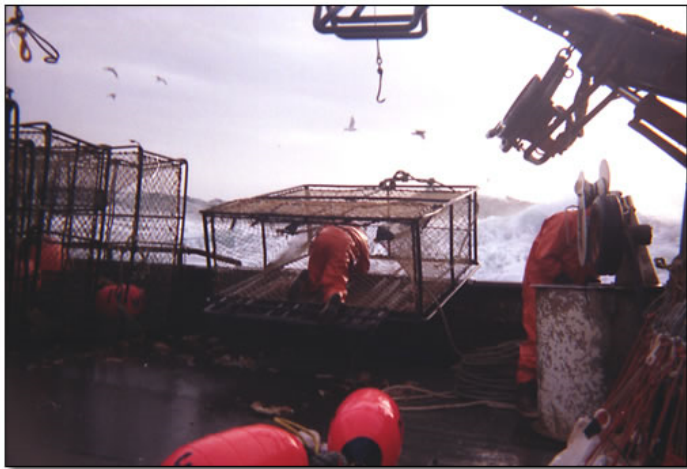


Fisheries



Photo by Roy H. Hansen



When the fishing is good, it is common for crabbers to have to crawl into the crab pots and add new bait to them before they are dropped back down into the water. In the lower right hand corner, you can see the tops of bait bags hanging and ready to be tied into crab pots. Common baits are herring and cod.

[Full Size](#) [Close Window](#)



Fisheries

Introduction: Economic and policy issues

Population dynamics

Sustainable catch-effort diagram

Bio-economic equilibria

- Free access.
- Sole owner

Traditional fishery management

- Limited entry
- Season closures
- Gear restrictions

Fisheries (cont.)

Rights-based management

- ITQs
- Private harvester agreement, cooperatives
- TURFs

Protecting marine ecosystems

- Protecting marine habitats
- Controlling bycatch

Aquaculture: Promise and problems

Fisheries (cont.)

Rights-based management

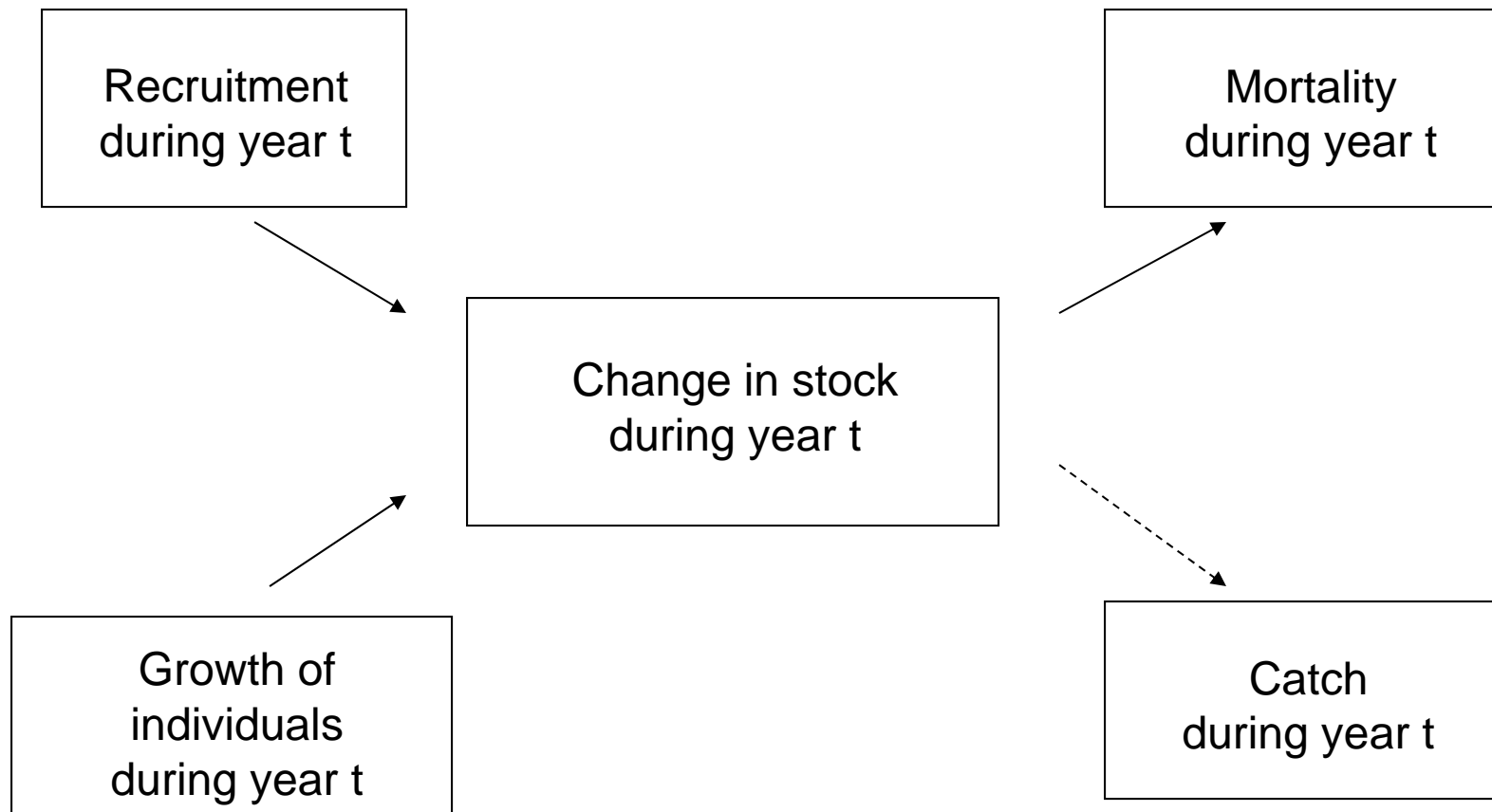
- ITQs
- Private harvester agreement, cooperatives
- TURFs

Protecting marine ecosystems

- Protecting marine habitats
- Controlling bycatch

Aquaculture: Promise and problems

Components of stock dynamics



Logistic model of population dynamics

Assumes recruitment, growth, and mortality are determined by $S(t)$. Natural growth is $f(S(t))$.

With catch, Q , equation for popul'n dynamics is

$$\frac{dS(t)}{dt} = f(S(t)) - Q(t)$$

Specific logistic growth function:

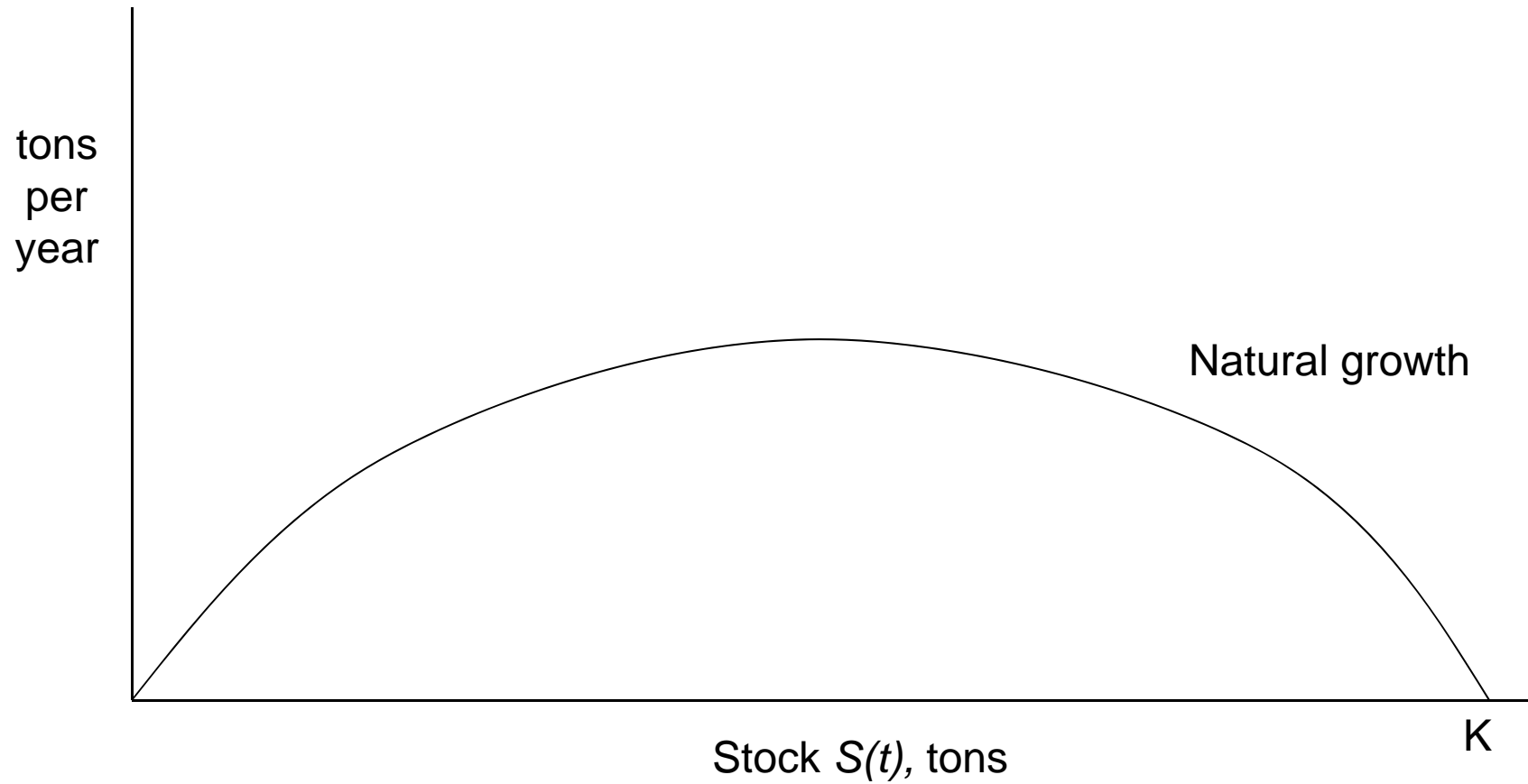
$$\frac{dS(t)}{dt} = aS(t)(K - S(t)) - Q(t)$$

K is carrying capacity; ' a ' is adjustment speed.

