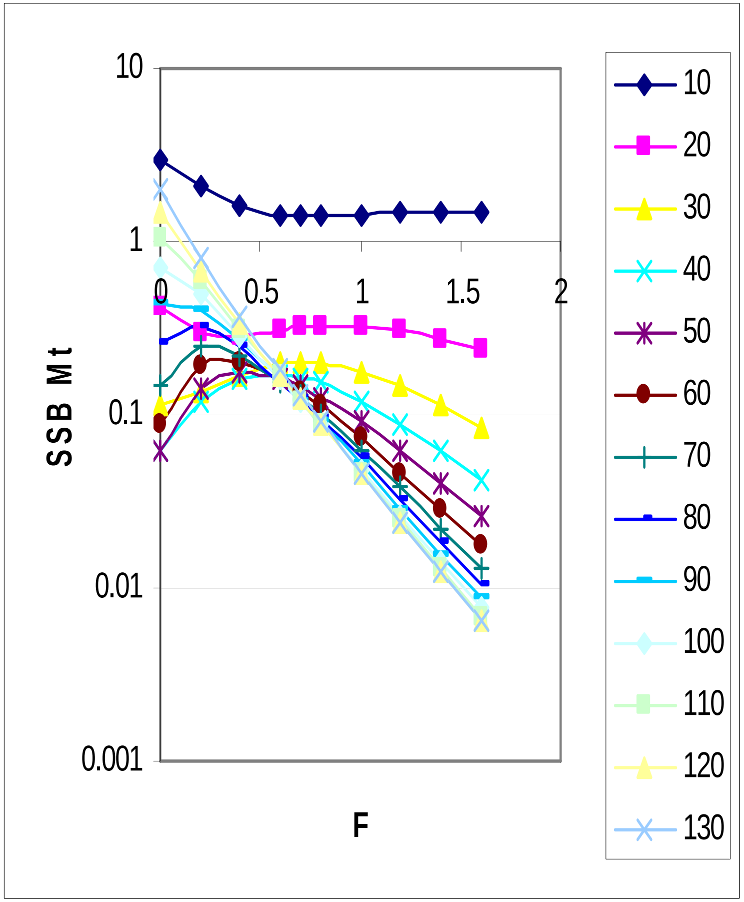


M2 by size as f(F)



“Recruitment” and SSB of each L_∞ “species” as f (F)





