Strengthening the Scientific Basis of the 2006 Management Requirements:
Optimal Yield from Mixed-Stock Fisheries

Steve Cadrin

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Acknowledgments

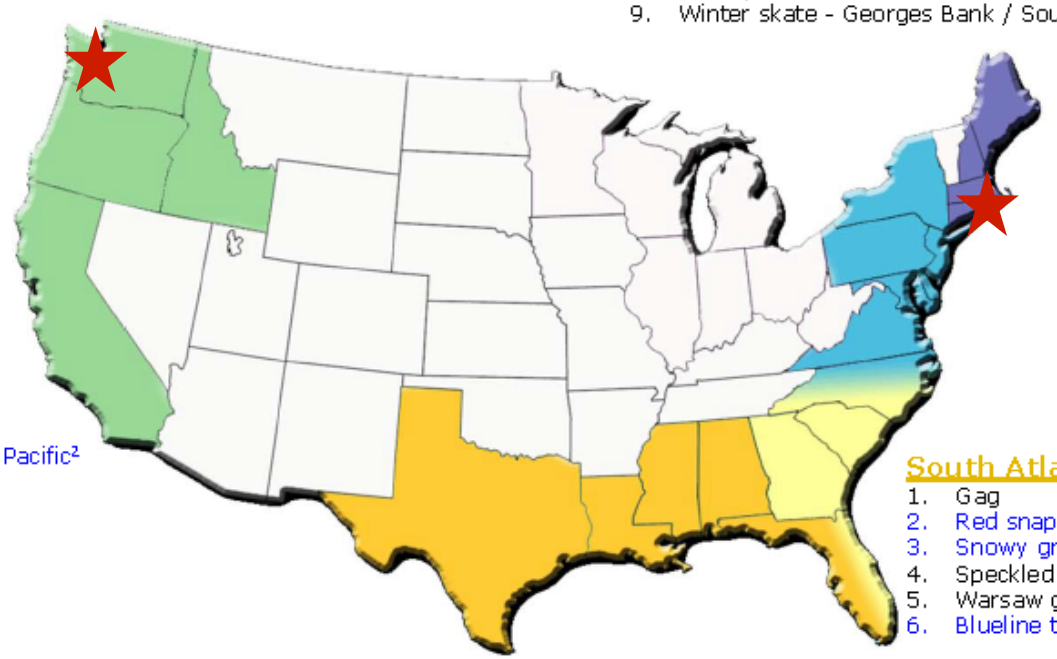
- Mixed-Stock Fishery Projections – Nikki Jacobson, Dorothy Dankel
- Conservation Engineering – Dave Martins, Sally Roman, Pingguo He
- Cod Spawning Closures – Doug Zemeckis, Micah Dean, Bill Hoffman
- Bycatch Avoidance – Cate O'Keefe, Greg DeCelles, Dave Bethoney

A Tale of Two Cities (and a remote Harbor)

- Seattle WA – 'The global epicenter of fisheries research' (Punt 2014)
  - University of Washington SAFS
  - Alaska Fisheries Science Center
  - Northwest Fisheries Science Center
  - International Pacific Halibut Commission
  - Commercial Fishing Industry
  - Dutch Harbor AK – #1 US fishing port for fishery landings.

SCHOOL OF AQUATIC and FISHERY SCIENCES

Stocks "Subject to Overfishing" (28) – as of December 31, 2013



New England:

1. Atlantic cod – Georges Bank
2. Atlantic cod – Gulf of Maine
3. Haddock – Gulf of Maine
4. Windowpane - Gulf of Maine / Georges Bank
5. Witch flounder
6. Yellowtail flounder – Cape Cod/Gulf of Maine
7. Yellowtail flounder - Georges Bank
8. Thorny skate - Gulf of Maine
9. Winter skate - Georges Bank / Southern New England

Highly Migratory Species:

1. Albacore – North Atlantic[2]
2. Blacknose shark - Atlantic
3. Blue marlin – Atlantic[2]
4. Bluefin tuna – West Atlantic[2]
5. Dusky shark - Atlantic
6. Sailfish – West Atlantic[2]
7. White marlin – Atlantic[2]
8. Scalloped hammerhead – Atlantic[1]

Pacific and Western Pacific

1. Bigeye tuna – Pacific[2]
2. Pacific bluefin tuna – Pacific[2]

Western Pacific

1. Striped marlin - Central Western Pacific[2]

South Atlantic:

1. Gag
2. Red snapper
3. Snowy grouper
4. Speckled hind
5. Warsaw grouper
6. Blueline tilefish[1]

Gulf of Mexico:

1. Hogfish
2. Jacks Complex[1]

1. Non-FSSI stock
2. Stock is fished by U.S. and International fleets.

Blue = Also Overfished

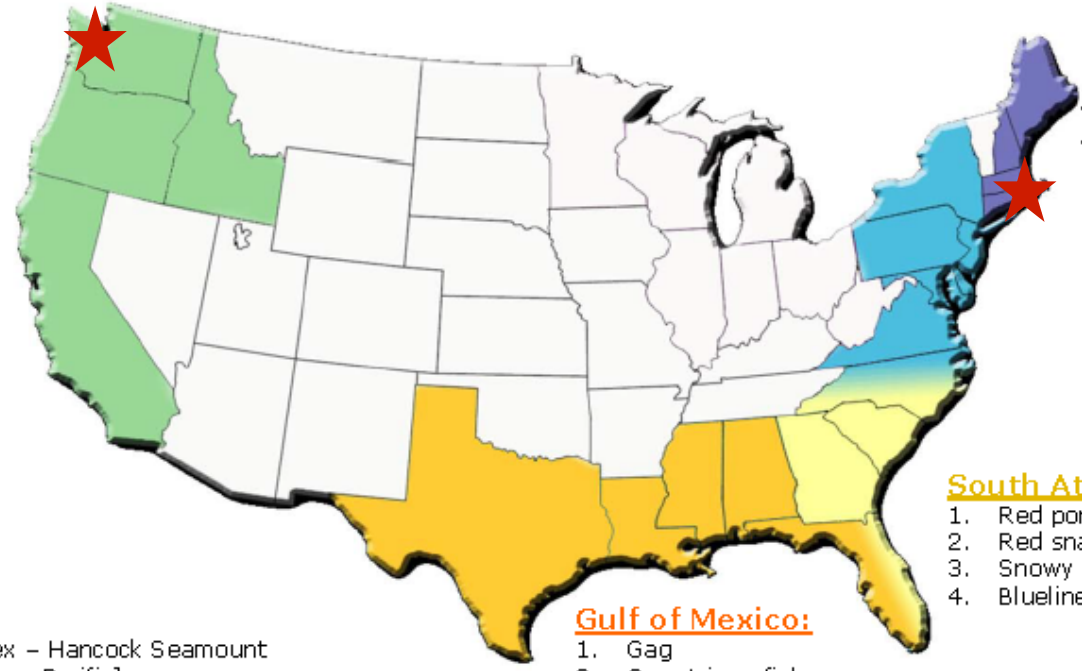
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Office of Sustainable Fisheries