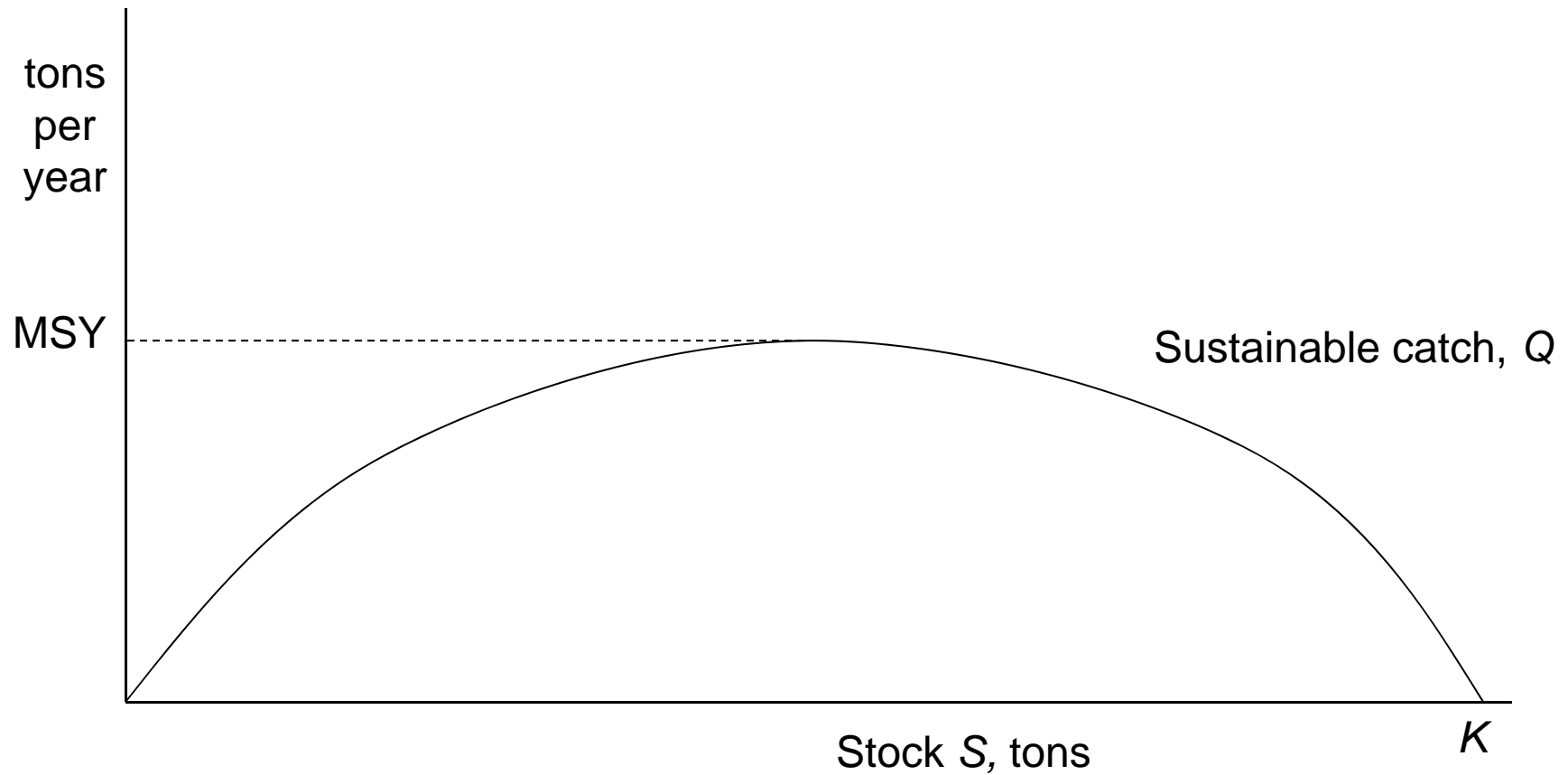
Numerical example of logistic model

$$\frac{dS(t)}{dt} = .01S(t)(100 - S(t)) - Q(t)$$

Logistic growth model



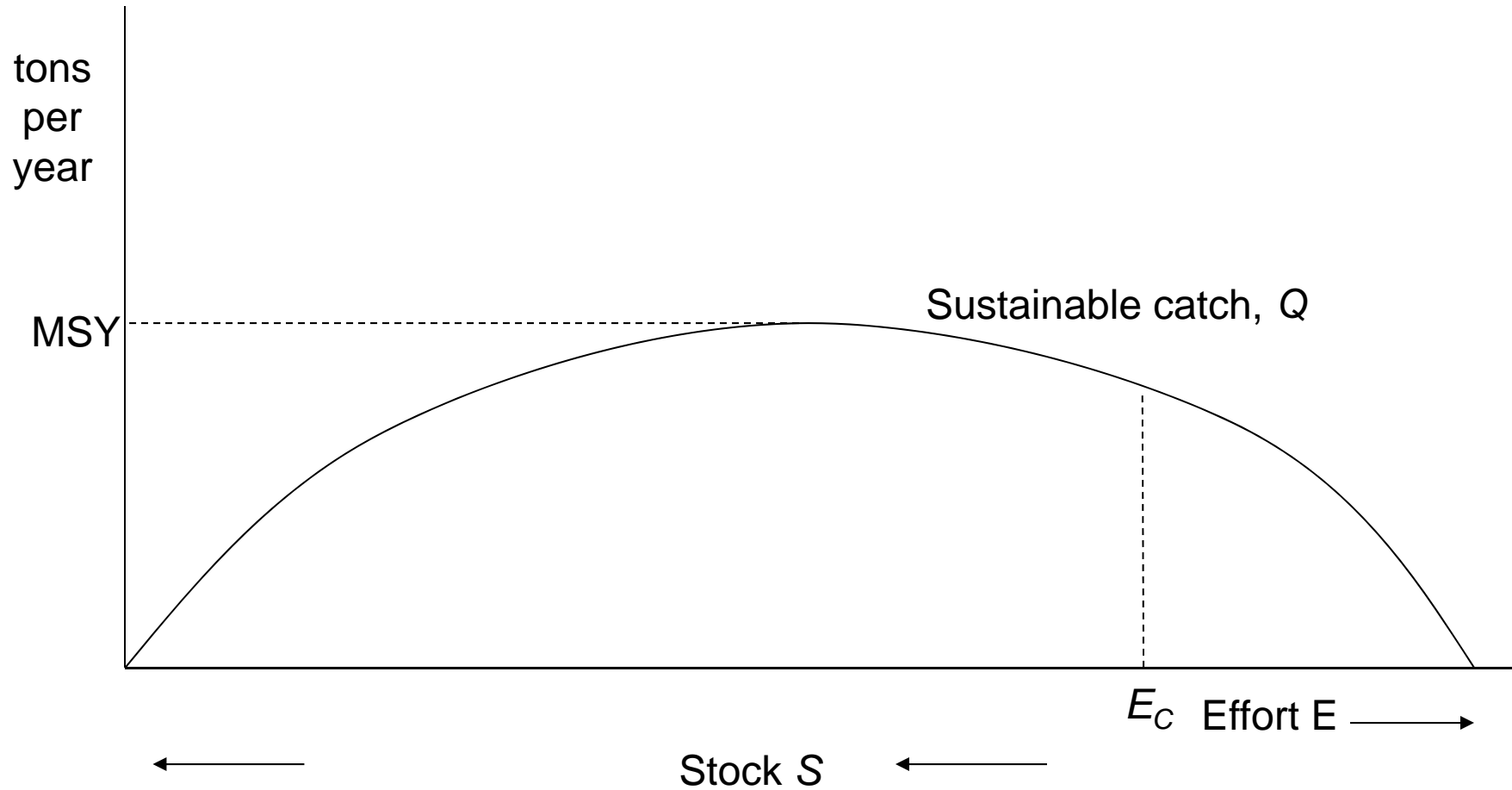
Sustainable yields



Note: $dS(t)/dt = f(S(t)) - Q(t)$.

Therefore, if $Q(t) = f(S(t))$, the stock is constant

Sustainable catch-effort curve



Note: With some growth functions and harvest technologies there may be a critical effort level, E_C , beyond which positive yields cannot be sustained.

Deriving Catch-Effort Relationship for Logistic Model

1. Population Growth, net of catch:
$$\frac{dS(t)}{dt} = f(S(t)) - Q(t)$$

Example:
$$\frac{dS(t)}{dt} = .01S(t)(100 - S(t)) - Q(t) .$$

Questions:

- In the absence of any catch, what is the equilibrium level of the stock?
- What level of stock maximizes the sustainable yield?

2. Production Function for Catch:
$$Q(t) = G(S(t), E(t))$$

Example:
$$Q(t) = .1S(t)E(t)$$

Problem:

- Express S (unobservable) in terms of Q and E (both observable).

3. Solve for Sustainable Catch as Function of Effort

(i) In a steady state equilibrium, $\frac{dS(t)}{dt} = 0$. Therefore, $f(S(t)) = Q(t)$ and all variables are constant over time so we drop t arguments in functions.

Example: $.01S(100 - S) = Q$.

(ii) We need to replace S , which is unobserved, by a function of E and Q , which are observed. To

accomplish this, use the production function $Q(t) = G(S, E)$ and solve for S .

Example: Production function $Q = .1SE$ implies $S = 10\frac{Q}{E}$.

3. Solve for Sustainable Catch as Function of Effort (cont.)

(iii) Finally, substitute the expression for S from step (ii) into the relationship between steady state Q and S from step (i). Solve the resulting equation for steady-state catch, Q , as a function of effort, E .

Example:
$$Q = .01S(100 - S) = .01\left(\frac{10Q}{E}\right)\left[100 - \left(\frac{10Q}{E}\right)\right],$$

which implies:

$$E = 10 - 1\left(\frac{Q}{E}\right), \quad \text{or } E^2 = 10E - Q.$$

Rearrange this to get the catch-effort relationship:

$$Q = 10E - E^2.$$

Question:

- What level of effort results in the maximum sustainable yield?

4. Bioeconomic Equilibrium under Free Access

Additional notation:

P price per unit

C cost per unit effort

Assumptions:

Demand is perfectly elastic, hence P is fixed.

Supply of E is perfectly elastic, hence C is fixed.

