

Modeling Upper Trophic Levels: Fish Species

Terry Quinn

School of Fisheries and Ocean Sciences

University of Alaska Fairbanks

Juneau Alaska

Terry.Quinn@uaf.edu

Stock Assessment

1. Data Collection
 1. Fishery
 2. Surveys
2. Modeling and analysis
 1. Population dynamics
 2. Uncertainty in measurement and in process
 3. Factors affecting the population (environment)
3. Management recommendations
 1. Biological reference points
 2. Sustainability
 3. Plan of action

Data from the Fishery

- Harvest data
 - Total catch and kill
 - Should include release and bycatch mortality
 - Composition: length, age, sex
 - Follow year-classes through time
 - Catch-per-unit-effort
 - Index of population change
 - Needs validation as proportional to abundance

Necessary biological information

- Survey index of abundance (time series)
- Natural mortality (see next slide)
- Recruitment (see next slide)
- Growth
- Movement and migration
- Maturity and fecundity (egg production)

Necessary Modeling

- Connects data and population dynamics
- $\text{New abundance} = \text{Previous abundance} - \text{Fishing Deaths} - \text{Natural Deaths} + \text{Recruitment} + \text{Immigration} - \text{Emigration}$
- Natural mortality: constant and known ($M=0.2$), estimated, a function of predators, a function of disease, a random walk
- Recruitment
 - Estimated annually

Goals of Modeling

- To explain time series of data
- To estimate population parameters
- To determine causes of population change
- To forecast future populations
- To reconcile conflicting information sources
- To specify uncertainty and risk

Challenge 1: Stochasticity

- What affects recruitment? ICES 1902
- Spawner biomass, or egg production
- Need stochastic effects for temporal change, environment
- Tremendous variability, an unsolvable problem?

Challenge 2: Varying natural mortality

- U-shaped distribution not well determined
- A function of predators and disease
 - Solution 1. Covariates (disease prevalence, predator abundance)
 - Solution 2. Multi-species models (more realistic but more uncertain, requires consumption data)

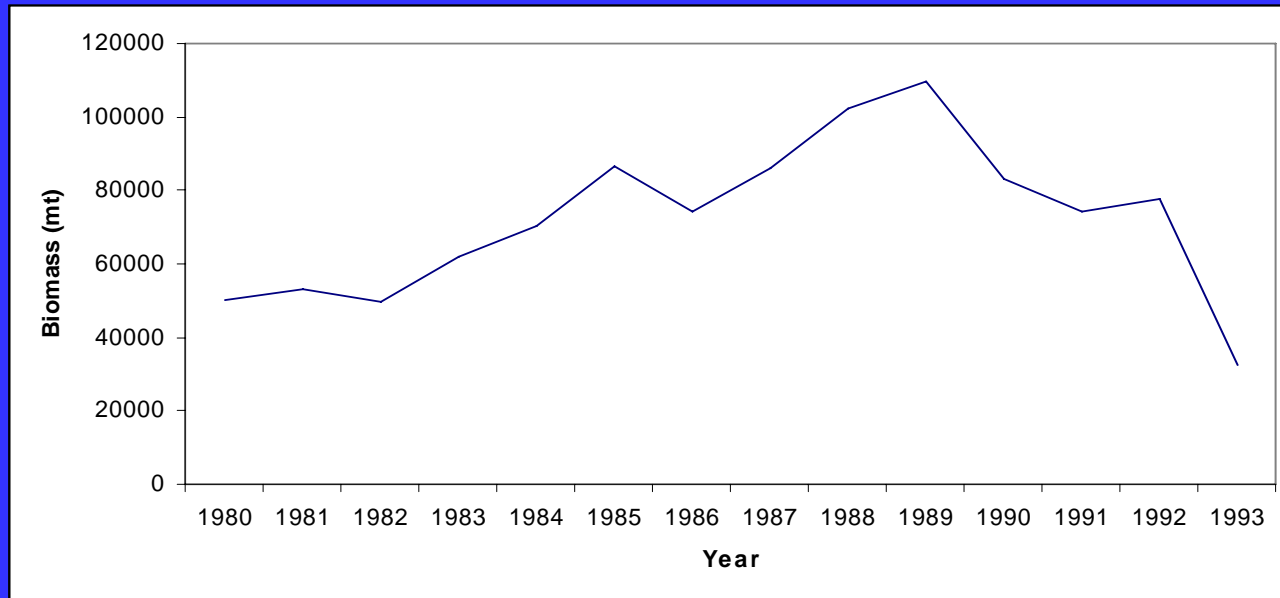
Cause and effect requires study of early life history (expensive, complex)

