Science, Service, Stewardship

Economics and ACLs

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Main Points

- Maximum economic yield (MEY) could proxy OY
  - Reflects benefits to society more directly than MSY
  - Can be calculated subject to any constraints
  - Basis for estimating opportunity costs of constraints
  - Can reflect specific uncertainties and risk preferences
  - MEY proxies?
- Risk/uncertainty
- Ongoing work (4 case studies)
  1. Probabilistic forecasts: Revenue v. risk in ACLs for Alaska King Crab
  2. MSY/MEY for Eastern Bering Sea Snow Crab
  3. Robust harvest policy under parameter uncertainty
  4. Optimal investment in learning

National Standard 1

- "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry."

- Preventing overfishing is a constraint
- OY is an objective

Optimum Yield

OY influenced by

- Risk preferences
- Harvest methods and institutions
  - Affect benefits and costs
  - Affect distribution of benefits and costs
  - Affect risk & uncertainty

OY & MSY

OY is defined by MSA Section 3(33) as "the amount of fish which—

[….]

(B) is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor; and

[….]

OY & MSY

Is MSY a 'good' objective?

- Resource persistence
- Costs are not considered
- Yield can be a poor proxy for benefits

OY & MSY

$$OY = MSY/X$$

vs

$$OY = \max f(.) \text{ s.t. } B_{OY} >= B_{MSY}$$
$$\text{s.t. etc.}$$

"…on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor…"

Maximum Economic Yield (MEY)

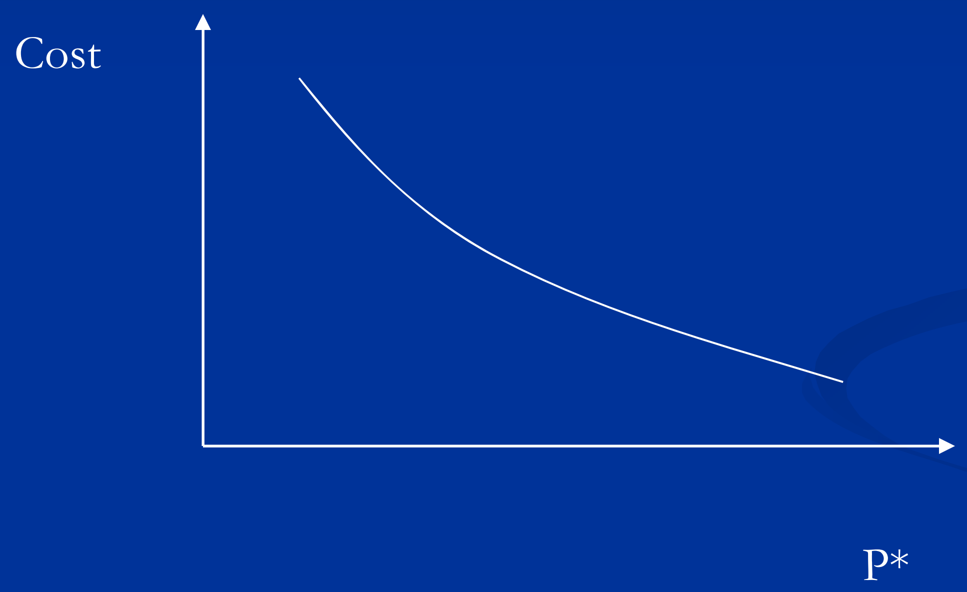
- MEY is harvest trajectory that yields greatest (net) economic benefits to society over time

- Subject to any constraints desired

- Often, $B_{MEY} > B_{MSY}$
  (If not, impose constraint $B_{MEY} >= B_{MSY}$)

Risk and Uncertainty

- Cost of risk reduction



Case 1: Probabilistic Wholesale Revenue Projections (NPFMC Crab ACL Analysis)

Total Revenue =
Random Catch x Product Recovery Rate x Price Forecast

$$TR_{yi} = C_{yi} \times PRR_i \times P_{yi}$$

$$= C_{yi} \times [\bar{K} + (\eta_{1i} \times \sigma_1)] \times [\bar{P}_y + (\eta_{2i} \times \sigma_2)]$$

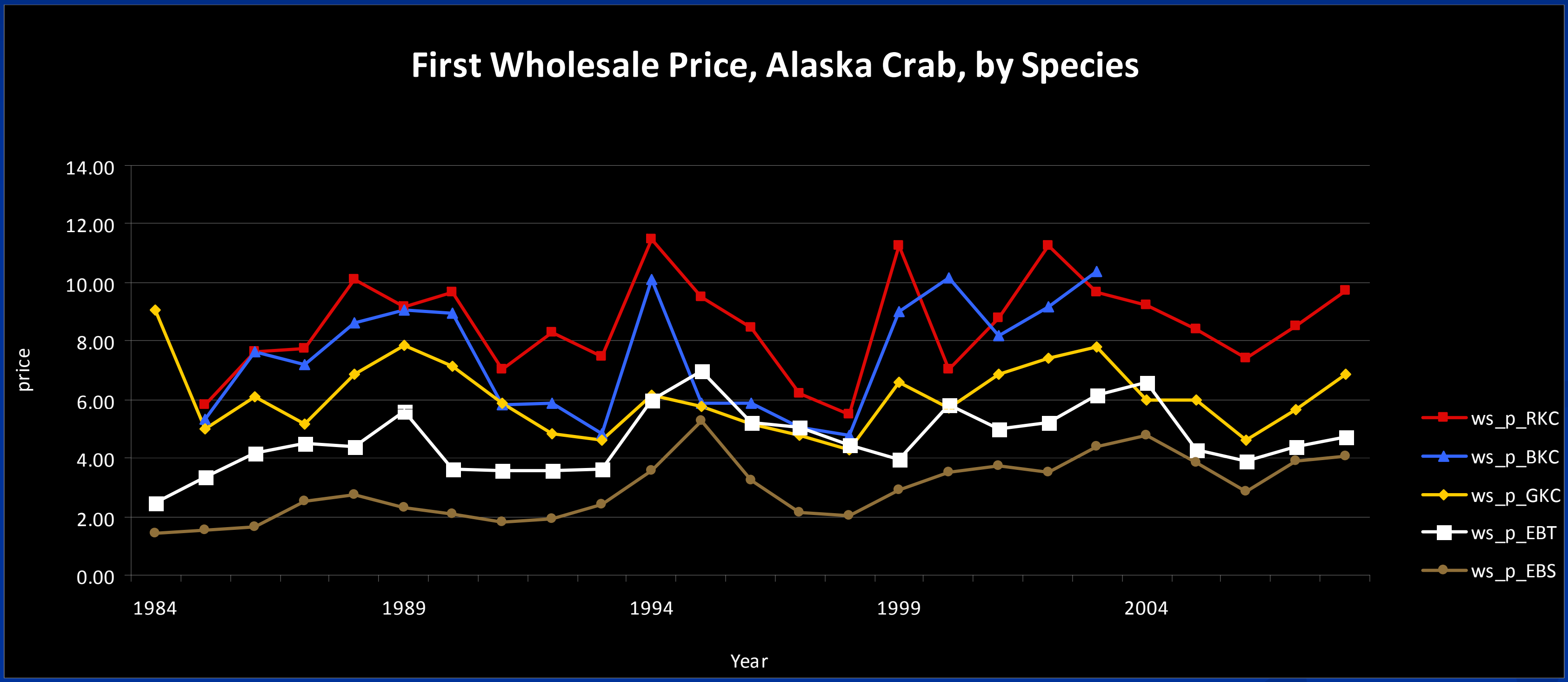
$$\eta_{1i}, \eta_{2i} \sim N(0,1) \quad i = 1, \ldots, 800$$