Free Access Equilibrium:

Profit = $PQ - CE$. (CE = Total cost)

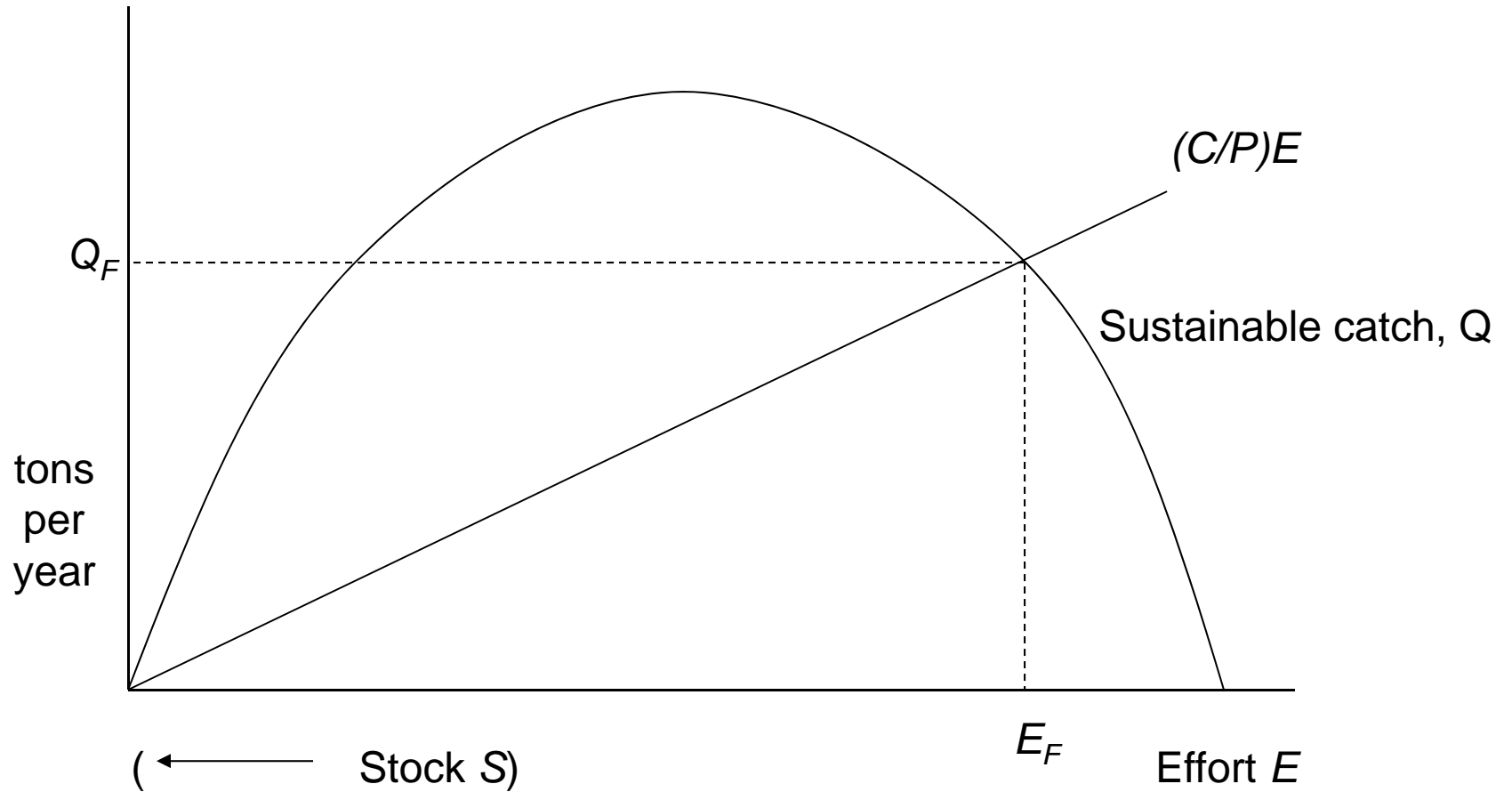
If Profit > 0 E increases; if Profit < 0 E decreases.

In long run equilibrium with free access, Profit = 0, or $PQ = CE$.

This implies: $Q = \frac{C}{P} E$.

Free access equilibrium

(vertical axis stretched up for easier viewing.)



Note: With free access $PQ - CE = 0$, therefore $Q = (C/P)E$.

4. Bioeconomic Equilibrium under Free Access

Example:

Use growth and production functions from preceding example.

Assume: $P = 1$, $C = 2$.

$$\text{Profit} = (10E - E^2) - 2E.$$

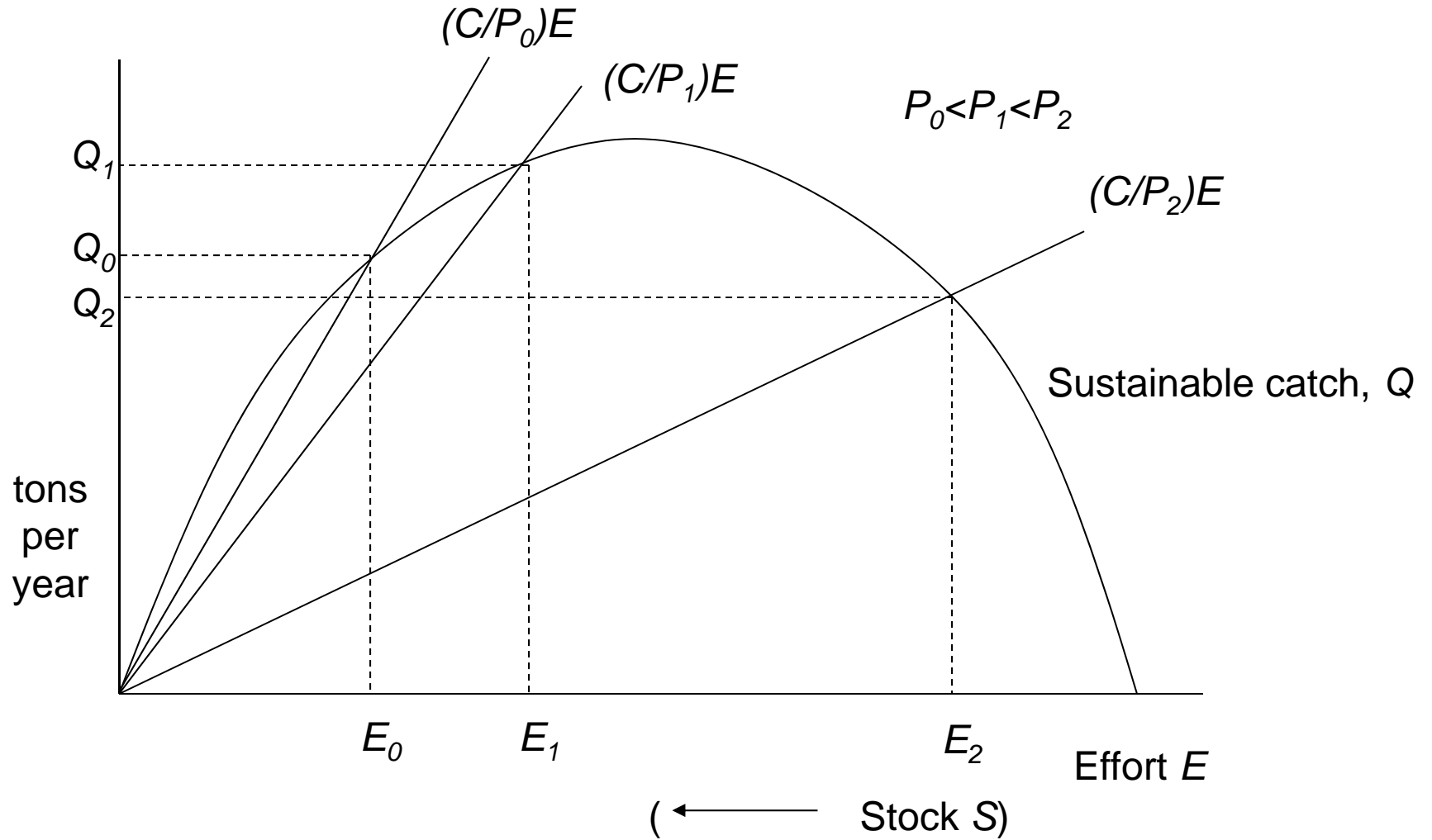
In long run free access equilibrium Profit = 0, so

$$(10 - E) = 2, \text{ or } E = 8.$$

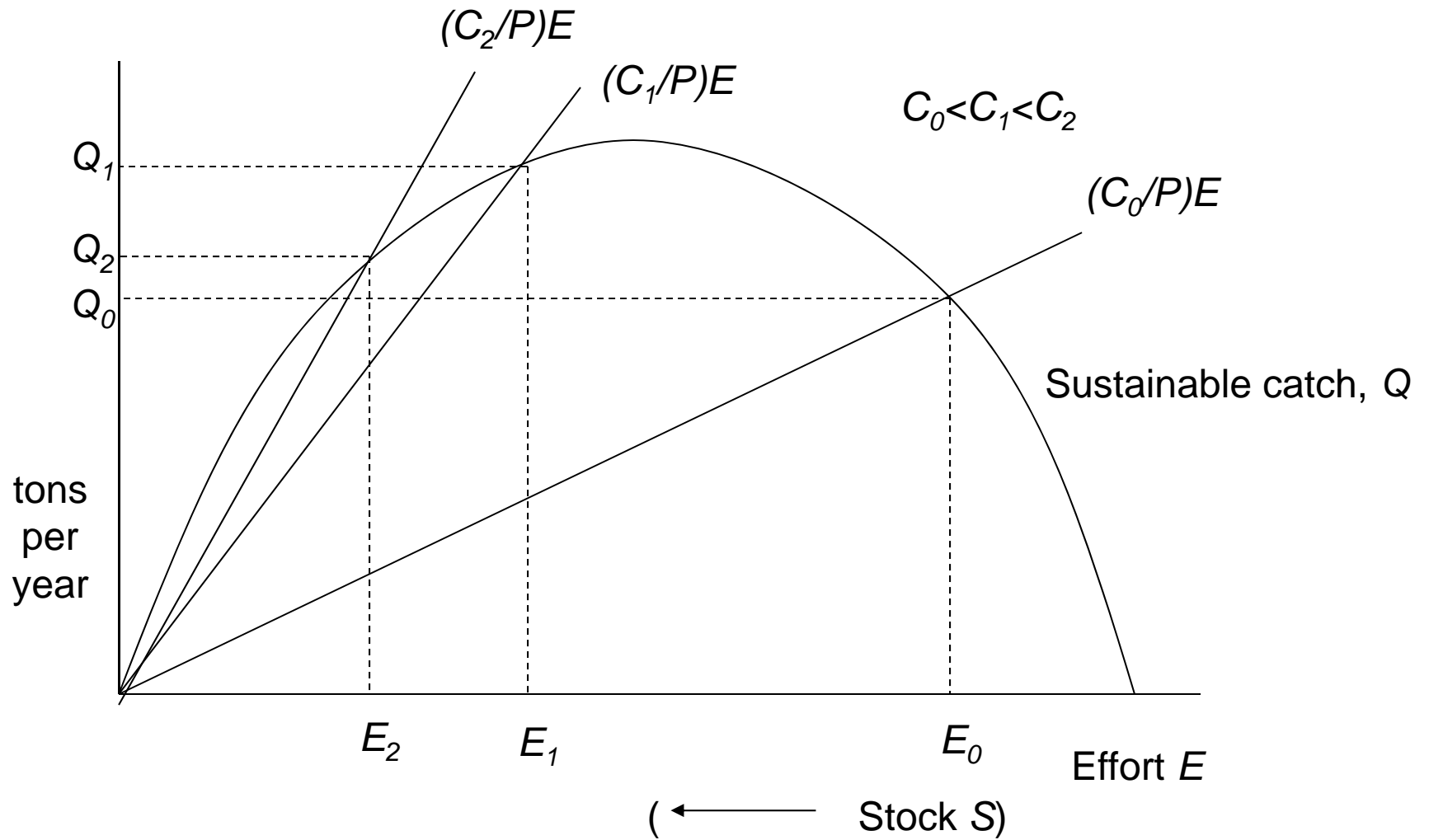
Questions:

- What is catch?
- What is stock?