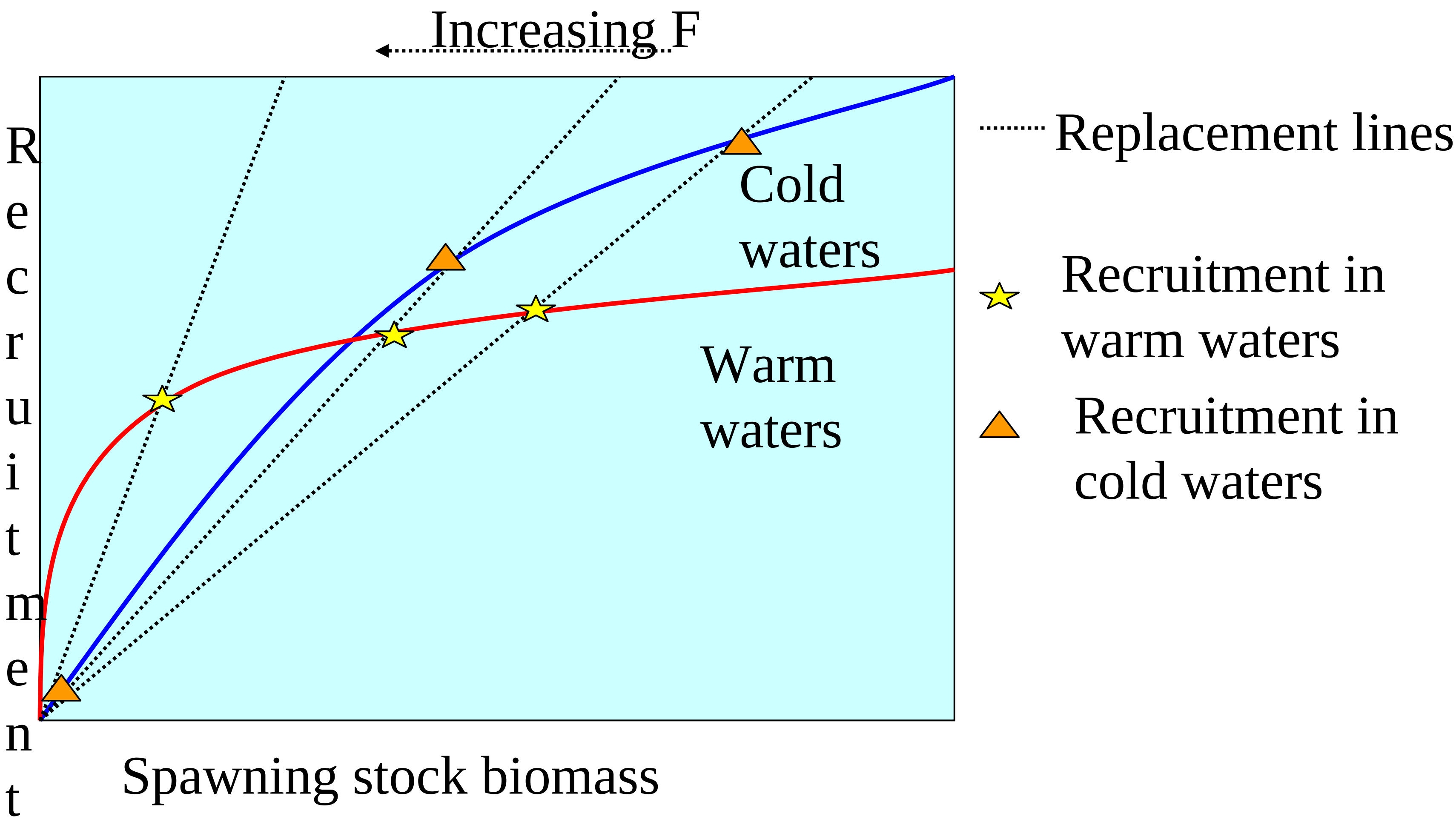
Charnov and Gillooly 2004: life history parameters scale with temperature and size

- Natural Mortality $M = \lambda_1 \exp(-E/kT)*m_\alpha^{-0.25}$
- Age first Maturity $\alpha = \lambda_2 \exp(E/kT)*m_\alpha^{0.25}$
- Spawning Prop. $c = \lambda_3 \exp(-E/kT)*m_\alpha^{-0.25}$

- These were not formulated in terms of the von Bertalanffy parameters the CSM used.
- BUT WE HAVE A CUNNING PLAN

Putting in the Environment

A linear stock-recruitment relationship makes the community more vulnerable to fishing



Charnov and Gillooly 2004: life history parameters scale with temperature and size

- Natural Mortality M $=\lambda_1 \exp(-E/kT)*m_\alpha^{-0.25}$
- Age first Maturity α $=\lambda_2 \exp(E/kT)*m_\alpha^{0.25}$
- Spawning Prop. c $=\lambda_3 \exp(-E/kT)*m_\alpha^{-0.25}$

- These were not formulated in terms of the von Bertalanffy parameters the CSM used.
- BUT WE HAVE A CUNNING PLAN