Overfished Stocks (40) – as of December 31, 2013

North Pacific:
1. Blue king crab – Pribilof Islands

New England:
1. Atlantic cod – Georges Bank
2. Atlantic cod – Gulf of Maine
3. Atlantic halibut
4. Atlantic salmon[1]
5. Atlantic wolffish[1]
6. Ocean pout
7. Thorny skate
8. Yellowtail flounder – Georges Bank
9. Yellowtail flounder – Cape Cod/Gulf of Maine
10. Windowpane - Gulf of Maine/Georges Bank
11. Winter flounder - Southern New England/Mid-Atlantic
12. Witch flounder

Pacific:
1. Canary rockfish
2. Pacific ocean perch
3. Yelloweye rockfish



Highly Migratory Species:
1. Albacore – North Atlantic[2]
2. Blacknose shark - Atlantic
3. Blue marlin – Atlantic[2]
4. Bluefin tuna – West Atlantic[2]
5. Dusky shark - Atlantic
6. Porbeagle shark - Atlantic
7. Sandbar shark - Atlantic
8. White marlin – Atlantic[2]
9. Scalloped hammerhead – Atlantic[1]

Pacific/Western Pacific
1. Pacific bluefin tuna – Pacific[2]

South Atlantic:
1. Red porgy
2. Red snapper
3. Snowy grouper
4. Blueline tilefish[1]

Western Pacific
1. Seamount Groundfish Complex – Hancock Seamount
2. Striped marlin - Central Western Pacific[2]

Gulf of Mexico:
1. Gag
2. Gray triggerfish
3. Greater amberjack
4. Red snapper

Caribbean:
1. Grouper Unit 1
2. Grouper Unit 2
3. Grouper Unit 4
4. Queen conch

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Office of Sustainable Fisheries

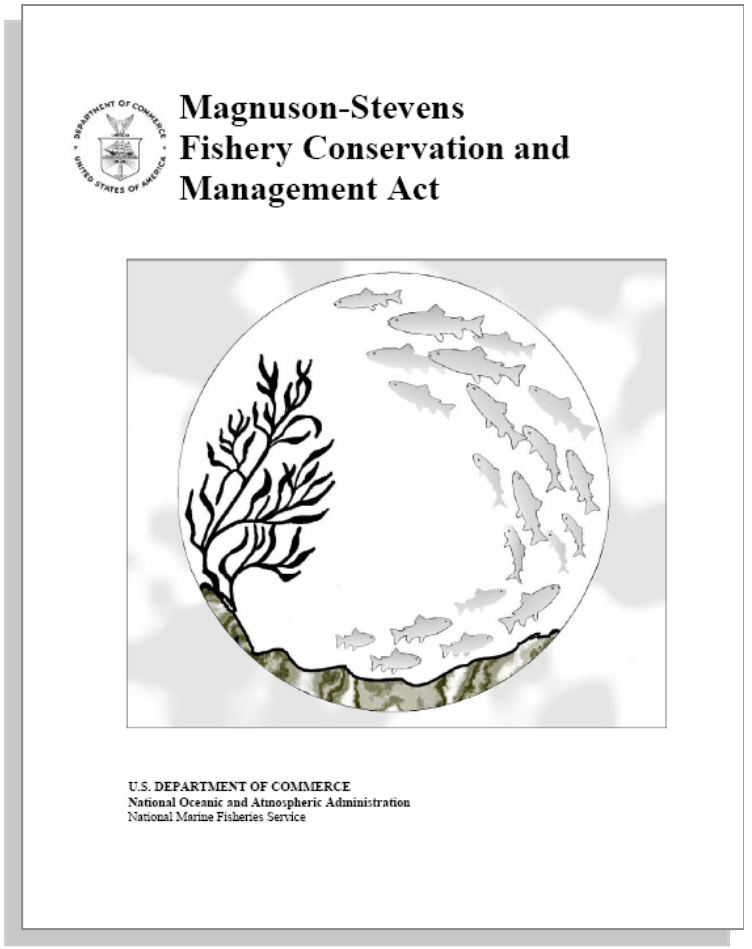
1. Non-FSSI stock
2. Stock is fished by U.S. and International fleets