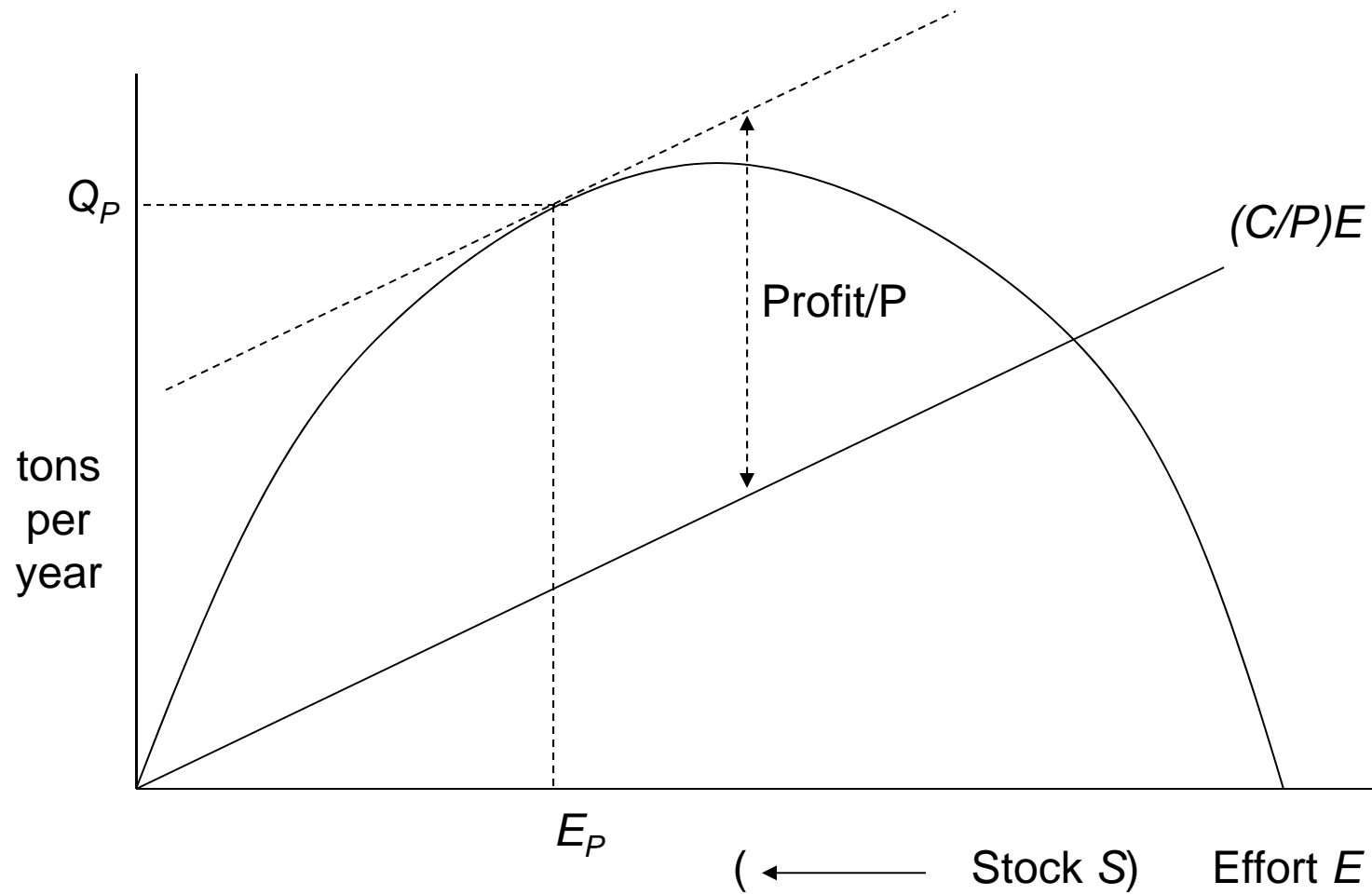
Free access: effect of P increase on Q



Free access: effect of C increase on Q



Maximum profit equilibrium



5. Bioeconomic Equilibrium: Max. profit per year.

Example:

Use growth and production functions from preceding example.

Assume: $P = 1$, $C = 2$.

$$\text{Profit} = (10E - E^2) - 2E.$$

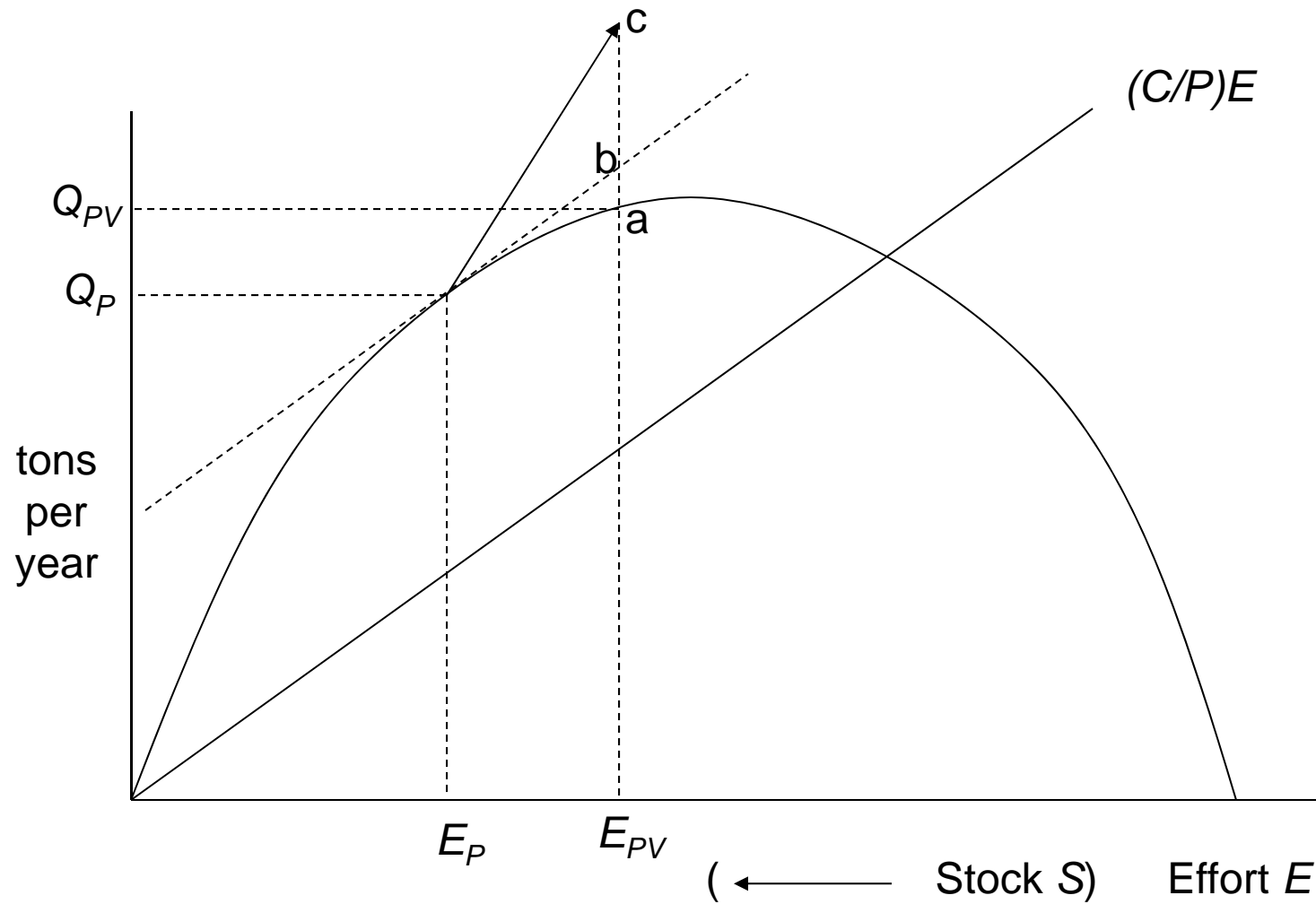
$$\text{Maximum profit: } d\text{Profit}/dE = 10 - 2E - 2 = 0.$$

$$\text{Solution: } E = 4.$$

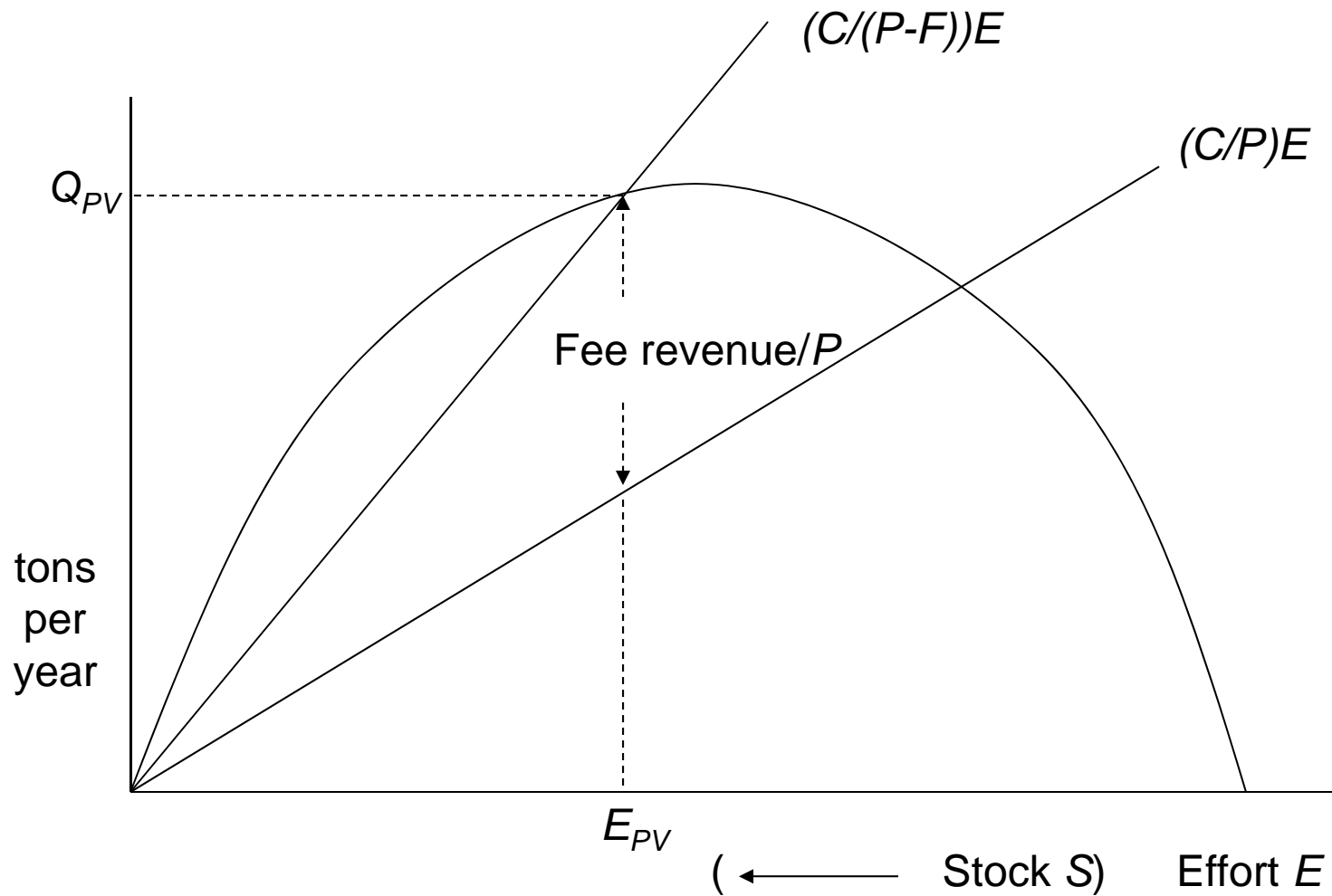
Questions:

- What is catch?
- What is stock?