Total Present Value = Discounted Sum of Total Revenues

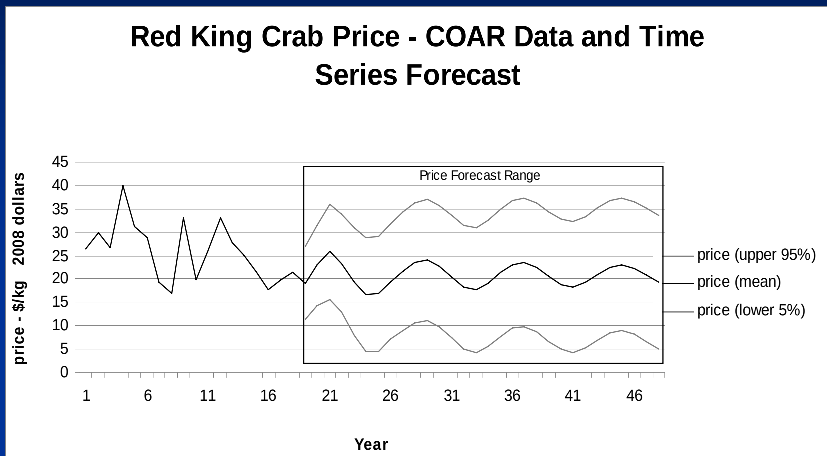
$$TPV_i = \sum_{y=1}^{Y} \left(\frac{1}{1+r} \right)^{y-1} TR_{yi}$$

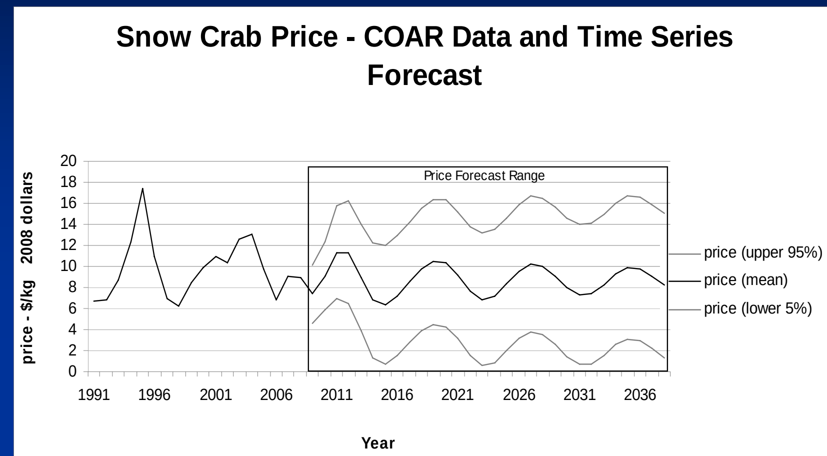
Sort TR_{yi}, TPV_i for $i = 1, \ldots, 800$: Median, lower/upper 5th percentiles give 95% prediction intervals for TR_y and TPV

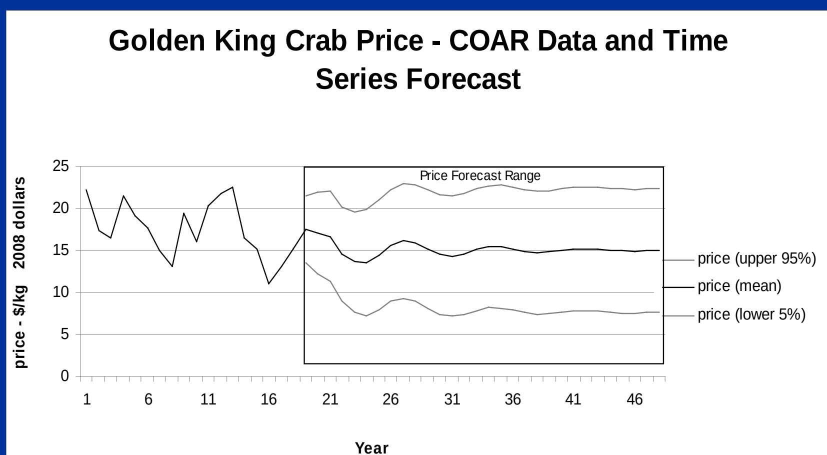
Alaska Crab Wholesale Prices 1984-2008
Source: Commercial Operators Annual Reports