Fishery Management Objectives

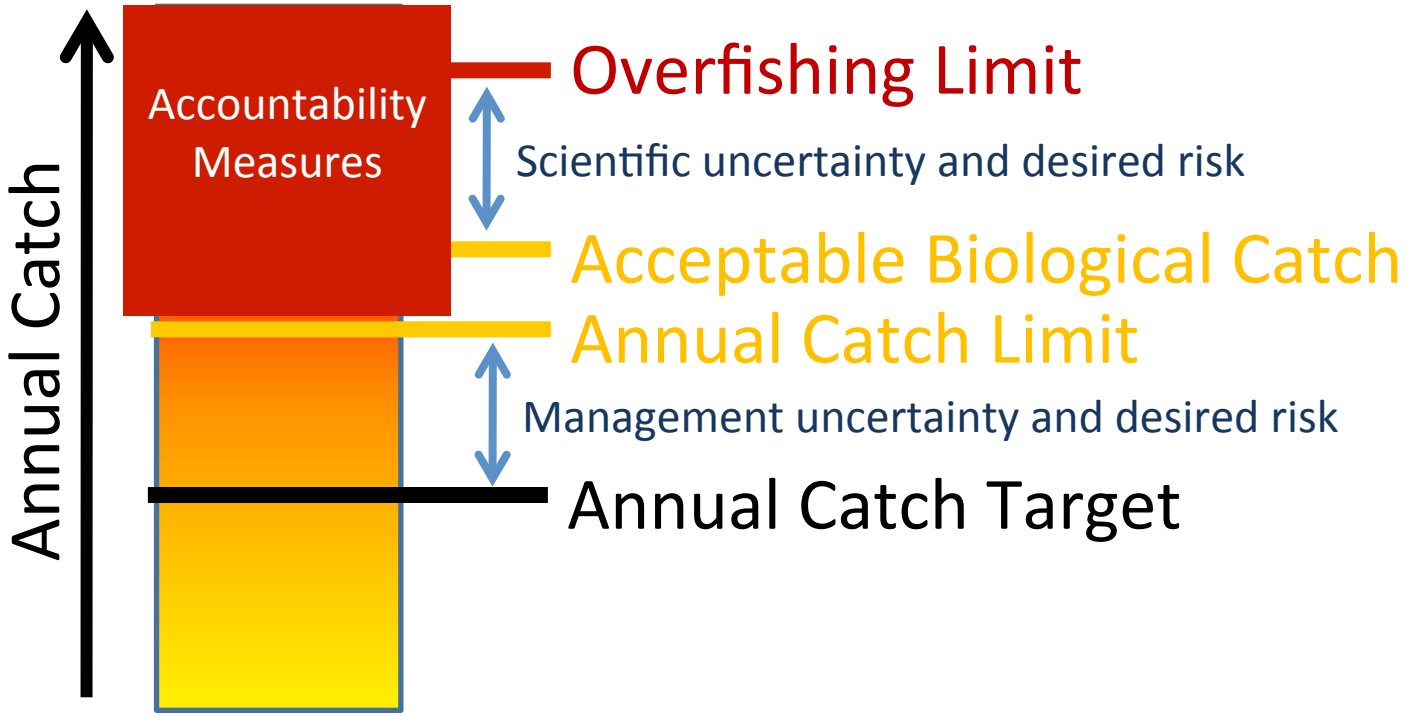
- Most fishery systems attempt to manage sustainable fisheries and achieve optimal yield (e.g., maximum sustainable yield, maximum economic yield, …).
- To achieve those higher-order goals, secondary objectives are required:
  - Avoid overfishing
  - Rebuild depleted stocks
  - Conserve productivity (ecosystem structure and function, age structure, spatial structure, …)
  - Maintain fishing communities

2007 Reauthorization of the Act

- The reauthorized Fishery Conservation and Management Act specifies that all fishery management plans shall establish a mechanism for specifying:
  - annual catch limits
  - such that overfishing does not occur in the fishery,
  - including measures to ensure accountability.



Annual Catch Limits



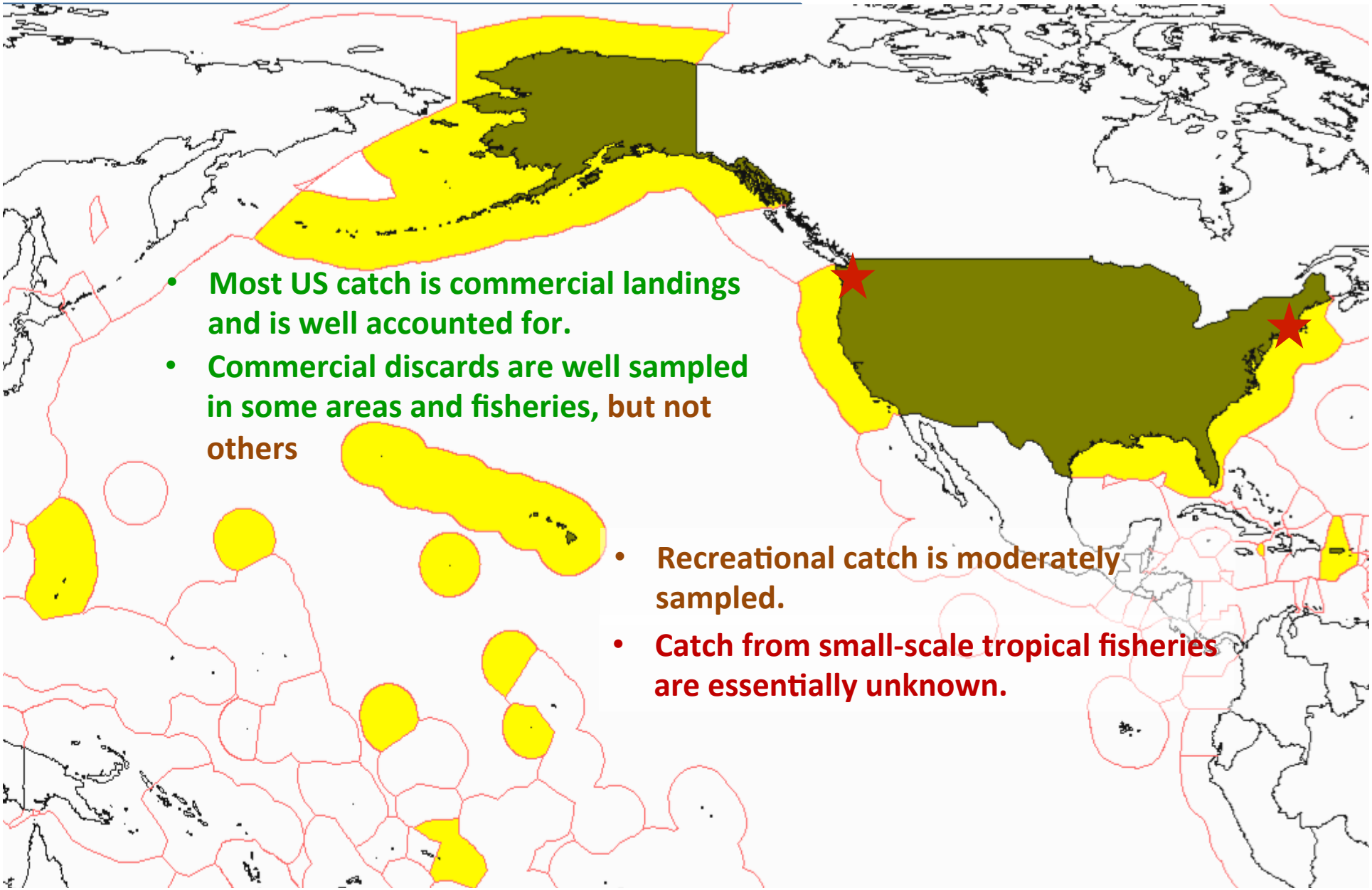
- The Annual Catch Limit system ideally accounts for scientific estimates of the overfishing limit, scientific uncertainty and implementation error.