Challenge 3a: Multiple datasets

- Data conflicts: Can affect interpretation of population dynamics
- Case study: Prince William Sound herring
 - Data since 1980
 - Exxon Valdez oil spill: March, 1989
 - Age-structured model, multiple datasets
 - Conflict between mile-days of milt and egg production
 - No *a priori* reason to reject either dataset

1993

1. Spawners arrive in PWS with 75% of the ASA estimated return biomass missing
2. Disease epidemic suspected in large mortality event
3. Subsequent disease research lead to the incorporation of a disease index into PWS herring ASA
4. Meanwhile, funds given to PWS Science Center to perform hydroacoustic surveys of herring



After 1993

1. Disease prevalence has been collected in Prince William Sound since 1994.
 - a. fungus *Ichthyophonus hoferi*
 - b. viral hemorrhagic septicemia virus (VHSV)
2. Fishery reopened in 1997.
3. Spawning failure occurred in 1999, fishery closed since then.

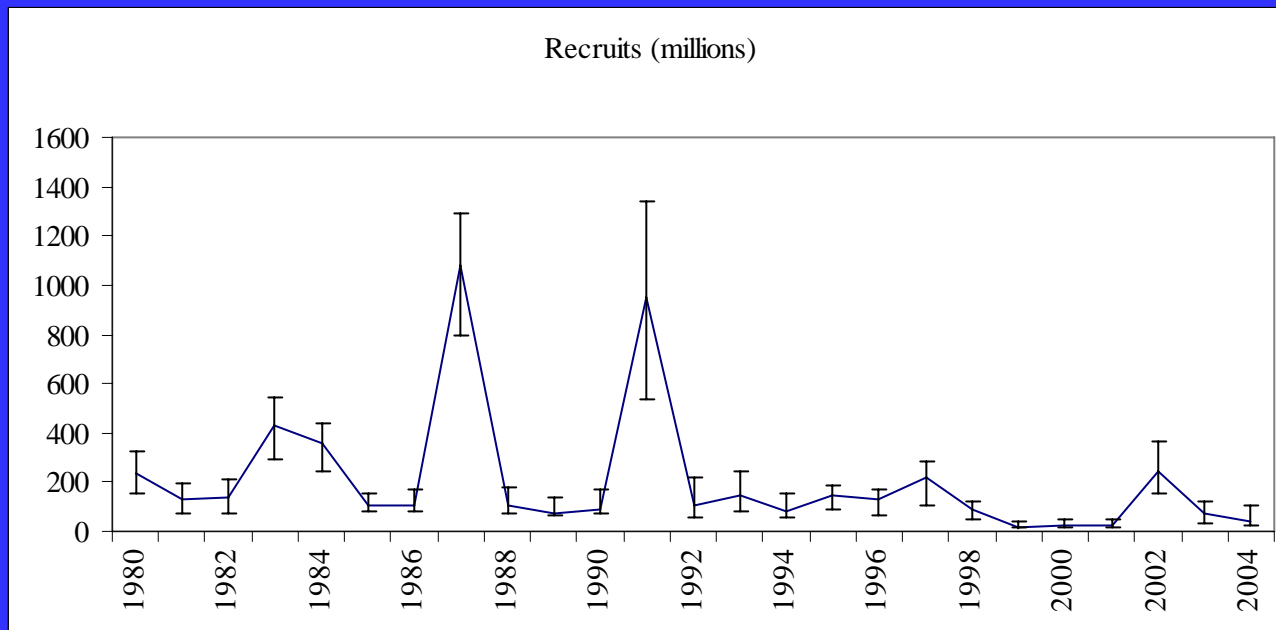
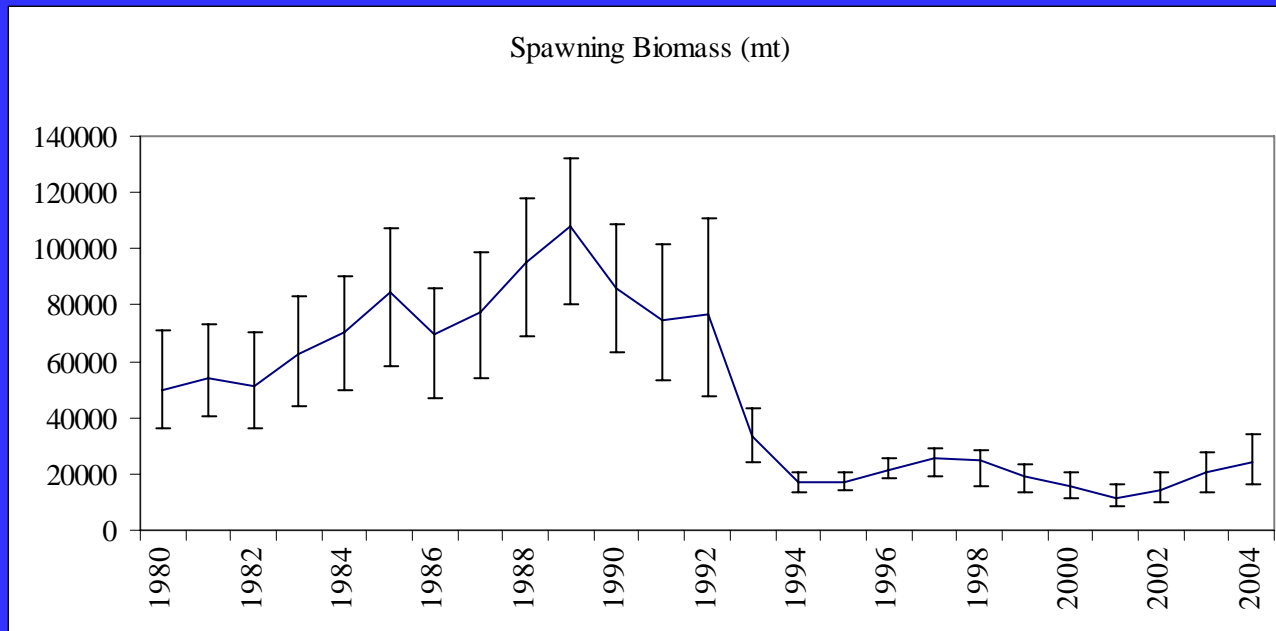
Model Details

- Estimated parameters: Recruitment and starting abundance, maturity, seine selectivity, milt calibration coefficient, hydroacoustic calibration coefficient
- Data: weight-at-age, seine age composition and total catch, other fisheries' catch-at-age, spawning age composition, egg survey biomass, acoustic survey biomass, mile-days of milt
- Natural mortality from non-disease $M_0 = 0.25$. After 1993, natural mortality is a linear function of disease variables
- Objective function: minimize weighted sums of squares of the seine, spawning, egg survey, acoustic survey, and milt information