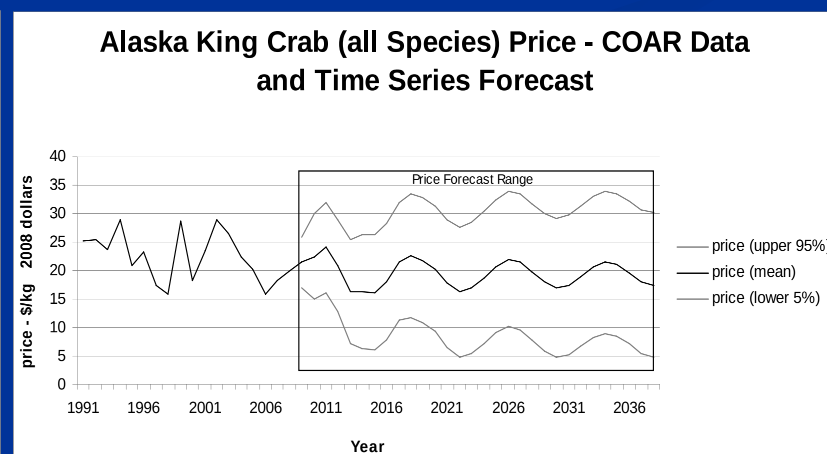


Probabilistic Price Forecasts from Time Series Model









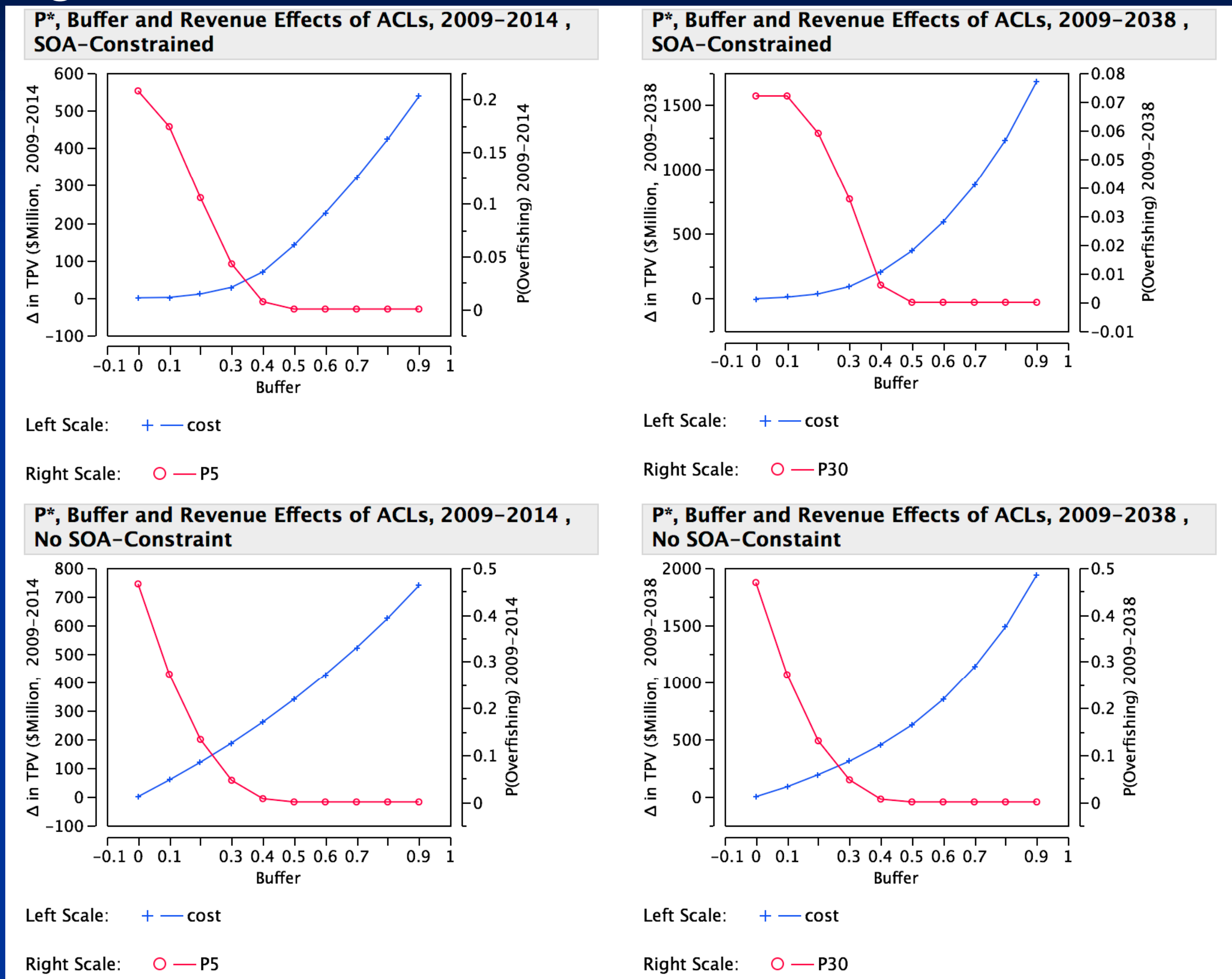
Short-Run Implications for P*

ACL defined by P* (additional uncertainty = 0.2)

Alternative	ABC_{tot}	ABC_{dir}	Multiplier	Revenue	
				Millions $	%Change
$P^* = 0.5$	10,774[&]	9,559	1.0	**142**	0%
$P^* = 0.4$	10,544	9380	0.94	**135**	5%
$P^* = 0.3$	9,952	8821	0.89	**127**	11%
$P^* = 0.2$	9,370	8306	0.83	**119**	16%
$P^* = 0.1$	8,565	7559	0.76	**109**	23%

& - set to the point estimate. Source: **Chapter 6 (BBRKC) Table 6-1 (c)**

Bristol Bay RKC:
Change in Forecasted Revenue from Baseline TPV (r=2.7%)

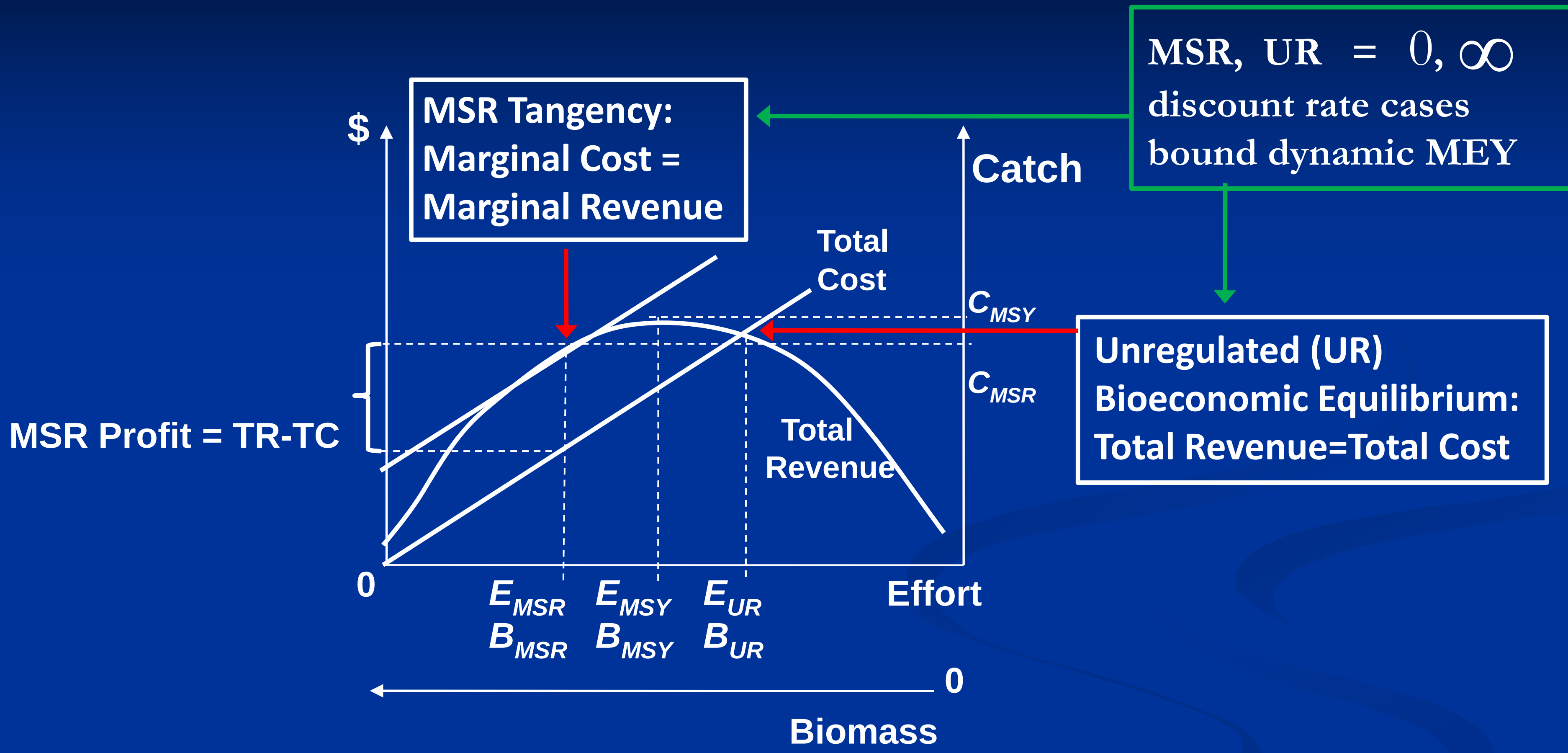


Case 2: Recent Scientific Interest in MEY

- *On implementing maximum economic yield in commercial fisheries* (Dichmont, Pascoe, Kompas, Punt, Deng, *PNAS* 2010)
- *Economics of overexploitation revisited* (Grafton, Kompas, Hilborn, *Science* 2007)
- *Limits to the privatization of fishery resources* (Clark, Munro, Sumaila, *Land Economics* 2010)
- *Limits to the privatization of fishery resources: Comment* (Grafton, Kompas, Hilborn, *Land Economics* 2010)
- *Limits to the privatization of fishery resources: Reply* (Clark, Munro, Sumaila, *Land Economics* 2010)