NMFS 2009

Output Controls

- Annual Catch Limits should perform well for avoiding overfishing and eventually rebuilding stocks, **if** …
  - catch can be accurately monitored, and
  - catch can be accurately reported in-season.
- The Accountability Measures system imposes incentives to avoid overfishing, **if** …
  - catch can be accurately monitored,
  - catch can be accurately reported in-season, and
  - individuals are accountable.

Estimating Catch



- Most US catch is commercial landings and is well accounted for.
- Commercial discards are well sampled in some areas and fisheries, but not others

- Recreational catch is moderately sampled.
- Catch from small-scale tropical fisheries are essentially unknown.

Annual Catch Limits

- The Catch Limit and Accountability system requires
  1. fishery monitoring data with accuracy, precision, timeliness and transparency; and
  2. stock assessments that are frequent and accurate, with reliable evaluations of uncertainty in catch forecasts.
- When either of these requirements is not met, the Annual Catch Limit system often fails to meet management objectives (e.g., overfishing or foregone yield)

In-Season Monitoring

- Monitoring and reporting needs to be timely enough to inform future catch limits and support fishery-dependent business decisions to avoid exceeding catch limits and accountability measures.

Butterfish Coastwide Weekly Landings Report

For week ending:	April 5, 2014
For data reported through:	April 9, 2014
Quota Period:	2014
Quota Period Dates:	01/01/14 to 12/31/14

Previously Reported Landings (Pounds)	Previous Weeks' Updates (Pounds)	Current Week's Landings (Pounds)	Cumulative Landings (Pounds)	Quota (Pounds)	Percent of Quota (%)
3,203,374	2,511	14,518	3,220,403	7,054,792	46
3,203,374	***2,511***	***14,518***	***3,220,403***	***7,054,792***	***46***