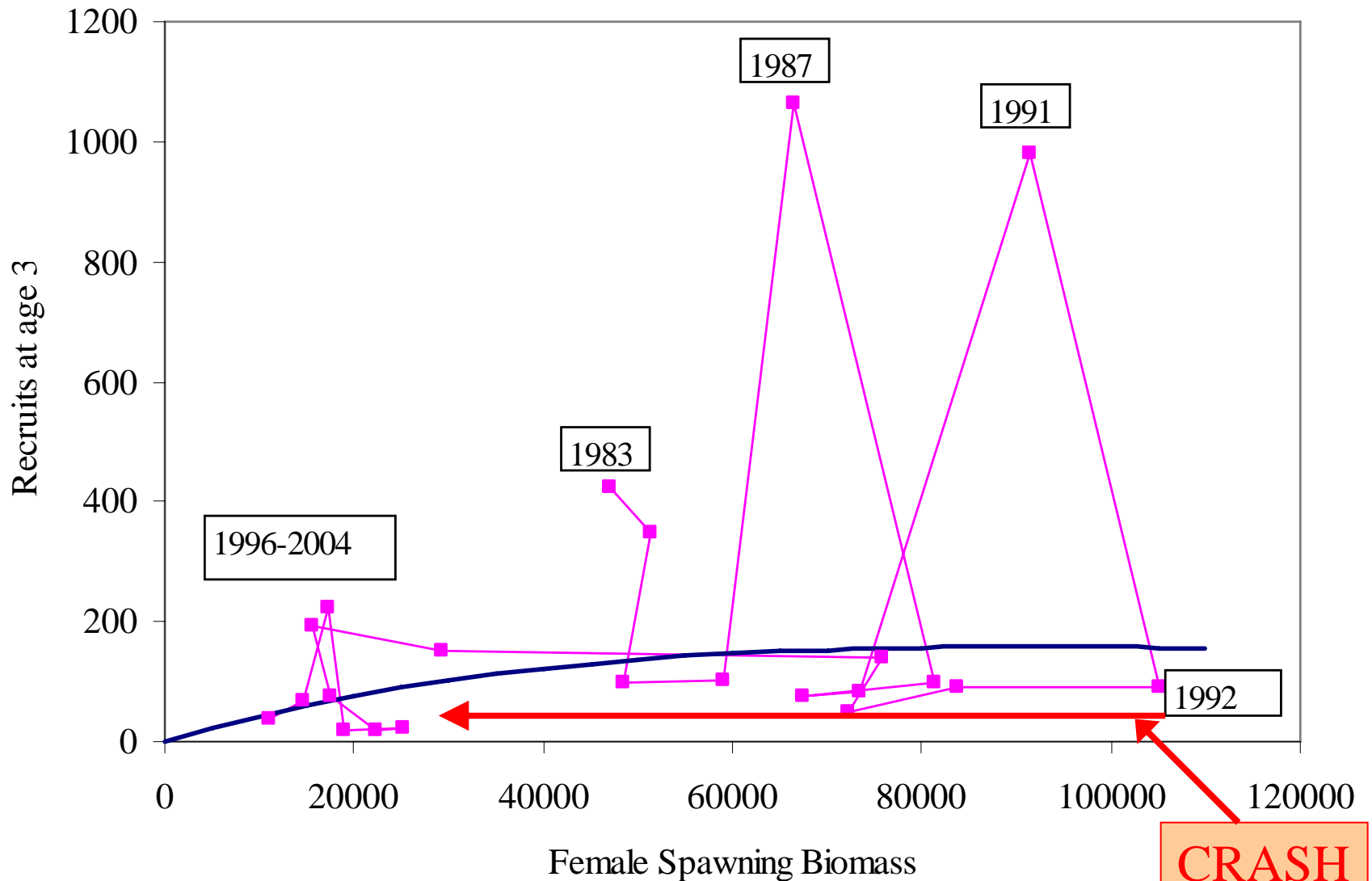
Disease variables

Year	Ages 3-4		Ages 5+	
	VHSV index	<i>I.Hoferi</i> index	VHSV index	<i>I.Hoferi</i> index
1994	1.04%	15.8%	0.06%	7.5%
1995	0.14%	3.8%	0.03%	12.0%