Maximum Sustainable Rent (MSR):

Static MEY in a Gordon-Schaefer Bioeconomic Model



Key result: $B_{MSR} > B_{MSY}$ unless Marginal Cost = 0 then $B_{MSR} = B_{MSY}$

If and only if: $C_{MSR} < C_{MSY}$ unless MC = 0 then $C_{MSR} = C_{MSY}$

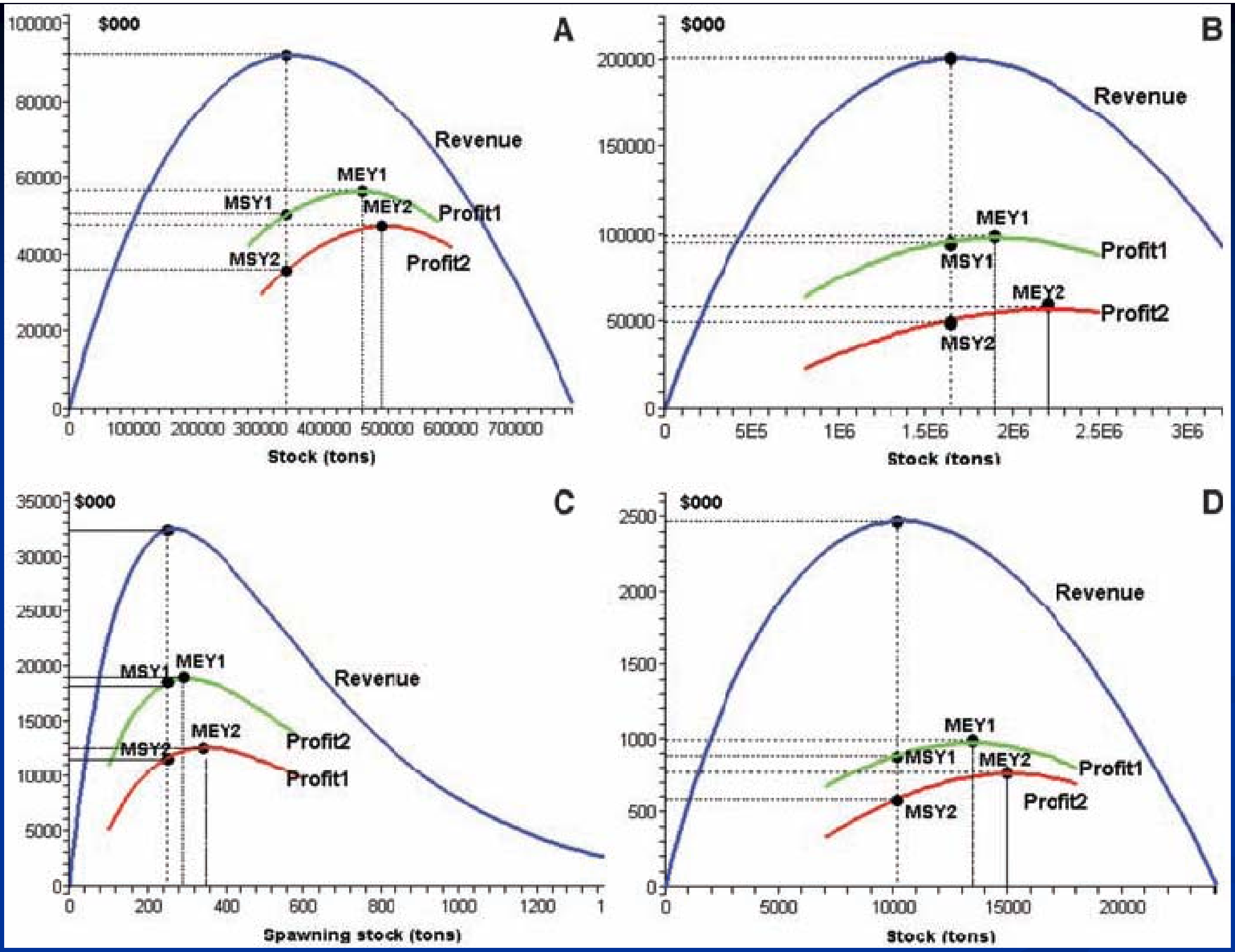


Fig. 1. (A) BMEY and BMSY of Western and Central Pacific big eye tuna. (B) BMEY and BMSY of Western and Central Pacific yellowfin tuna. (C) BMEY and BMSY of Australian northern prawn fishery. (D) BMEY and BMSY of Australian orange roughy fishery.

Source: Grafton et al. 2007, Economics of Overexploitation Revisited, *Science* 318:1601

Bioeconomic Model = Optimal Control Problem

$$\underset{\{C_t \geq 0\}}{\text{Max}}\ \text{E}\left\{\sum_{t=0}^{\infty} \beta^t \left(V_t' C_t - \frac{1}{2}(C_t - C_{t-1})'\mathbf{A}(C_t - C_{t-1}) \right)\right\}$$