From Beverton invariant M/K we infer

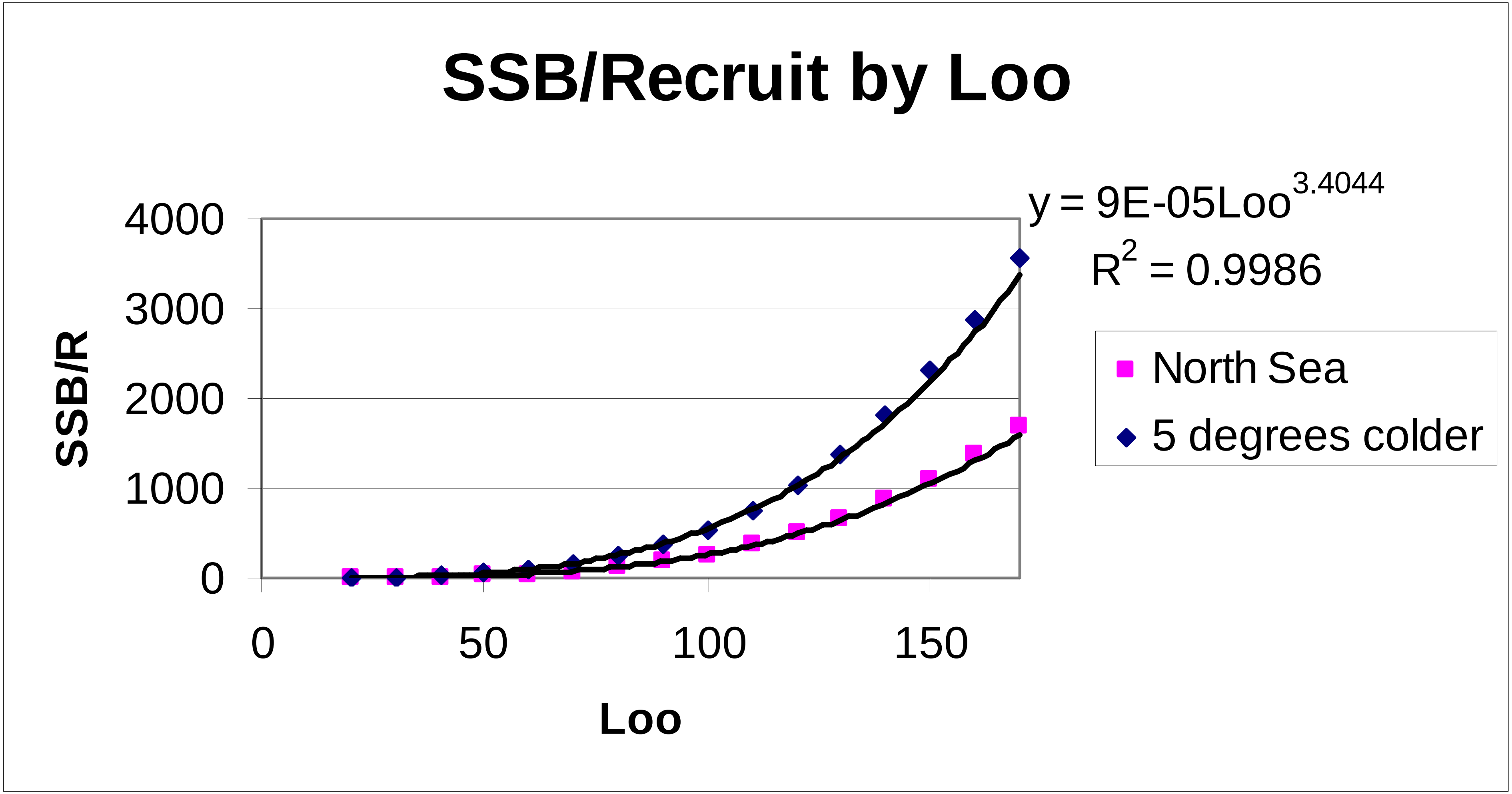
- von Bert. K = $\lambda_4 \exp(-E/kT) * m_\alpha^{-0.25}$
- Using $L_\alpha = L_\infty^{0.93}$
- Thus $K = \lambda_4 \exp(-E/kT) * L_\infty^{-0.70}$
- Very like the CSM's form
- $K = 4.5 * L_\infty^{-0.67}$
- But with a temperature term exp(-E/kT)

We can augment the CSM

Use Life History parameters by temperature to Calculate for different ecosystems

- SSB/Recruit
- Replacement Lines
- Intersect with Recruitment/ SSB relationship
- Resulting species SSB
- Resulting species total Biomass

Temperature change maintains relative SSB/R by L_∞



Total Biomass: With φ close to 1.0 the system is easy to flip.