1996	0.00%	5.1%	0.00%	11.3%
1997	0.09%	4.5%	0.05%	10.2%
1998	0.60%	2.9%	0.16%	15.2%
1999	0.01%	3.2%	0.00%	11.2%
2000	0.00%	0.0%	0.00%	11.2%
2001	0.01%	8.0%	0.01%	20.0%
2002	0.14%	2.7%	0.04%	15.8%
2003	0.01%	8.1%	0.003%	30.3%
2004	0.05%	4.3%	0.003%	16.4%

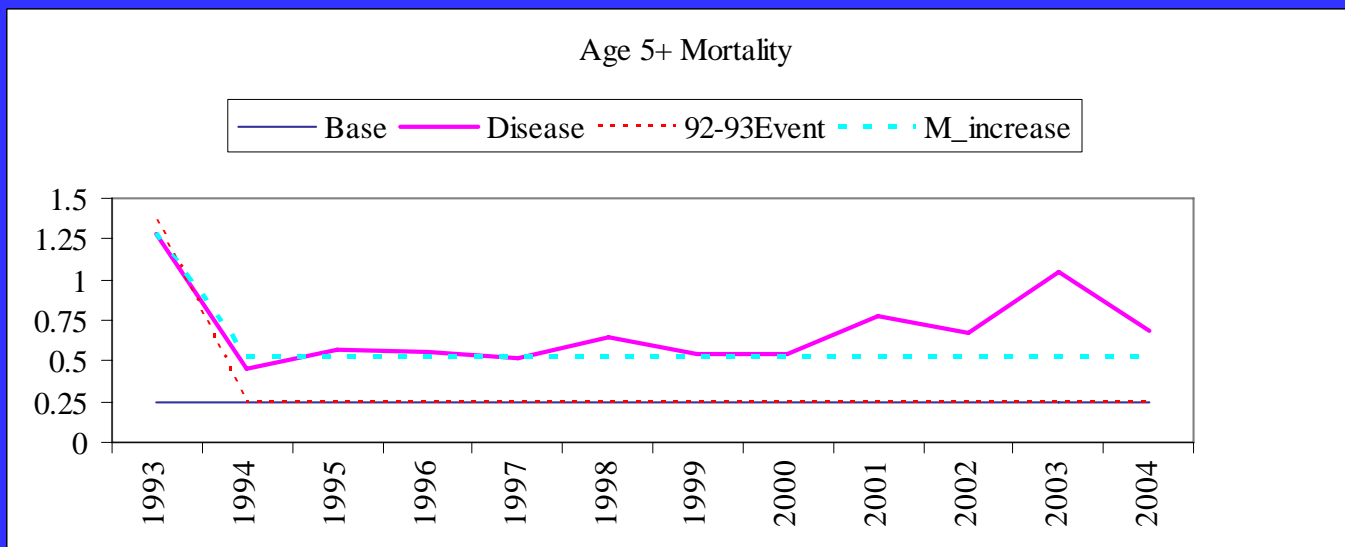
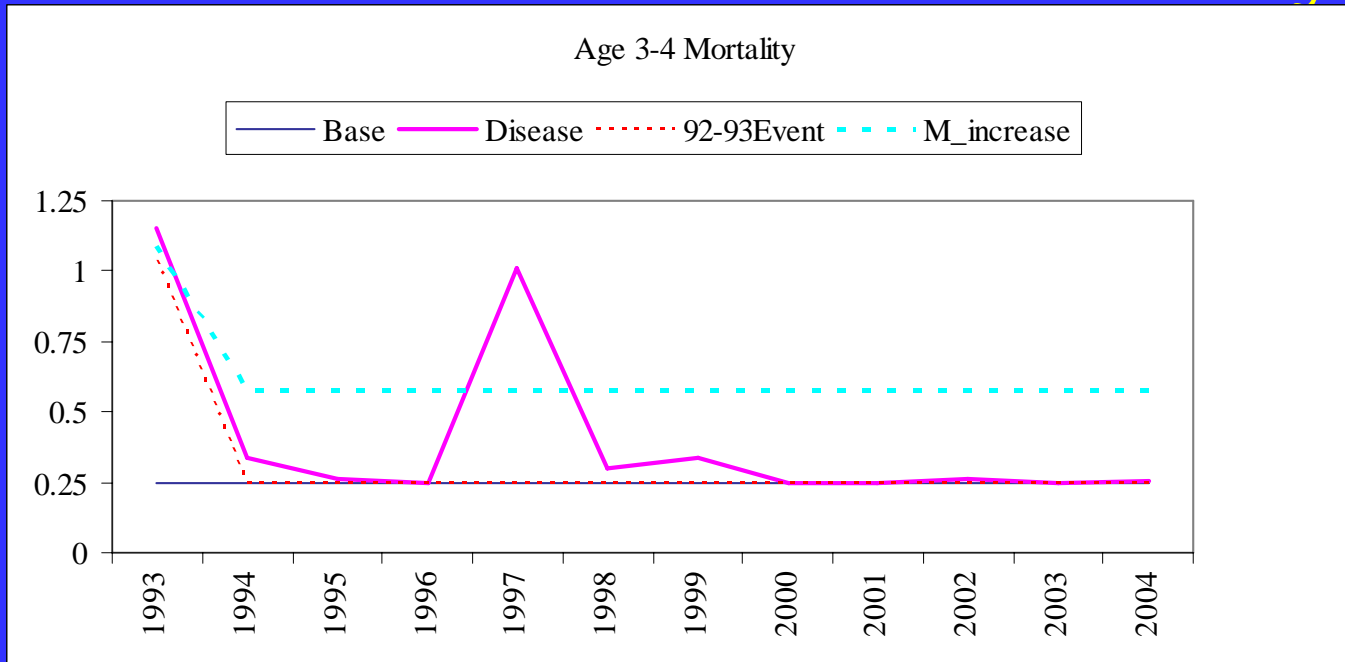
Spawning Biomass and Recruitment