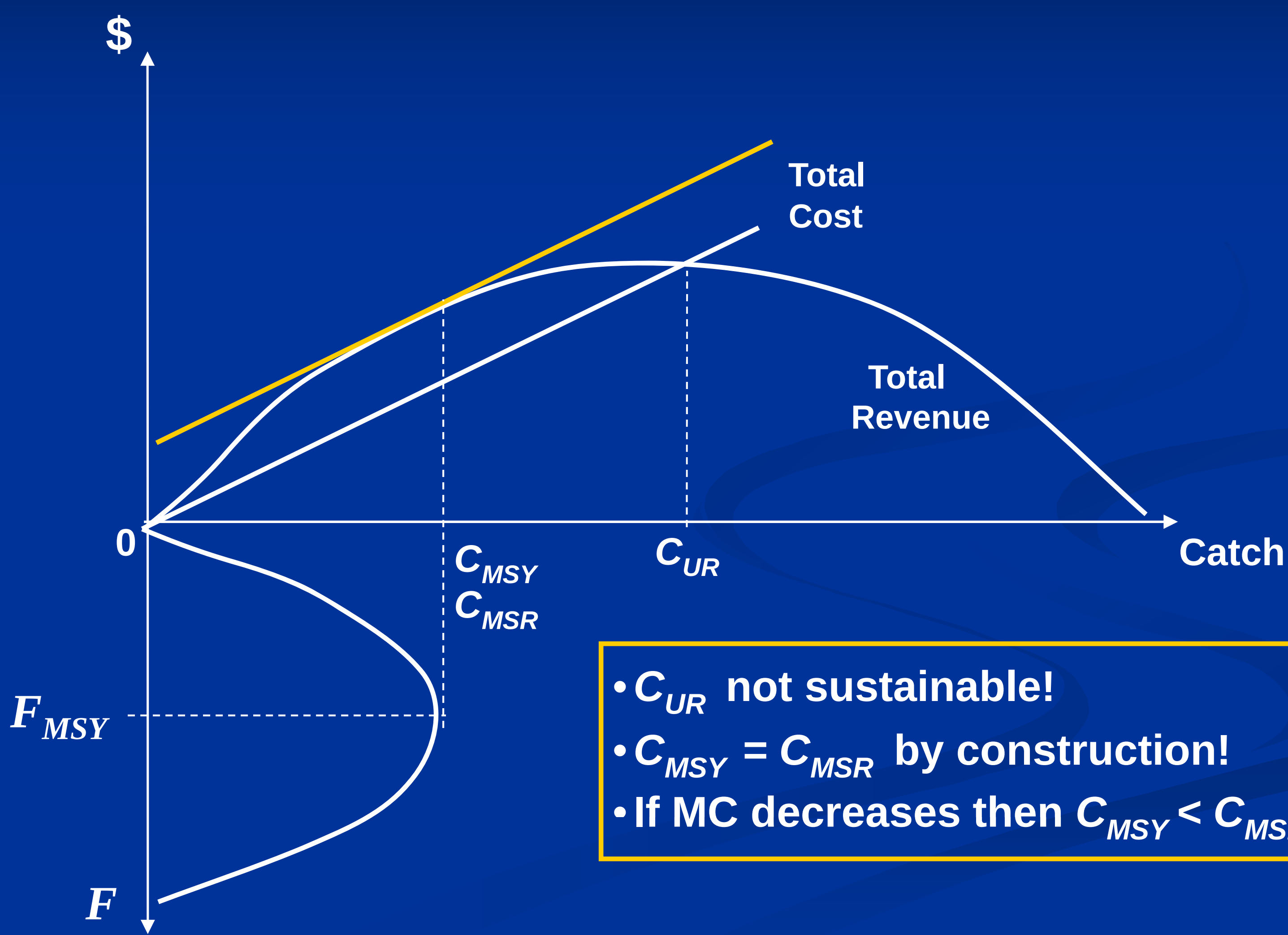
$$\text{s.t. } N_t = \mathbf{GM}N_{t-1} - \mathbf{GM}^{\frac{1}{2}} C_{t-1} + R_t$$

$$V_t = P_t - \theta - \mathbf{\Psi} C_t + \mathbf{\Phi} N_t$$

- Prices P_t and recruitment R_t are <u>exogenous</u> stochastic processes
- θ is a vector of cost parameters; $\mathbf{G}$, $\mathbf{M}$ are growth, net mortality
- Except for matrices (in bold), variables are random vectors
- Baranov, Pope's approx give pop dynamics in catch-explicit form
- Selectivity vector implies a scalar control problem in F
- Solution is summarized by an intertemporal decision rule

Population Dynamics and Demand-Side Effects:

Static MEY Alternative to Gordon-Schaefer



- C_{UR} not sustainable!
- $C_{MSY} = C_{MSR}$ by construction!
- If MC decreases then $C_{MSY} < C_{MSR}$

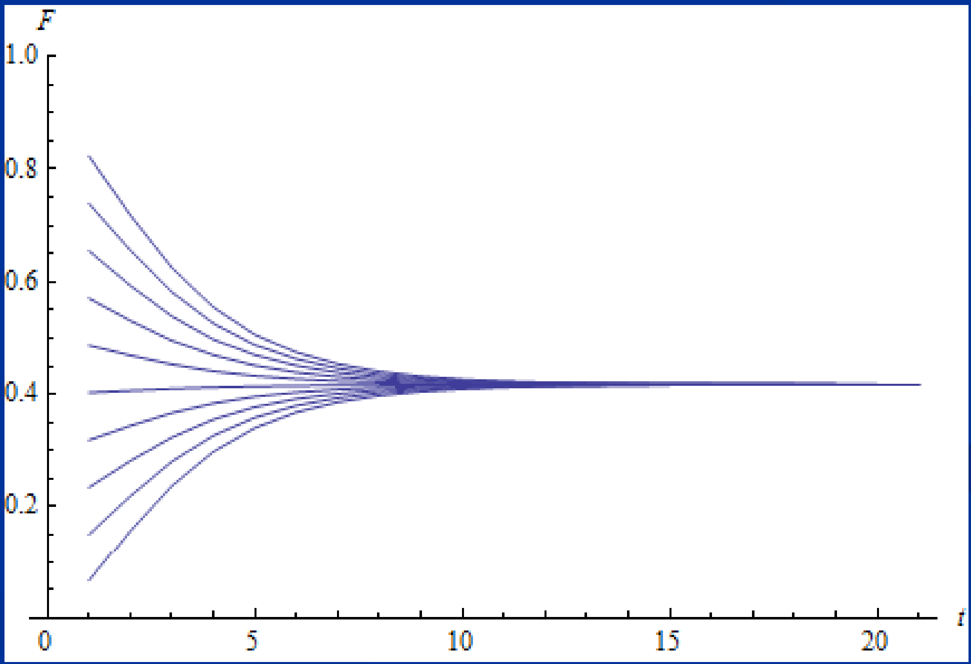
Stochastic Dynamic MEY & Bioeconomic Equilibrium

- Intertemporal decision-rule implies time series $F_t(\omega)$
- $F_t(\omega) > F_{MSY}$ or $F_t(\omega) < F_{MSY}$ are possible events
- **Probability function** $\Pr(\omega \mid \square)$ **measures likelihoods**

Optimal dynamics to F_{MSY} from different initial conditions

Simple example (*5-size classes*):

1. Deterministic (easily relaxed)
2. Constant recruitment = $1.9\text{x}10^6$
3. Constant price = \$2/crab
4. Constant direct cost = \$1.65/crab
5. No stock externality or bycatch
6. Small price elasticity of demand