Maximum net present value (PV) equilibrium



Tax or fee (F) on catch to attain maximum PV equilibrium



Traditional fishery regulation

Goal: Reduce effort toward some target.

- 1 Initial strategy: Limit number of licenses, require each vessel have a license;
- 2 Industry response: Larger, faster, more powerful vessels;
- 3 Regulator reply: Limit vessel characteristics (length, horsepower, gear, etc.)
Efficiency effects: Technology constrained, not efficient, no innovation.
- 4 Industry response: Fish more intensively—more days per year, more hours per day, use larger crew, more complex fish-finding technology;
- 5 Regulator reply: Limit season length (few days per year)
- 6 Industry response, Race to fish:
Congestion and dangerous conditions on fishing grounds
 - Most of catch is frozen
 - Excessive processing capacity
 - Fish during dangerous weather ('Deadliest catch')
 - Excessive bycatch
 - 'Ghost fishing' by lost gear.
 - Use tenders to avoid runs back and forth to port

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Efficiency effects of traditional regulation: Examples

Gear limitations reduce efficiency

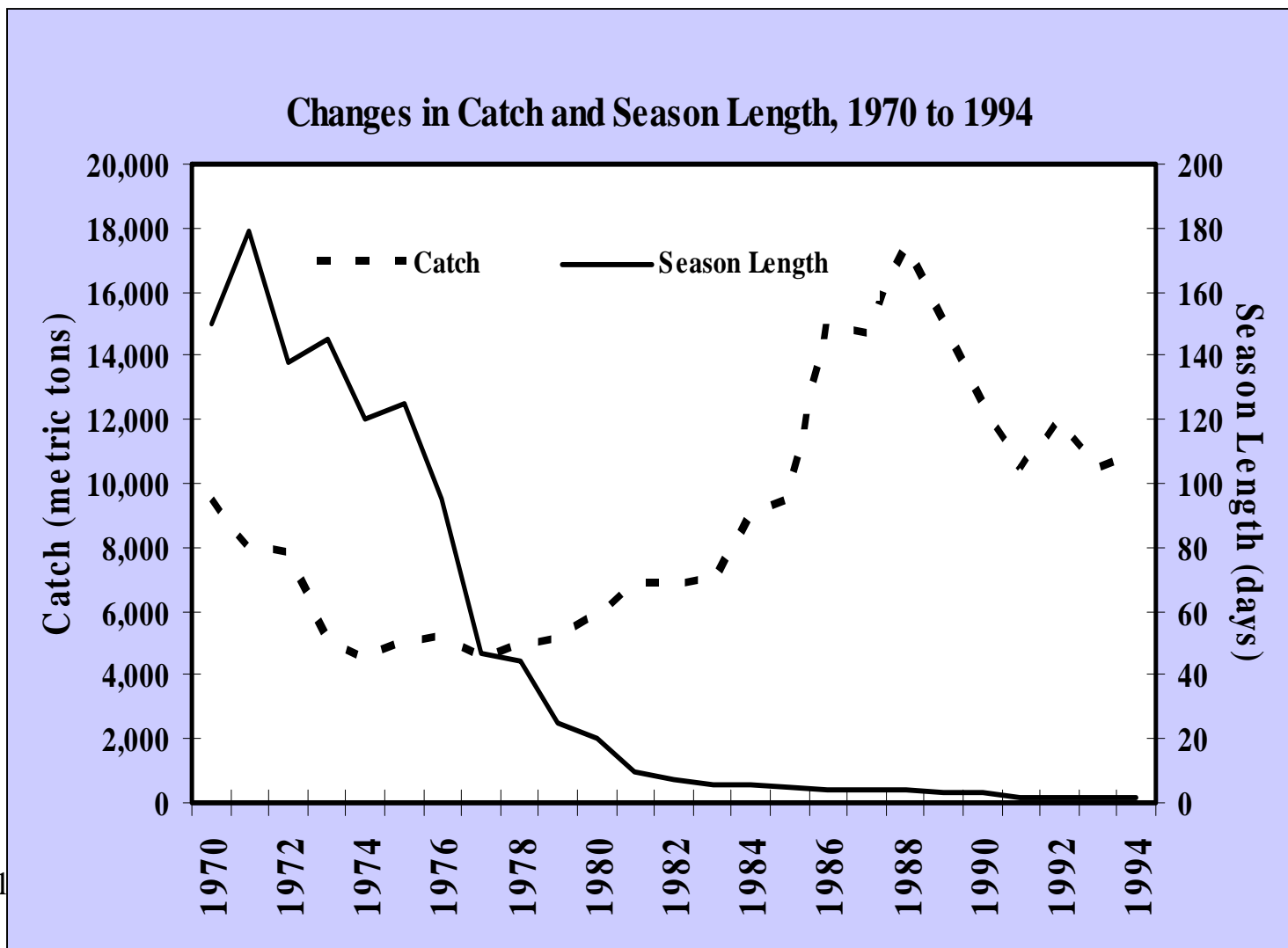
- Pre-1952, gillnetters could not use 'power'
- Bristol Bay gillnetters cannot exceed 32 feet in length

Season closures and excessive capital in fleet reduce efficiency

- Congestion: Bristol Bay gillnet fishery, >1,800 licenses (one-third not fished)
- Fish in unsafe conditions: *Deadliest catch* for Alaska crab.
- Poor quality due to compressed season, race to fish

Alaska Halibut fishery, pre-ITQ: Limited entry with TAC enforced by closing season.

Data from 1970-1994



Halibut Season pre-ITQ: Two to Three 24-Hour Openings

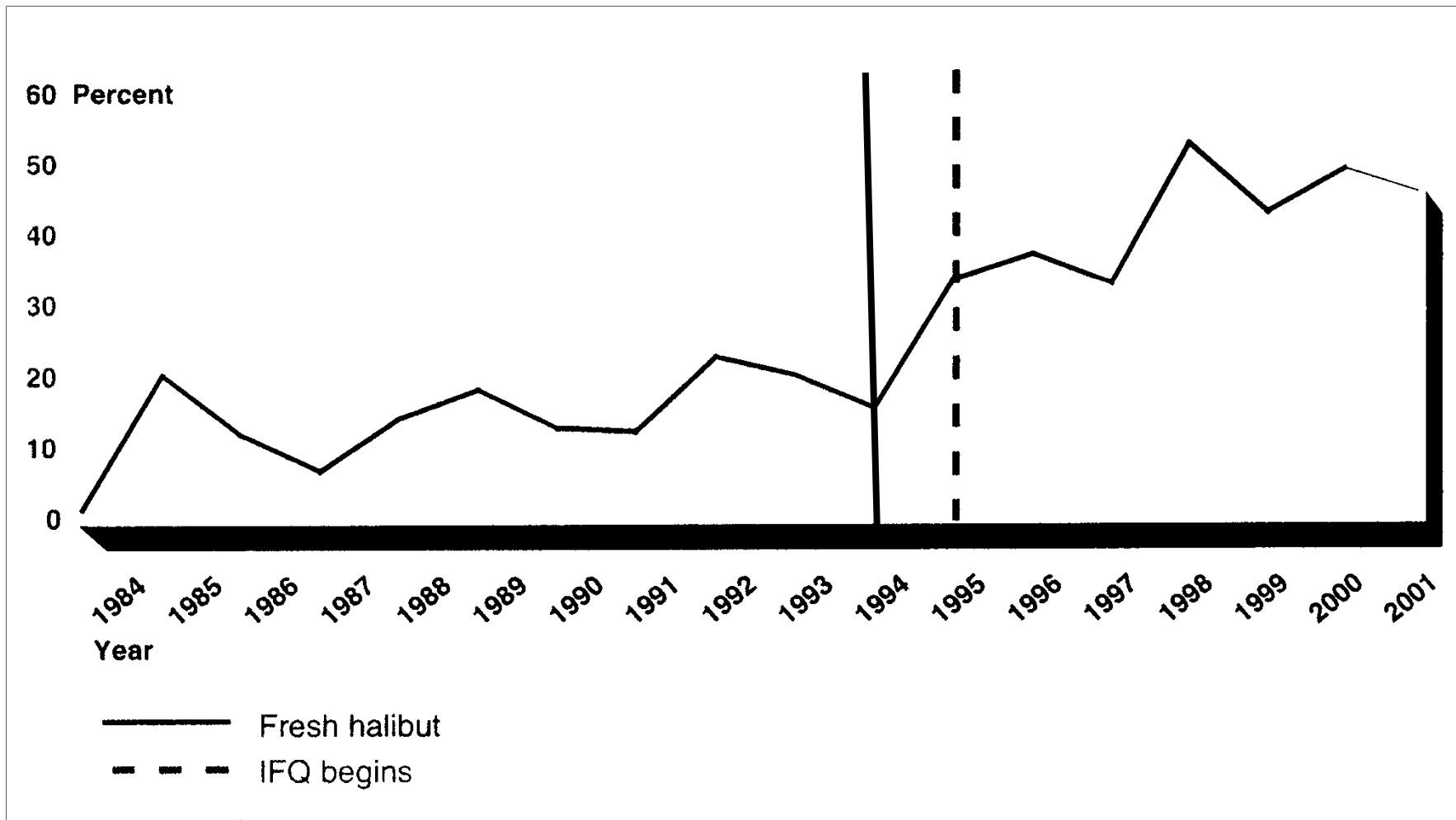
- Harvest waste (1/3 catch spoiled on boats in 1991)
- Market gluts (depressed prices)
- Ghost fishing (fish caught by lost or abandoned gear)
- Hazardous fishing (“perfect storm”)
- Actual catch often exceeded target (guessing wrong on fishing power)