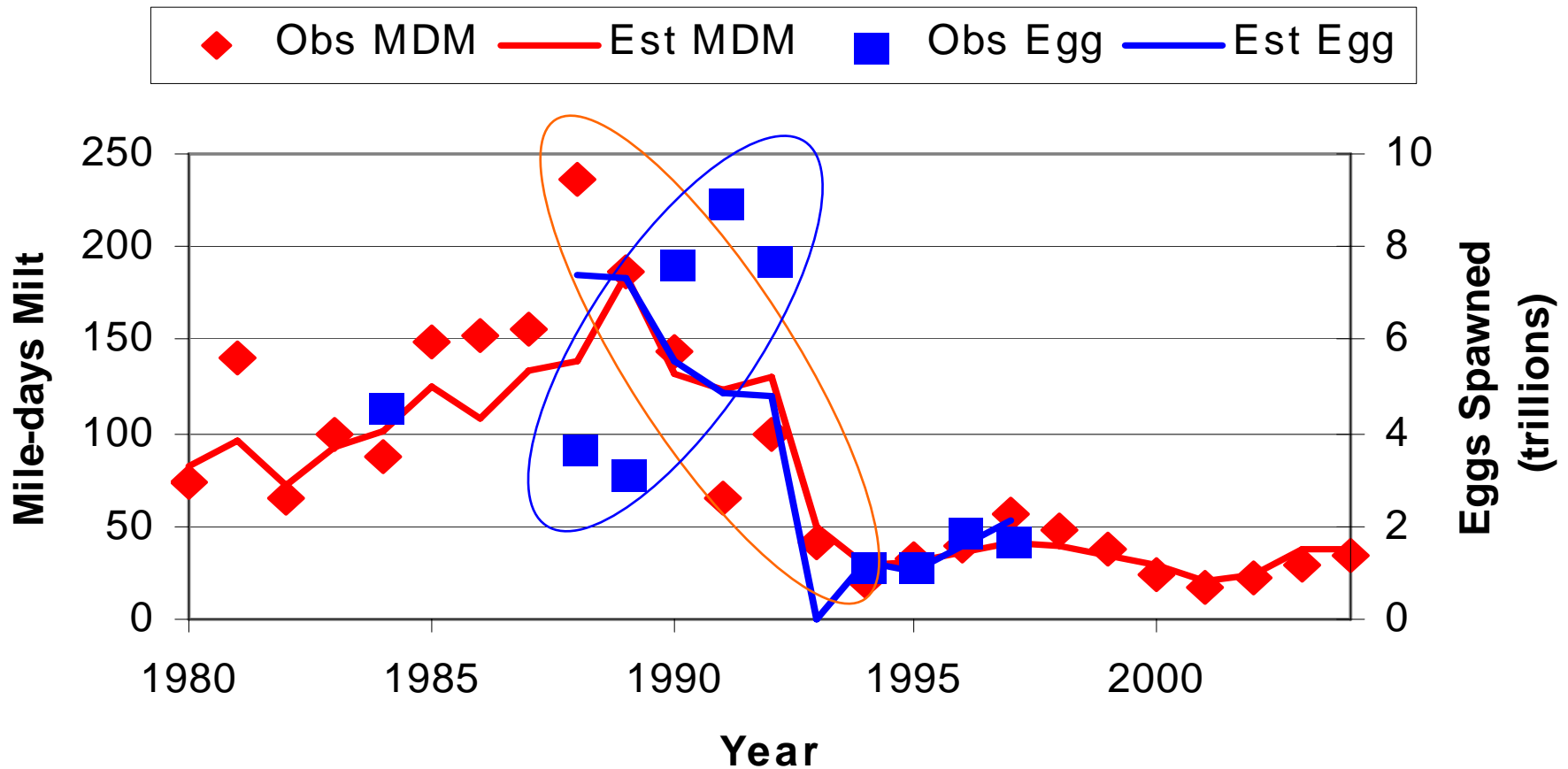
Spawner-recruit relationship



Estimated Natural Mortality



Conflict between reproductive datasets



- Greater belief in Mile-days of Milt: Decline in egg production and spawning biomass began in 1989.
- Greater belief in Egg Survey: Egg production and spawning biomass collapsed in 1993.

Challenge 3b: Conflicts

- Indirect conflicts with other datasets: spawning and catch age composition, disease prevalence
- At least it is better to expose conflicts and state uncertainty than to ignore it or hide it.

Challenge 4: Parameter inflation for biological realism

- For each year of new data, any number of parameters can change (as $t \rightarrow \infty, p \rightarrow \infty$)
- Examples: natural mortality, gear selectivity, survey catchability, maturity
- There is little theory for highly-parameterized models
 - Solution: AICc, BIC, DIC for parsimony

Ecosystem input to fishery models

- Physical and oceanographic variables: relation to recruitment
- Lower trophic level data: relation to recruitment; understanding mortality and growth of the fish population's early life history
- Disease and predation: effect on natural mortality

Fishery model output to ecosystem studies

- Recruitment as a time series
- Natural mortality as a time series
- Abundance, biomass, and weight as time series
- Direct estimates of consumption (with gut data)
- Patterns, trends, and anomalies
- Spatially explicit models
 - Spatial survey data
 - Compartment models with movement

Summary

- Both biological and statistical issues are critical in fishery modeling
- Lots of data; lots of parameters, yet we still feel uncertain
- Innovative solutions have and will occur.
- Many interesting theoretical issues need attention.