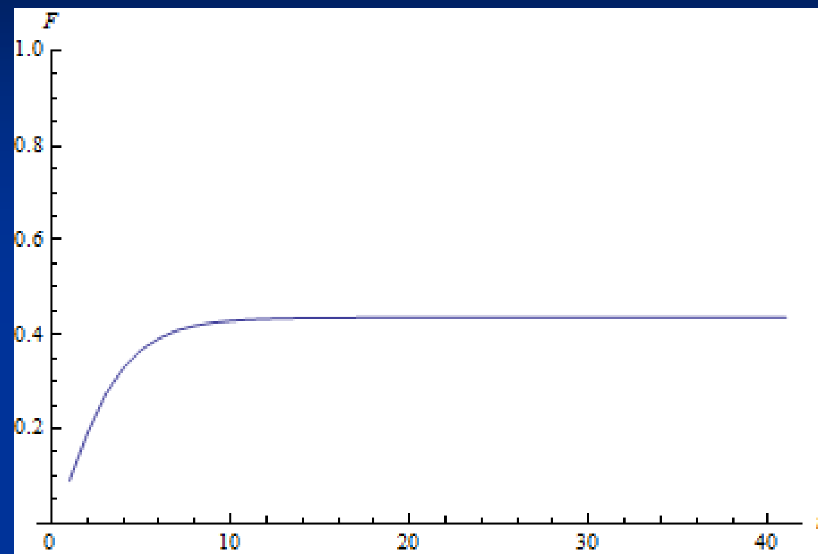


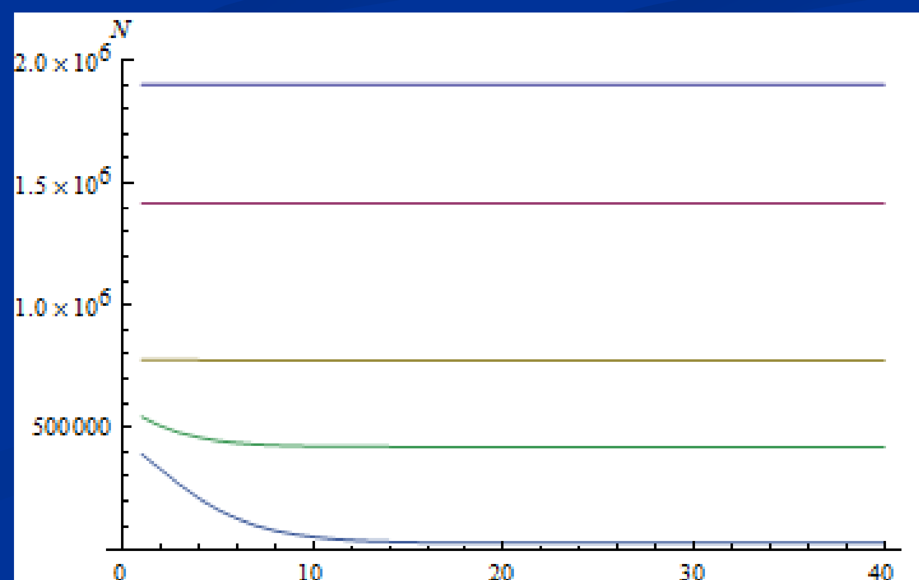
Optimal Dynamics of Unfished Population to MSY

Dynamic F_{MEY} *and Numbers of crab*

<u>Simple example (*5-size classes*)</u>:

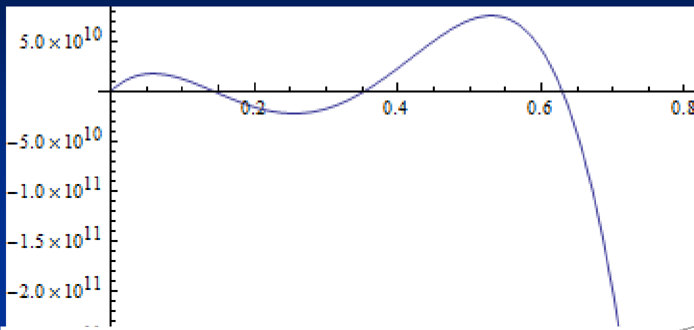
1. Deterministic (easily relaxed)
2. Constant recruitment = 1.9×10^6
3. Constant price = \$2/crab
4. Constant direct cost = \$1.65/crab
5. No stock externality or bycatch
6. Small price elasticity of demand



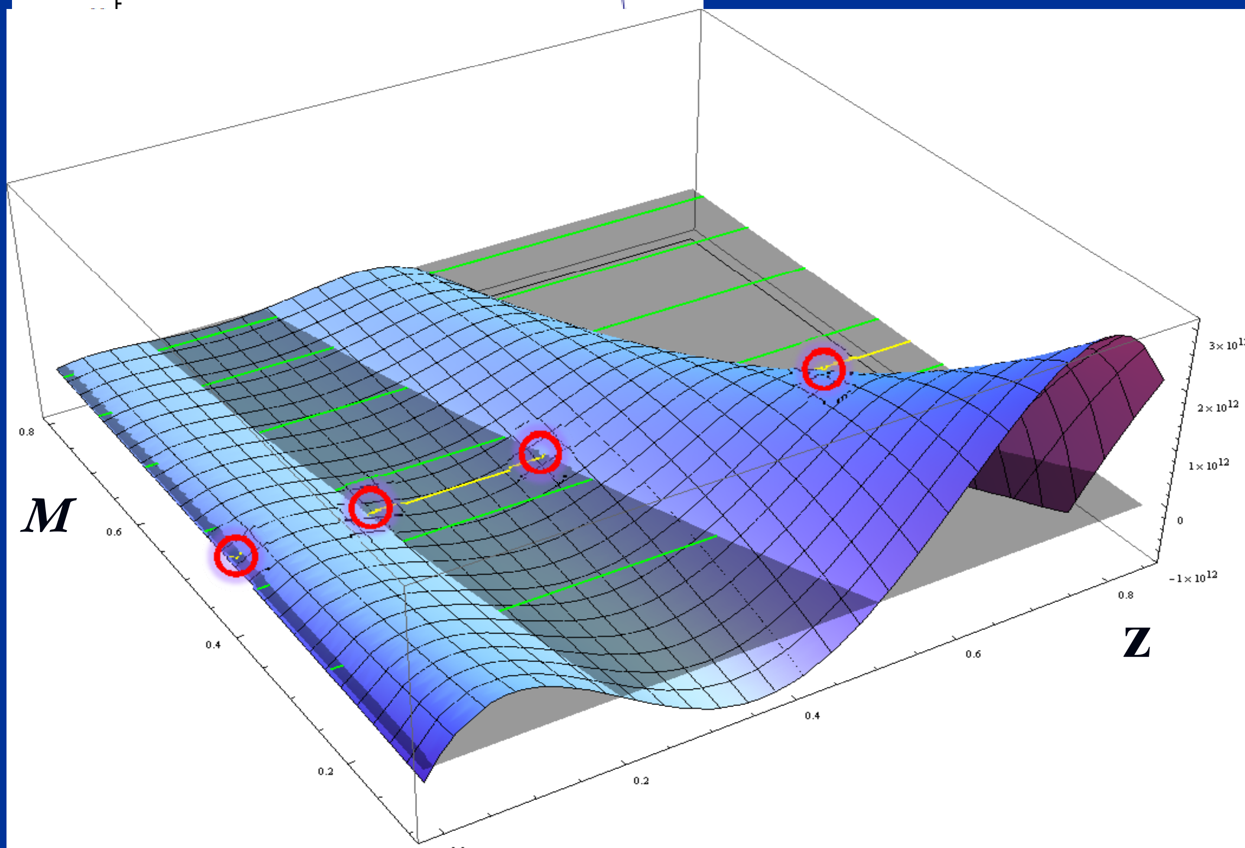


Factor characteristic polynomial to solve the model

Shape driven by parameter estimates of population model



5-1 stable roots (<1) and 1 unstable (>1)
Roots govern system dynamics, optimal speed-of-adjustment to fluctuations in recruitment, prices



z-M plot (point-estimate yellow): Characteristic polynomial with variation in natural mortality *M*

Real Roots = Stable Solution!