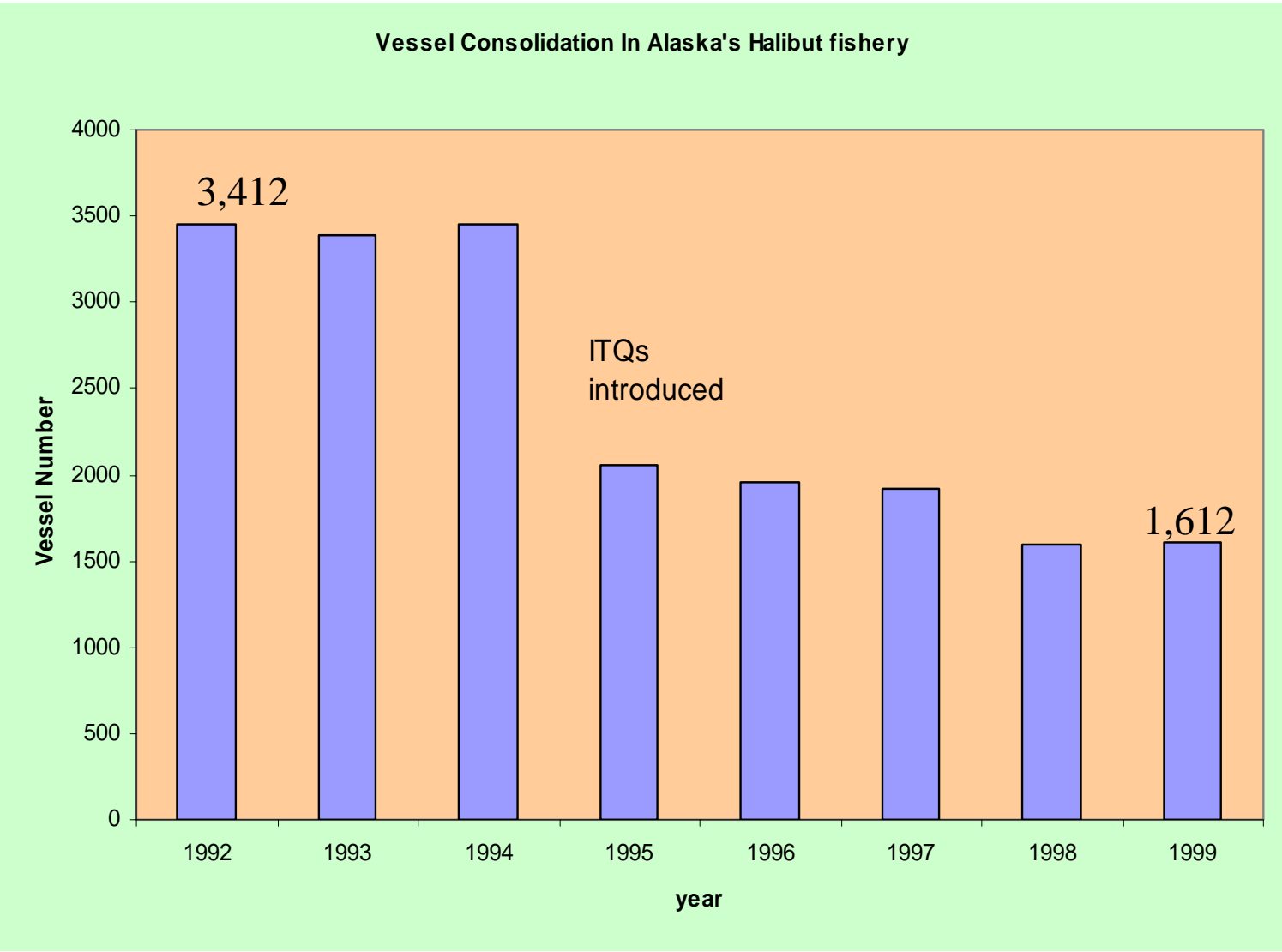
1995-Individual Transferable Quotas (ITQs) adopted in Alaska halibut fishery

- Government sets total allowable catch (TAC).
- Fishermen receive initial shares based on historical catch.
- Shares tradable with certain restrictions
- Season extends to 8 months

More fresh Alaska halibut with ITQs

Fresh Halibut As A Percentage of Total Halibut Production, 1984-2001





Dramatic Rise in value of Halibut ITQs

- In 1995, aggregate value of the quotas was just over \$295 million.
- In 1998, aggregate value of the quotas had grown to nearly \$495 million--a 67 percent increase in 4 years

Safety improved: Number of search and rescue missions

| Pre-ITQ | 1995 | 1996 | 1997 | 1998 | 1999 |
|---------|------|------|------|------|------|
| 28* | 15 | 7 | 9 | 9 | 10 |

* Annual average 1991-1994

Greater Precision in Managing the Catch

Alaska Halibut Fishery Percent of TAC Harvested

| Period | Management Area | | | |
|-----------|-----------------|-------|-------|-------|
| | 2C | 3A | 3B | 4A |
| 1990 | 102.2 | 93.0 | 102.3 | 139.1 |
| 1991 | 117.4 | 86.2 | 135.6 | 132.6 |
| 1992 | 98.2 | 100.7 | 98.0 | 117.3 |
| 1993 | 112.9 | 109.8 | 120.9 | 126.8 |
| 1994 | 94.4 | 95.6 | 96.5 | 100.2 |
| 1995-ITQs | 85.6 | 88.7 | 85.1 | 80.6 |
| 1996-ITQs | 93.6 | 96.5 | 94.4 | 88.9 |
| 1997-ITQs | 95.6 | 96.7 | 97.3 | 94.0 |
| 1998-ITQs | 90.8 | 94.3 | 96.1 | 91.4 |

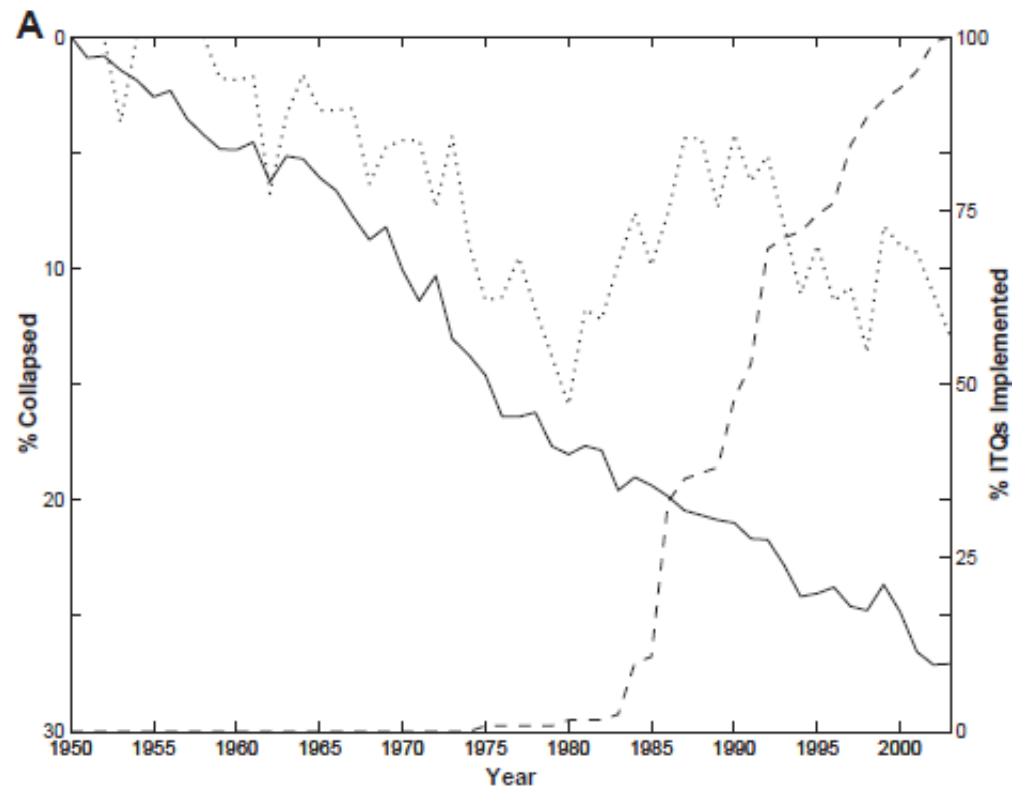
5/11/ Source: Alaska Commercial Fisheries Entry Commission, 1999. 33

Fisheries Under ITQs

| Species | Beginning of ITQs | Stock Biomass | Productivity | Change in Quota Value |
|------------------|-------------------|---------------|--------------|-----------------------|
| NZ Hoki | 1986 | Stable | Increasing | +1200% (1995) |
| NZ Orange Roughy | 1983 | NA | Increasing | +60% (1995) |
| NZ Snapper | 1986 | Stable | Increasing | +280% (1995) |
| NZ Rock Lobster | 1990 | Stable | Increasing | +143% (1995) |
| NZ Oreos | 1983 | NA | Stable | +180% (1995) |
| NZ Paua | 1987 | Increasing | Increasing | +468% (1989) |
| US Surf Clams | 1990 | Stable | (Doubled) | Increasing (1997) |
| Icelandic Cod | 1984 | Increasing | Increasing | +454% (1997) |
| Canadian Halibut | 1993 | Increasing | (Doubled) | Increasing (1996) |

C. Costello et al., Science 321, 1678 -1681 (2008)

Fig. 1. (A) Percent of fisheries collapsed with (dotted line) and without (solid line) ITQ management using the Worm et al definition and data. Dashed line shows number of ITQ fisheries (r.h. scale) worldwide.



Cooperative or user-based management

- User groups assigned management responsibility
- To work, must include right to exclude outsiders
- Potential Advantages:
 - Users often have stronger incentives to manage and enforce effectively than do government regulators.
 - Assigning management rights to a group (rather than individuals) can make it easier to coordinate effort.

Examples of coop or user-based management

- Alaska pollock cooperatives
- The Chignik (Alaska, US) salmon cooperative

TURFS that also operate as coops (presented later):

- Mexico's harvesting cooperatives
- Bangladesh's community managed cooperatives

North Pacific Pollock Cooperatives

- Owners of 20 catcher-processor vessels formed one cooperative
- Owners of 7 catcher vessels formed the separate cooperative
- Harvest shares based on catch history
- Trading allowed within and between co-ops
- Federal observers; fines for exceeding allocations

First year results . . .