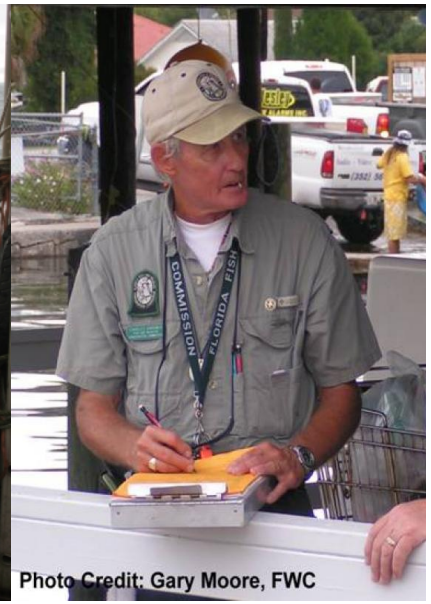
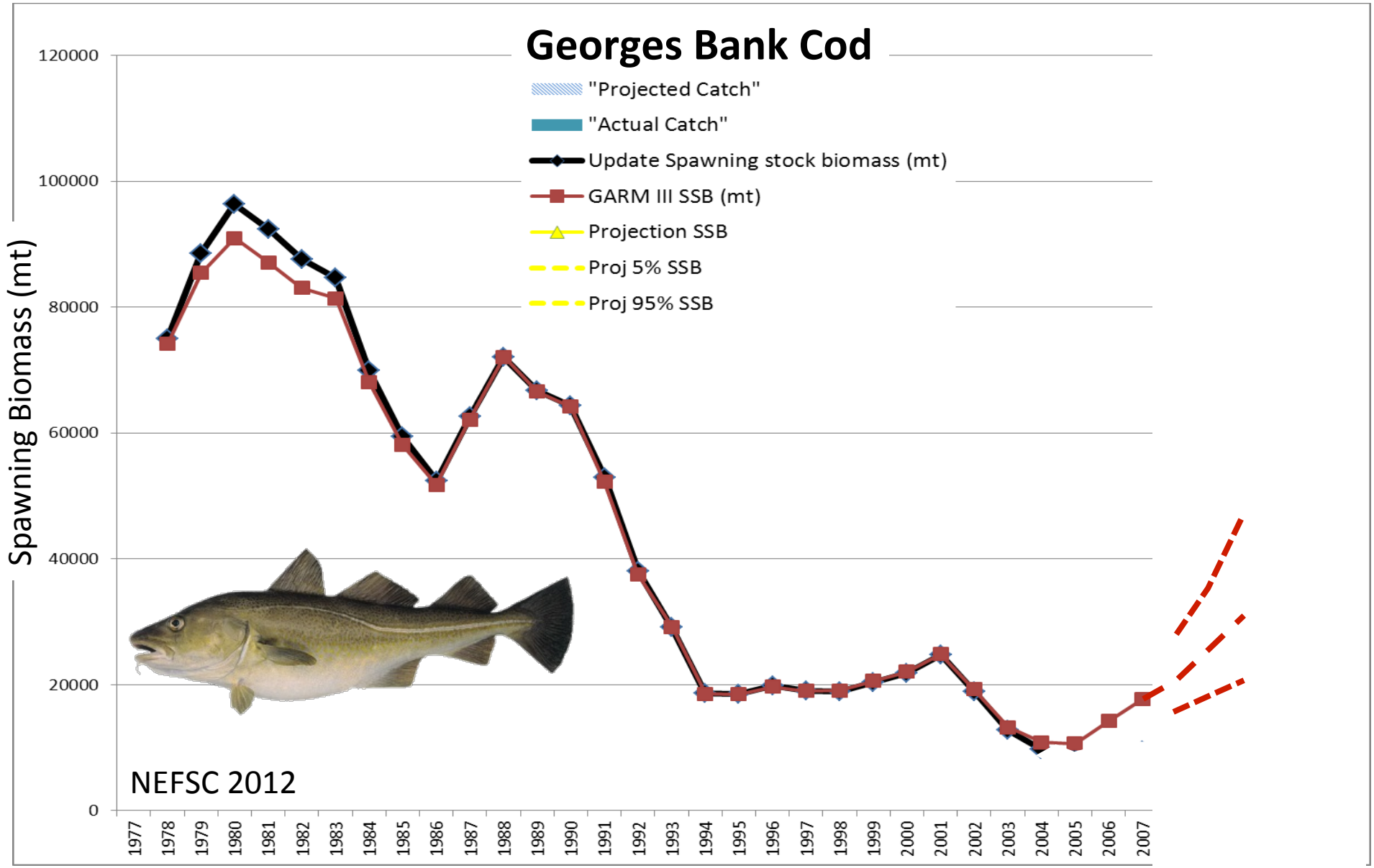
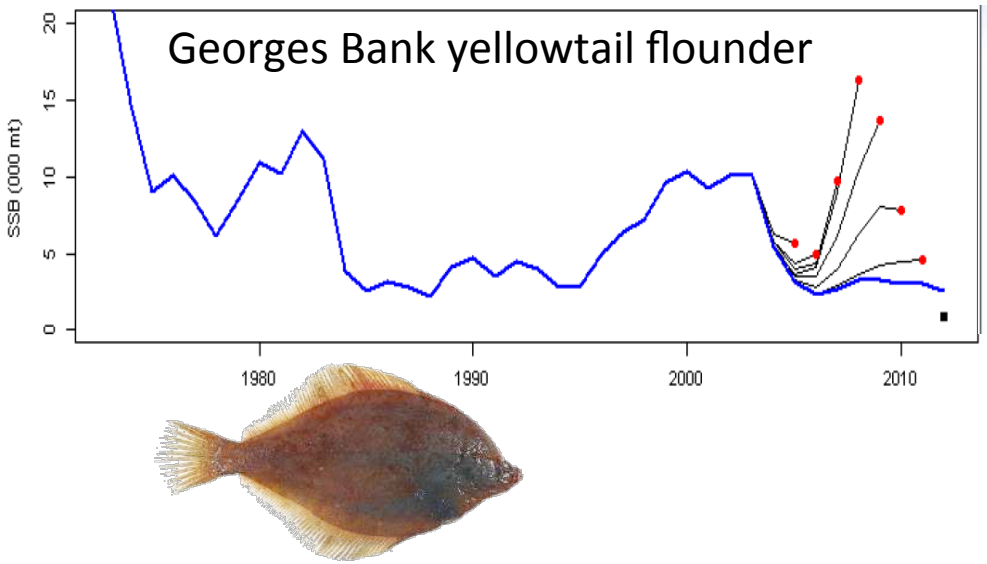