Case 3: Risk, Uncertainty, and Robust Control

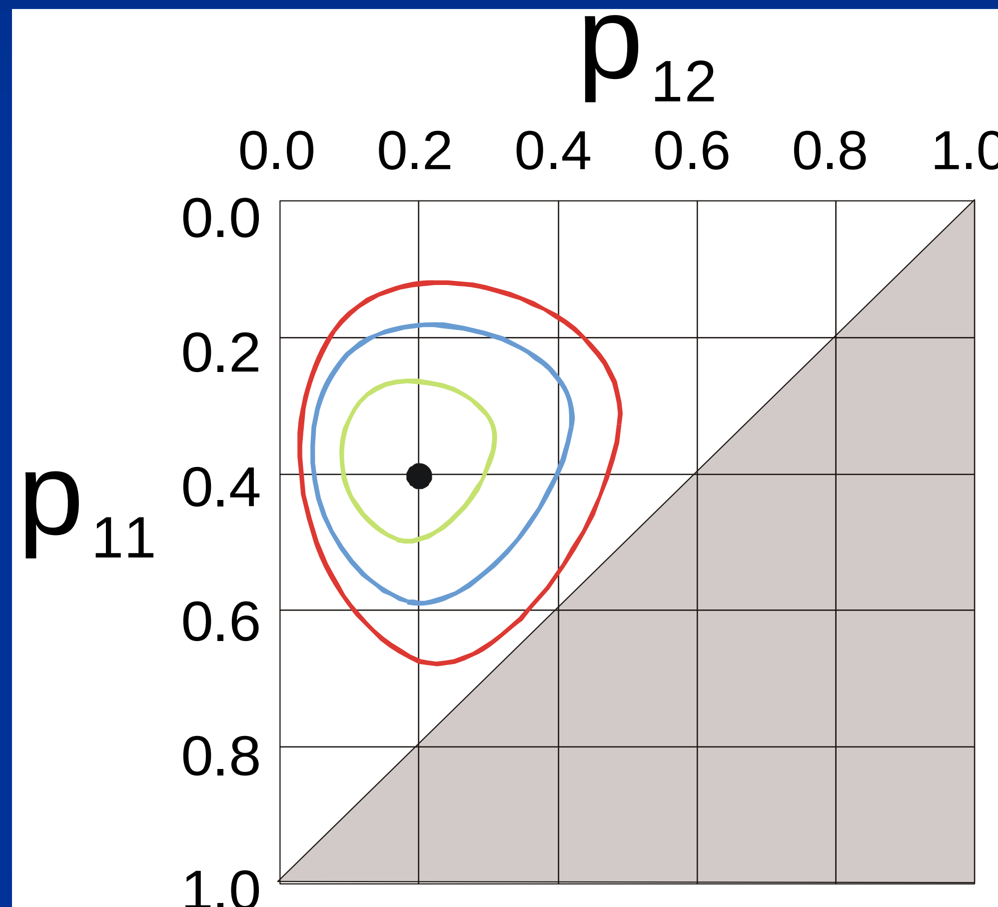
- Risk
- Uncertainty
  - Parameter uncertainty
  - Model uncertainty
  - Observation uncertainty
  - Stationarity uncertainty

How can we capture parameter uncertainty in control rules?