- Number of active vessels went from 27 to 16
- Season length doubled to 149 days in 1999
- Daily harvest rates 60% lower than 1995-98 avg.

Financial impact

- Prior to co-op, revenues ~\$800/ton
- Under co-op, 2002 \$1200 - \$1400/ton.
- Co-op generating estimated profit ~\$500 million/year.



Chignik (AK) Sockeye salmon cooperative

- Alaska commercial salmon fishery
- Purse seine fishing, ~100 participants
- Managed by limited entry and season closures since 1974

Innovation

- State dedicates portion of TAC to cooperative, with voluntary joining
- Share of TAC depends on proportion that join
- Non-joiners fish competitively as before, with separate seasons

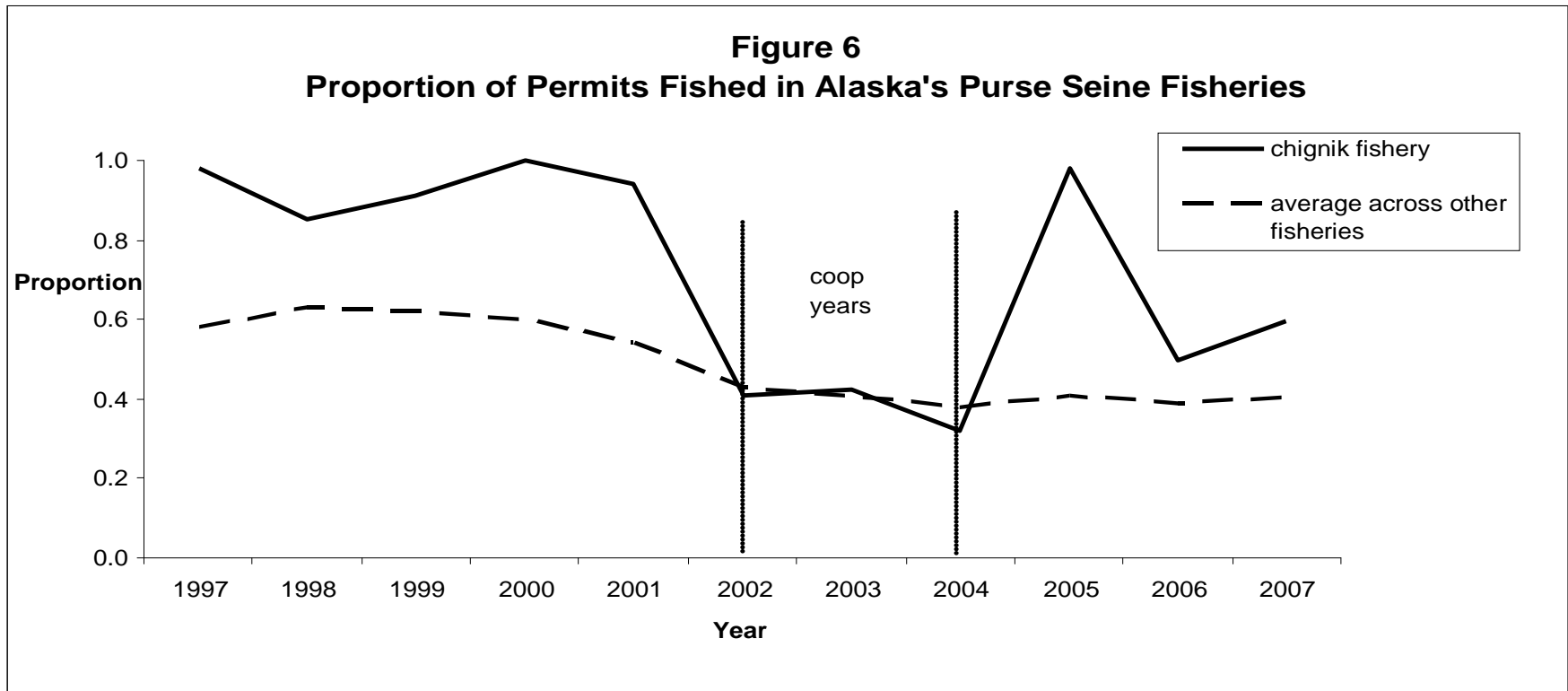
How the Co-op

- Joiners sign 1-year contracts before season
- Some coop members fish (22 out of 77) and are paid for effort.
- Profits after paying fishers are split equally.
- Coop elects managers to make decisions.

Predicted effects on behavior

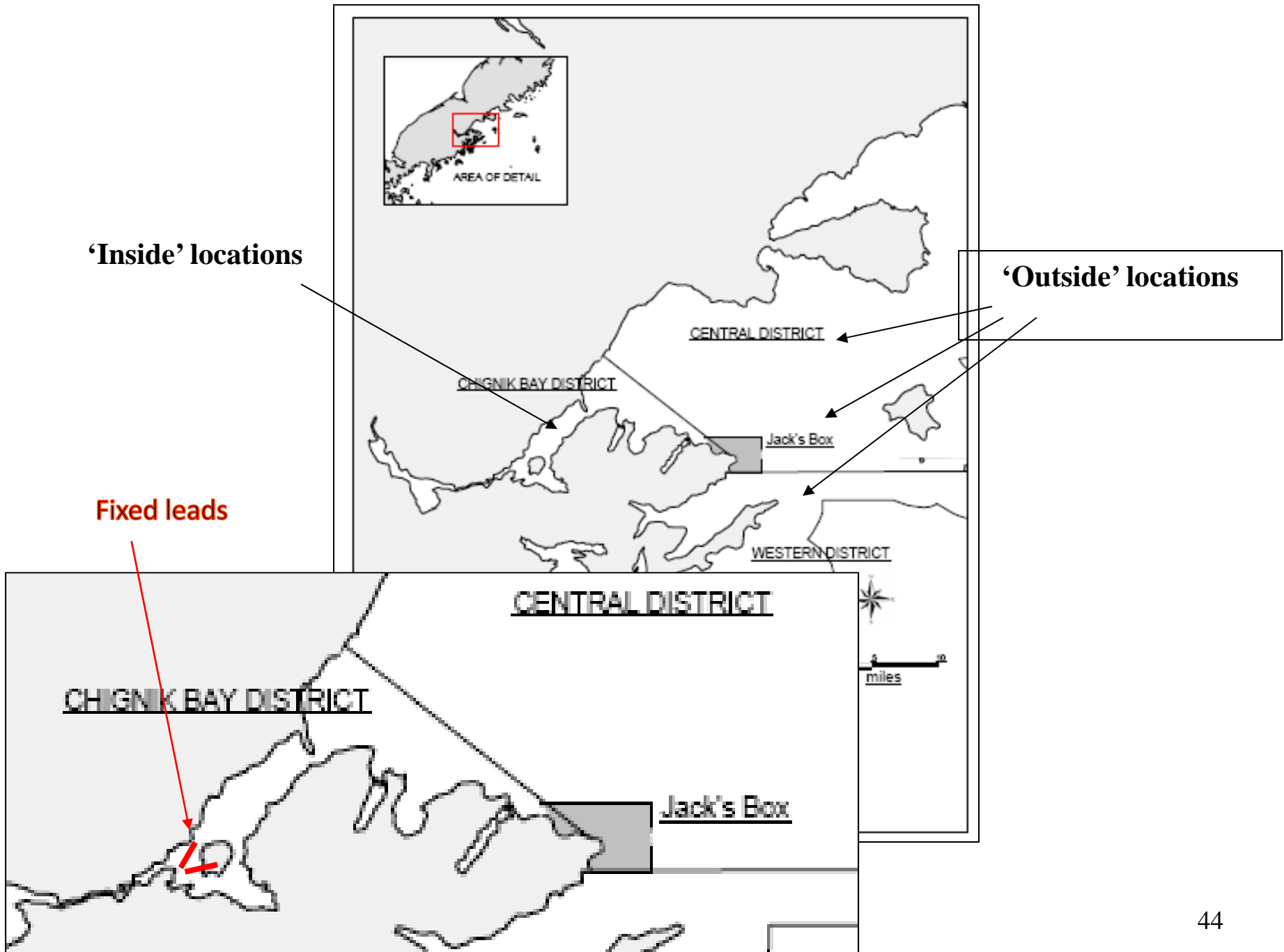
- Less skilled fishers most likely to join
- Co-op expected to: eliminate excess capacity, slow rate of fishing, have most efficient members do fishing
- Collective actions: share information, coordinate effort over space / time, provide shared inputs

Test for elimination of redundant effort



Evidence on co-op public inputs

- Centralized info on stock locations, dispatched effort;
- Precise spatial coordination of effort (inside vs. outside)
- Temporal control of effort, exploit tides;
- *Coordinated effort* in order to:
 - match processor capacity (released live fish!)
 - raise product quality (delivered live fish);
- Installed 'fixed leads' (funnel) on migration route.



Territorial User Right Fisheries (TURFs)

Spatial harvest rights:

- Native Americans established spatial rights on salmon streams in US
- Native Americans had tribal rights to beaver harvest areas in Canada
- Oyster beds privatized in 1800s in Washington
 - Harvesters invested in augmenting stocks.
- Japan: 1750 TURFs operate
- ~700 TURFs operating in Chile.

Extended example: Maine lobster fishery (See Tietenberg)

Example: Community Based TURF Fisheries in Bangladesh

Background:

- Freshwater fisheries (~12,000), highly productive
- Largely unmanaged by government, no local ownership
- Result: open access outcomes, poor stewardship.

Hypothesis:

- Assigning spatial management rights (TURFs) to communities improves stewardship

NGOs persuade government to experiment:

- Assign TURF rights to ~80 fisheries to the local communities
- Keep ~20 fisheries as 'controls', under old system
- Track both sets of fisheries to see effects on management and productivity

... *Coop / TURF* management in Bangladesh: **Results**

- Catch/effort (stock abundance) 50-75% higher in coop fisheries than in controls.
- Coops practiced stewardship
 - Established protected areas or sanctuaries in ~65% of fisheries
 - Adopted season or area closures to protect stocks in ~ 90% of fisheries
- Control fisheries rarely (< 10%) took any of these management actions.

Bangladesh Coop / TURF fishery



Freshwater 'marine' protected area

Controlling Bycatch & Habitat Degradation: Marine Conservation Easements

Adapting the conservation easement approach

How conservation easements work

TNC's initiative in Morro Bay

Strategies for Protecting Marine Environments

- Goal reduce 'bycatch' and other environmental damage
 - Bycatch: incidental take of a species that has value to someone else
- Policies proposed
 - Fishery-wide TAC for prohibited species
 - ITQs for bycatch
 - Time and area closures
 - Gear restrictions (e.g. turtle excluder device)



Terrestrial Conservation Easements

Agreements between landowners and conservation NGOs

Typically conserve 'open-space' scenery & habitat, limit development

Easements "run with the land"—become aspect of property right

Valued as the difference between encumbered and unencumbered price of the land

Efficiency advantages vs. land use regulations

- Easements are incentive-based
- Can be customized to land attributes

Efficiency Advantages of Conservation Easements

- In contrast to land-use regulations
 - Easements are incentive-based
 - Can be customized to selected parcels, based on attributes
- In contrast to outright ownership
 - Land-based commodities (e.g., soil, timber, or minerals) are better managed by a specialized landowner
 - Potential advantage depends on transaction costs

Adapt easements to a marine setting?