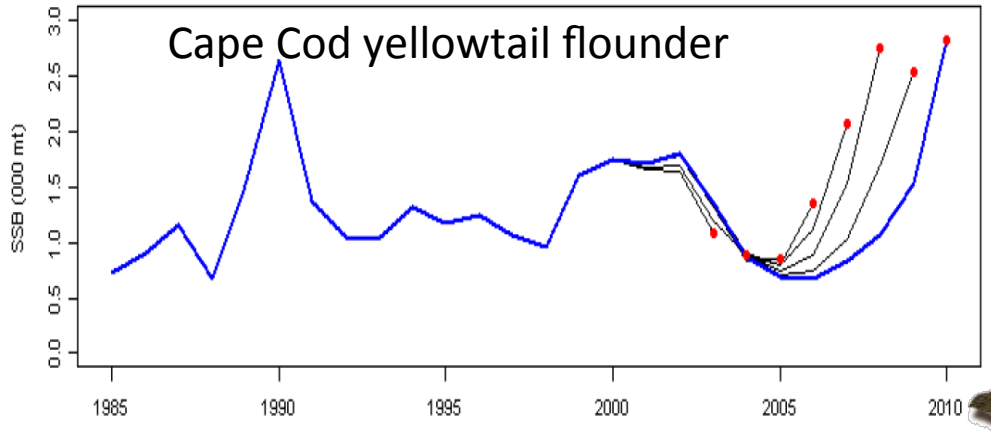
Photo Credit: Gary Moore, FWC

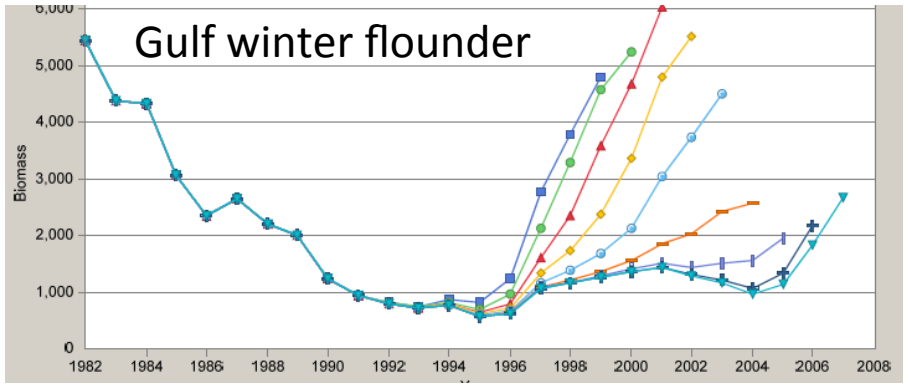
Stock Assessment Uncertainty

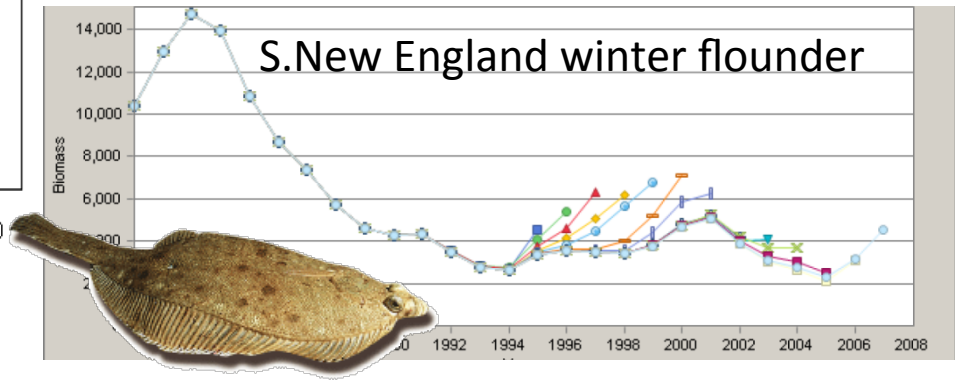


Retrospective Patterns









NEFSC 2008, NEFSC 2012, TRAC 2013

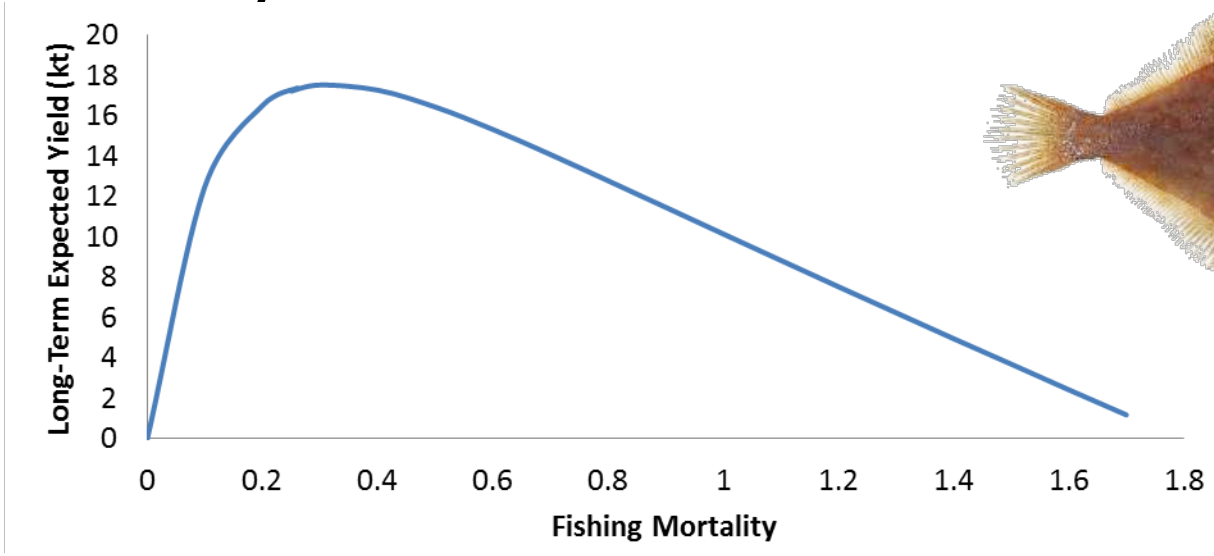
Mixed-Stock Fisheries

- Ricker (1958) "Maximum sustainable yields from fluctuating environments and mixed stocks."
  - Potential catch from mixed-stock fisheries is less than when each stock is fished separately at its optimum level.
  - Attempts to optimize mixed-stock yield will have different effects on different stocks, causing some to increase and others to decrease.
  - Different responses of each stock to environmental changes makes the situation worse.