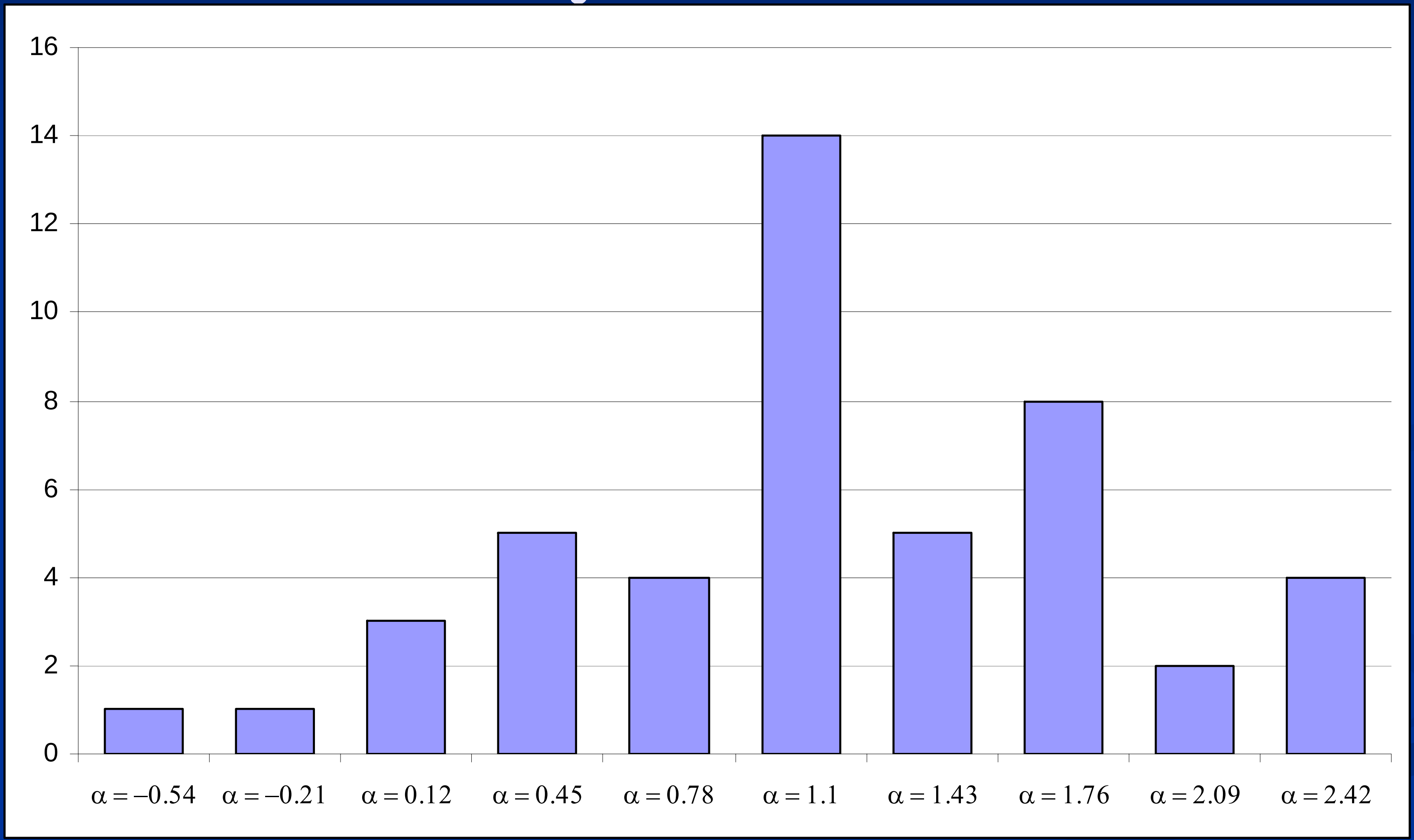
Observed transitions

		x_{t+1}		
		1	2	3
x_t	1	4	2	4

Uncertainty Bounds

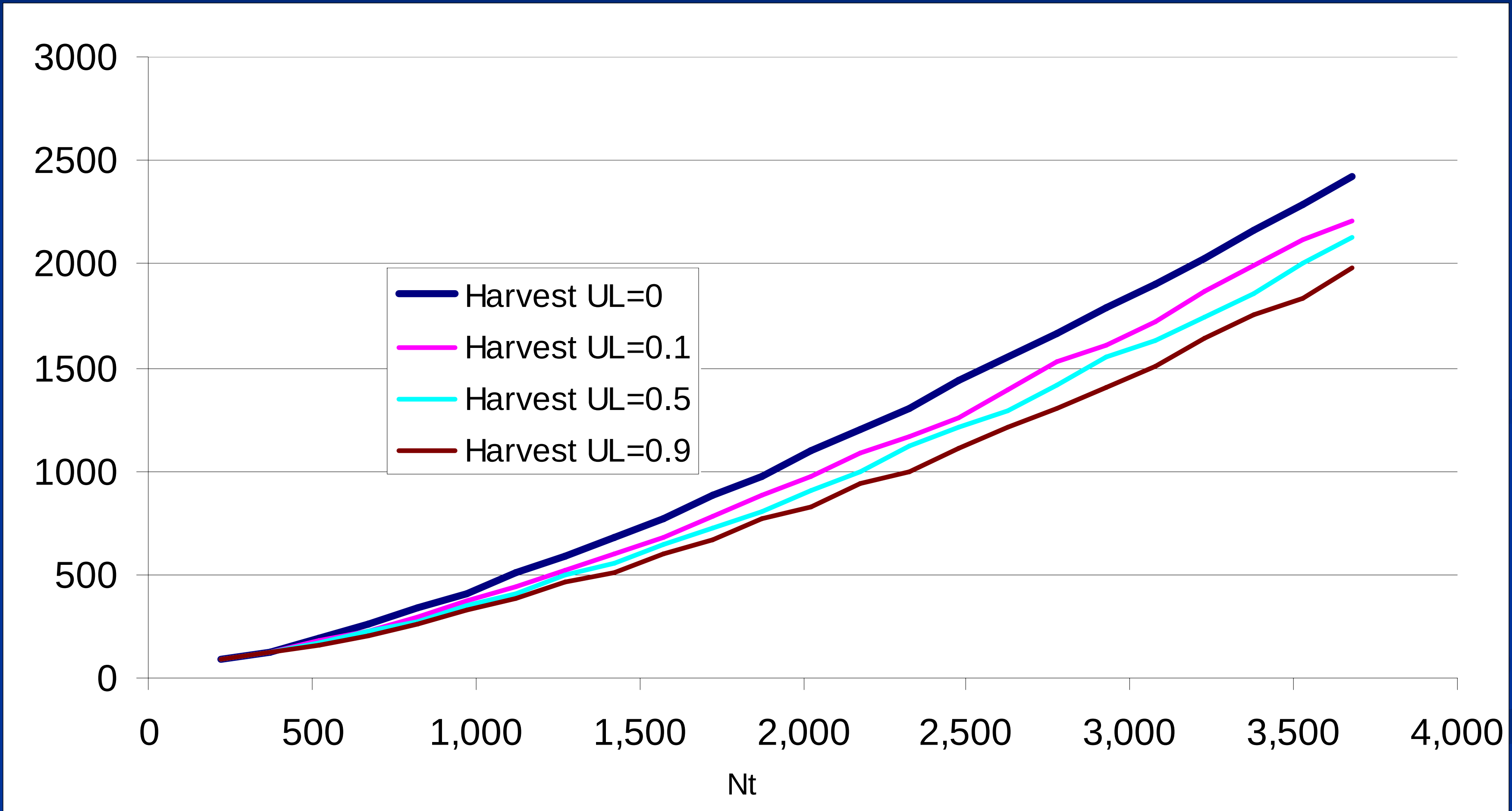


How can we capture parameter uncertainty in control rules?



Source: Based on data presented in Walters (1975) and Hilborn and Walters (1992)

How can we capture parameter uncertainty in control rules?



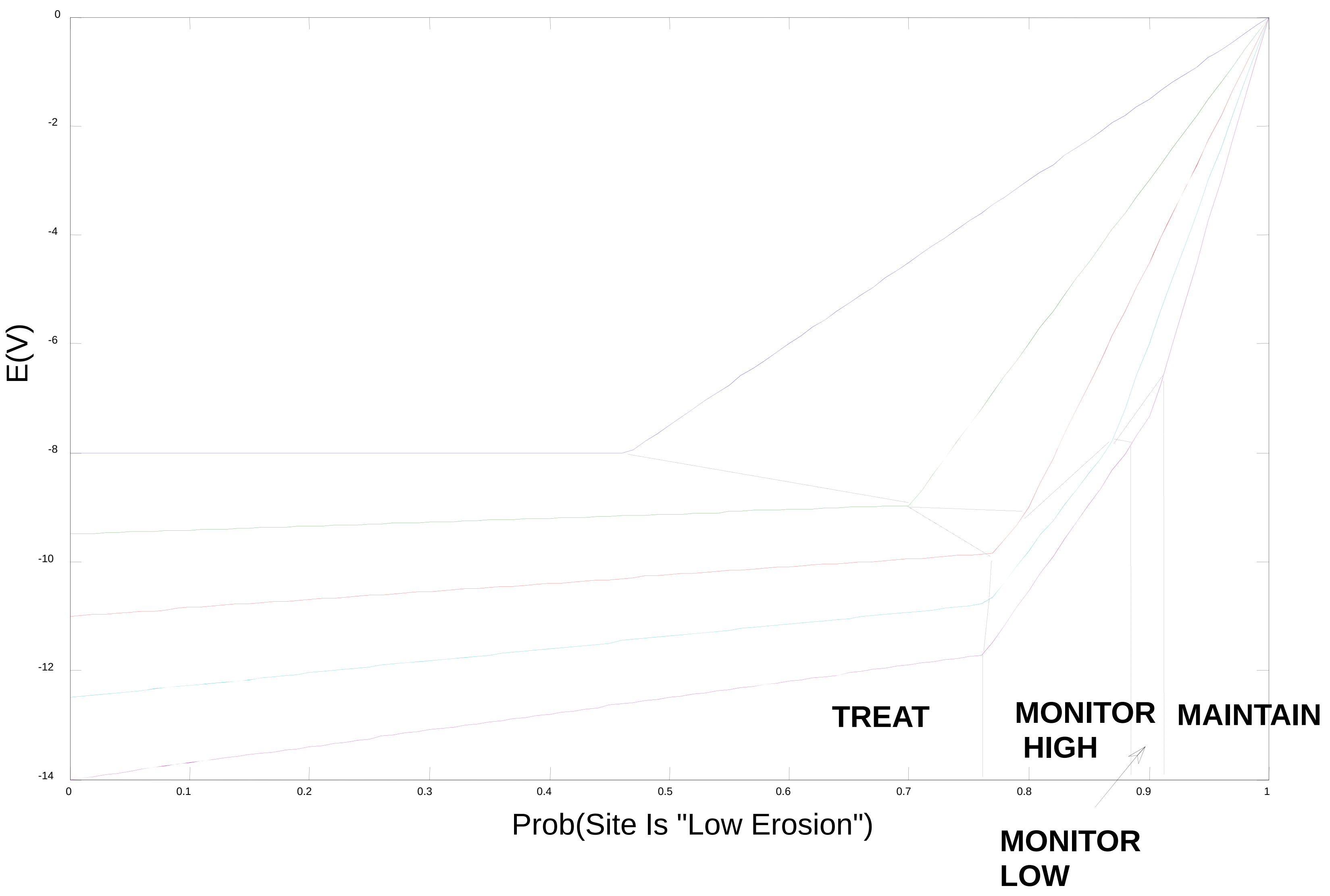
Case 4: Optimal investment in learning

How can we think about whether to invest in

a) cheaper, lower quality information vs.

b) more expensive, higher quality information?

Choice of learning protocol



Conclusions

OY is objective, MSY can be treated as a constraint in control problem

MEY can proxy OY … constrain MEY any way you like

MEY calculated appropriately implies ACL or ACT

Information is part of the value of catch, so part of OY

Various work to capture risk and uncertainties is underway