- Key difference: marine habitats are not owned
- But, fishery regulations assign rights to use marine habitats and resources
- Negotiate with permit-holder to control fishing methods—a 'marine easement'

Feasible?

TNC Transaction

- Purchased 7 trawling permits and 4 trawling vessels for \$3.8 million (2007)
- Goal: Reduce bycatch of rockfish and negative impacts of bottom trawling
- TNC leased some permits back to vessel owners, with restrictions on gear used, areas fished
- Obtained industry support for 'no trawl' zone

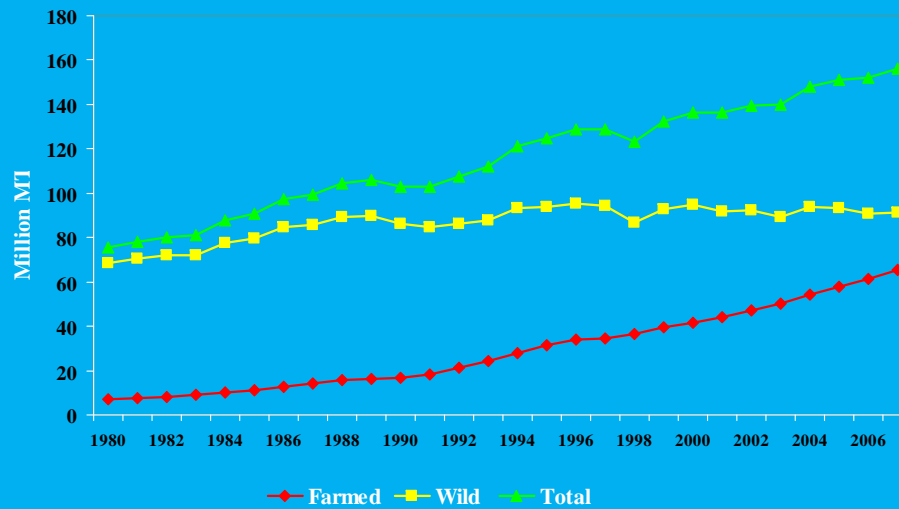
Aquaculture, issues:

- Increasing dominance of aquaculture
- Hatcheries as quasi-aquaculture
- Pollution in marine estuaries, competition for food sources
- Displacement of wild harvests, through market effects

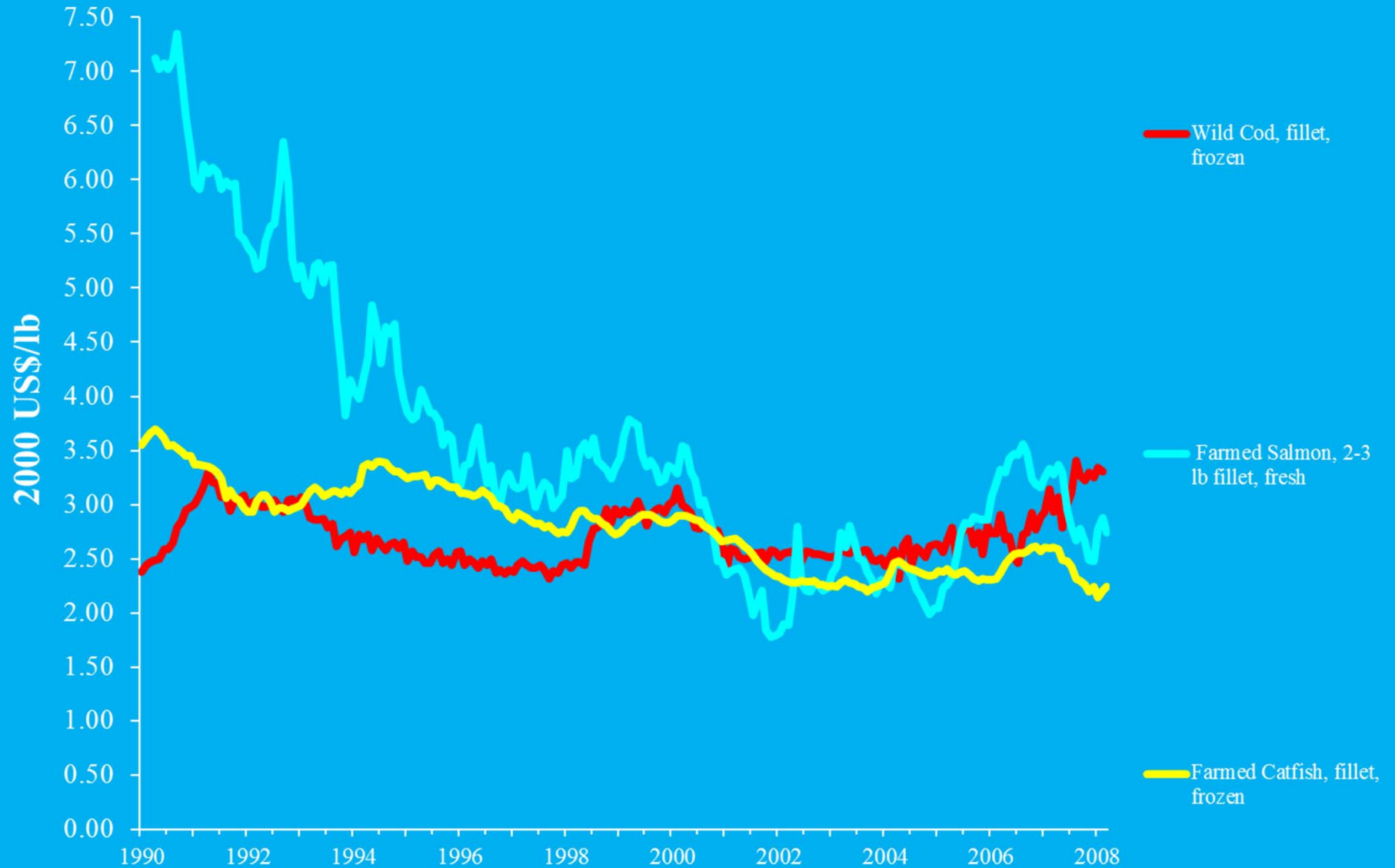
World Fisheries Production

Aquaculture accounted for 42% of world fish production in 2007.

Aquaculture accounted for only 10% in 1980.



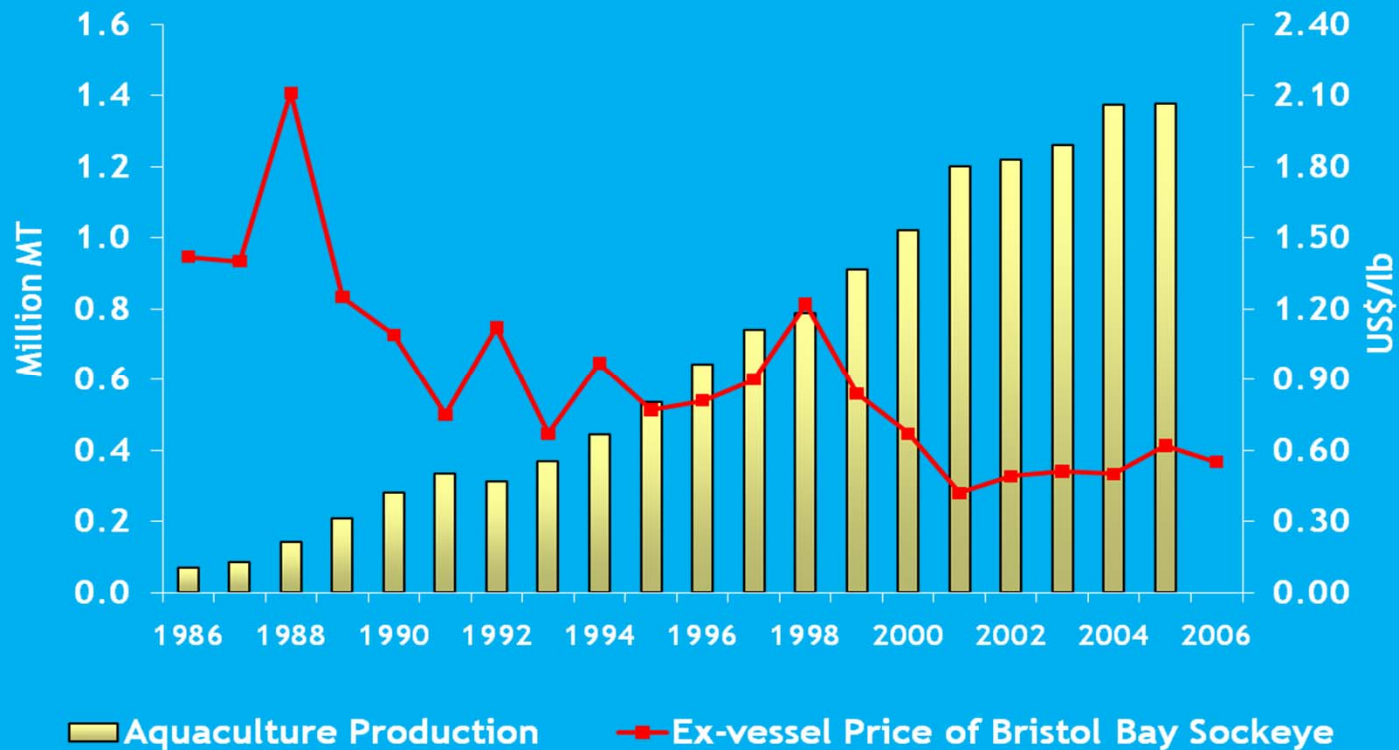
Real Price Trends of Seafood



5/11/2012

Sources: USDA, 1990-2008; Urner-Barry Publications, 1990-2008; USDC/NMFS, 1990-2008.

World Aquaculture Production of Atlantic, Chinook, and Coho Salmon Vs. Ex-vessel Price of Bristol Bay Sockeye Salmon



Sources: FAO (2007); ADF&G (2007).

Aquaculture

Pros:

- Displace pressure on wild stocks

- Protein for human consumption

- Displace protein production on land, envt. damages?

Cons:

- Pollution in areas of aquaculture production

- Release of exotics into the wild

- Genetic effects of cross breeding with wild species

Topics not treated

- Optimal size limits in size-selective fisheries.
- Pros and cons of marine protected areas as a management tool
- Spatial models of fishing.
- Incorporating uncertainty into management strategies.