Beamish et al. 2003

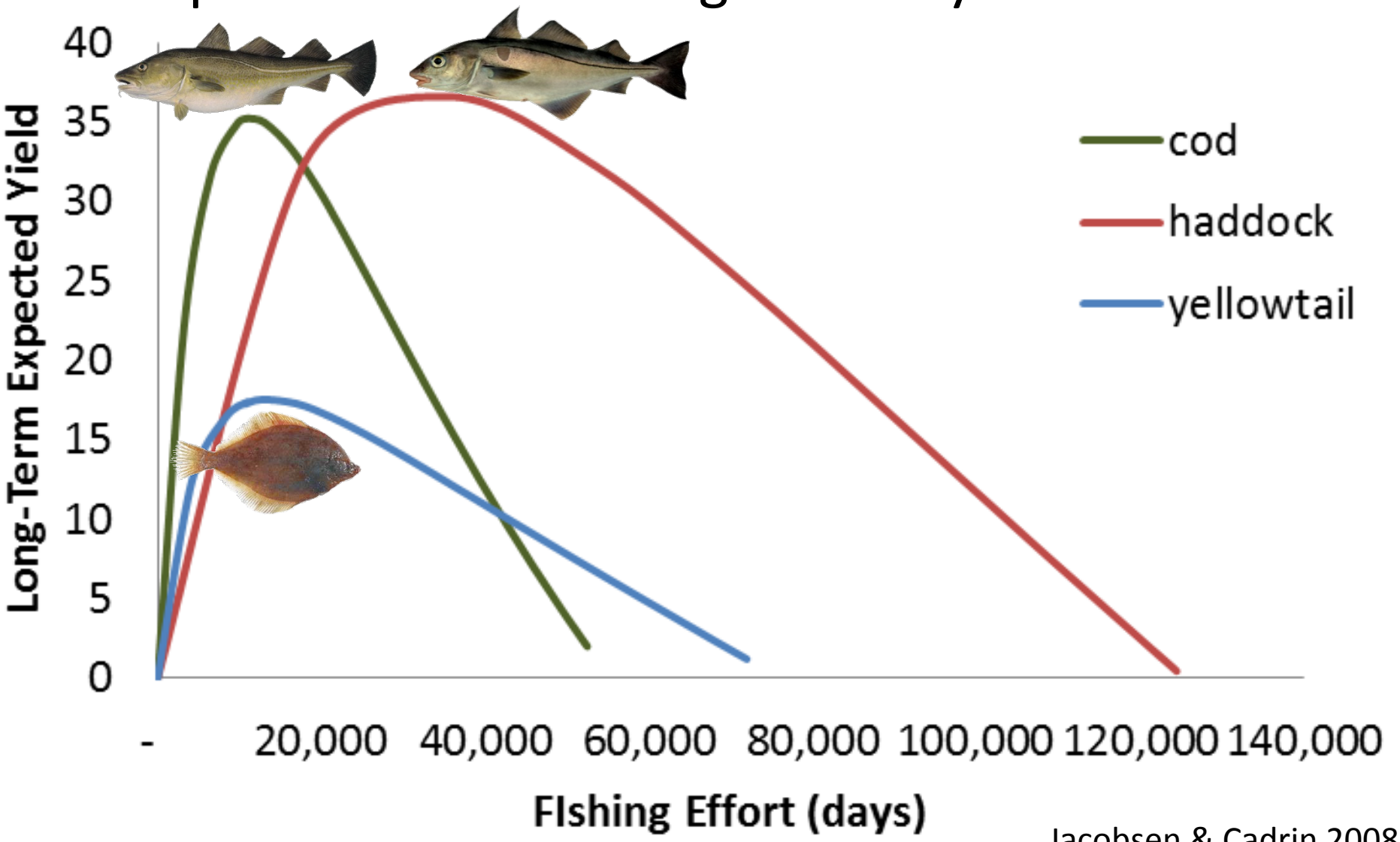
Maximum Sustainable Yield

- Georges Bank yellowtail flounder



Mixed-Stock Fishery

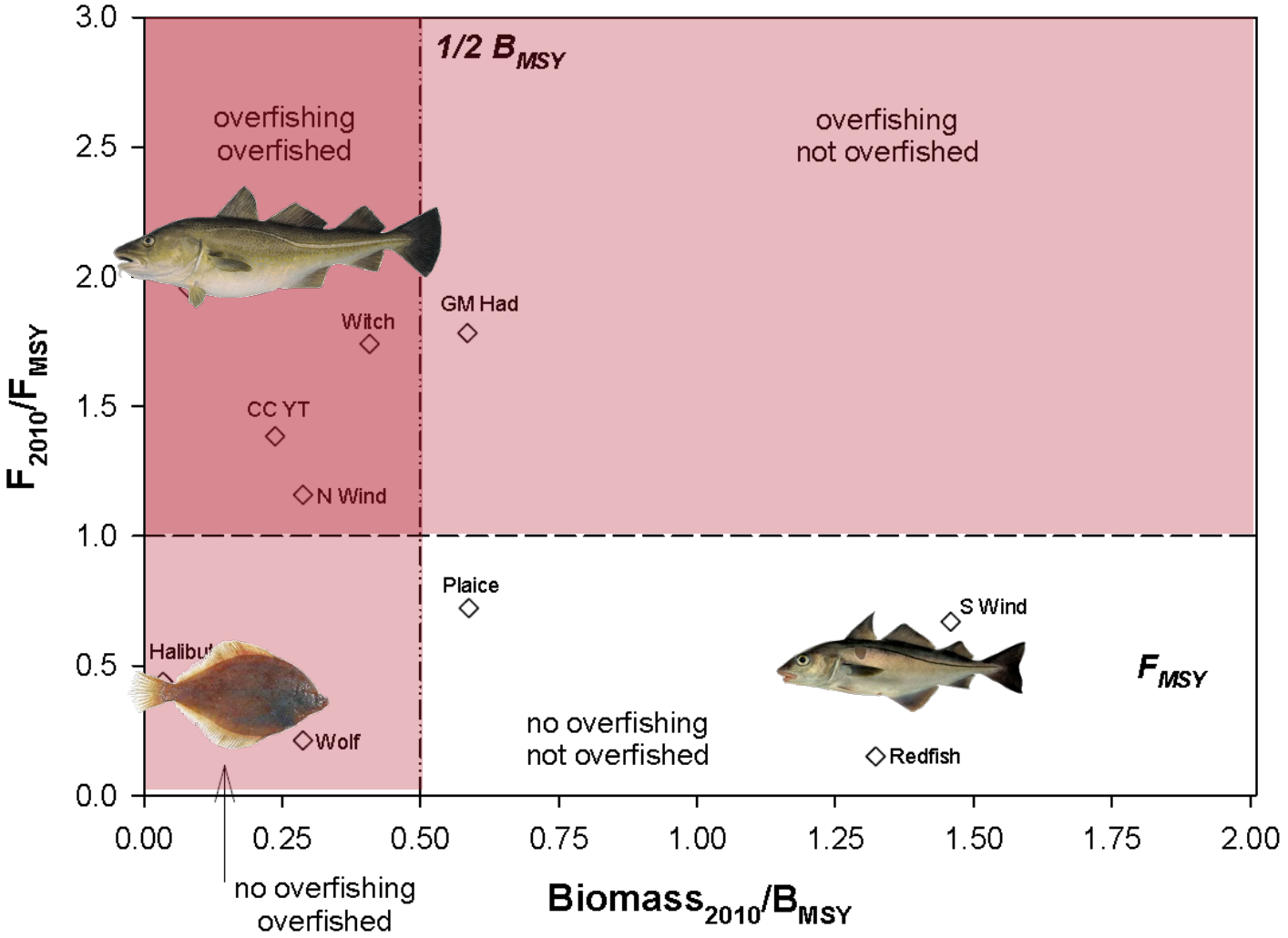
- The optimal rate of fishing varies by stock.



Jacobsen & Cadrin 2008

Mixed Stock Fishery

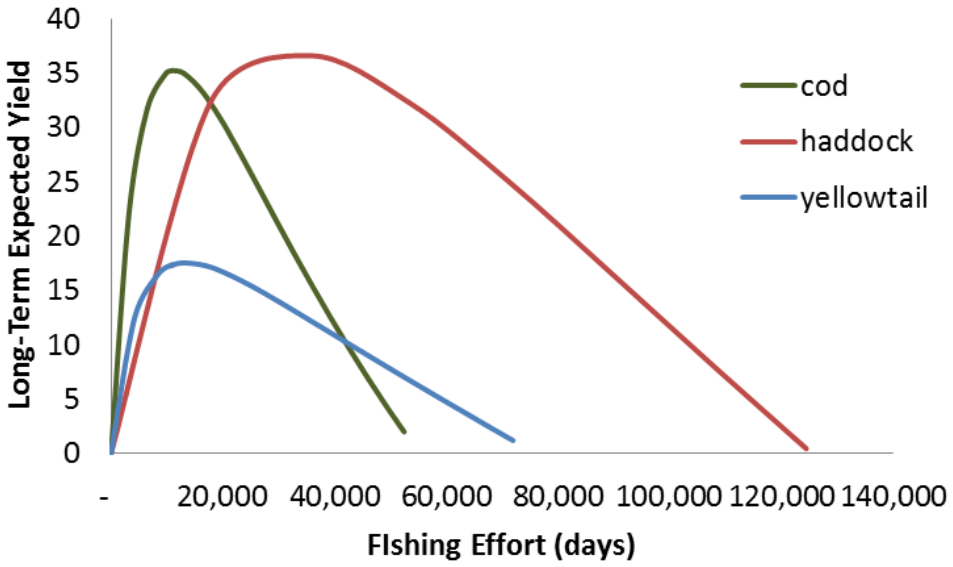
- Stock conditions vary, and some are fished at a lower rate to promote rebuilding.



NEFSC 2012

Choke Stocks

- Ideally, multispecies catch allocations match the mix of species available on the fishing grounds.
- When catch allocations do not match the mix of species available on the fishing grounds, fisheries are often constrained by the most limiting species allocation.



Choke Stocks

- When some stock assessments are biased or uncertain, the proportions of fish available to fishermen are different than the proportional catch allocation.
- Catch limits of rebuilding stocks remain low while the stock rebuilds, increasing the challenge to avoid them.
- Accountability measures further reduce the catch limits on bycatch stocks, increasing the mismatch between the catch limit and the species mix on the fishing grounds.

Foregone Yield

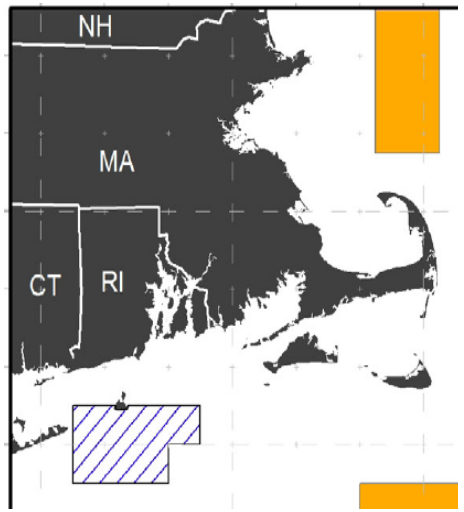
- Single-species management constrains optimal yield.
- 2012 New England groundfish allocations and catch (lb):

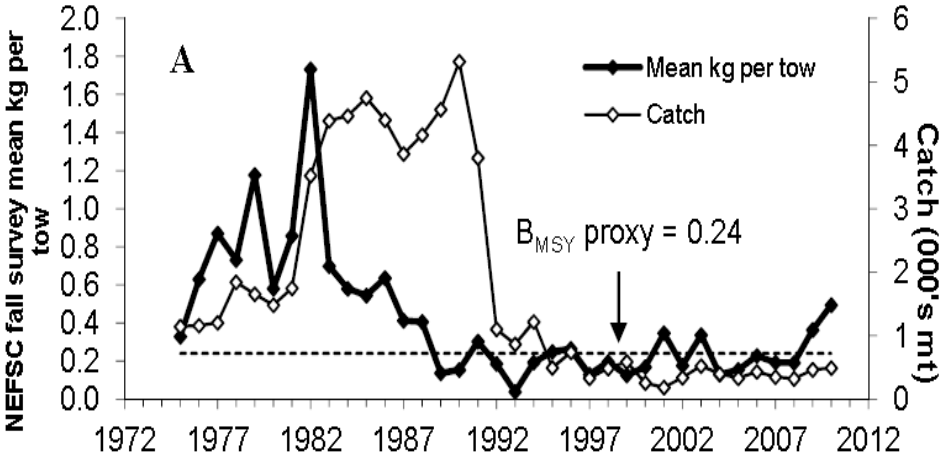
Stock	Allocation	Catch	% Caught
E Georges Bank cod	349,326	146,887	42%
W Georges Bank cod	10,320,365	3,331,816	32%
Gulf of Maine cod	8,761,312	4,699,621	54%
E Georges Bank haddock	15,074,308	777,622	5%
W Georges Bank haddock	49,398,411	1,808,495	4%
Gulf of Maine haddock	1,784,067	522,917	29%
Plaice	7,400,614	3,426,646	46%
Pollock	29,305,283	13,688,091	47%
Redfish	19,052,388	9,096,051	48%
White hake	7,365,297	5,294,489	72%
Georges Bank winter flounder	7,695,773	4,237,884	55%
Gulf of Maine winter flounder	1,561,490	562,334	36%
Witch flounder	3,291,703	2,122,567	64%
Cape Cod yellowtail flounder	2,433,611	2,067,901	85%
Georges Bank yellowtail flounder	798,315	474,236	59%
S New England yellowtail flounder	1,342,708	938,303	70%
All Stocks	165,934,971	53,195,860	32%

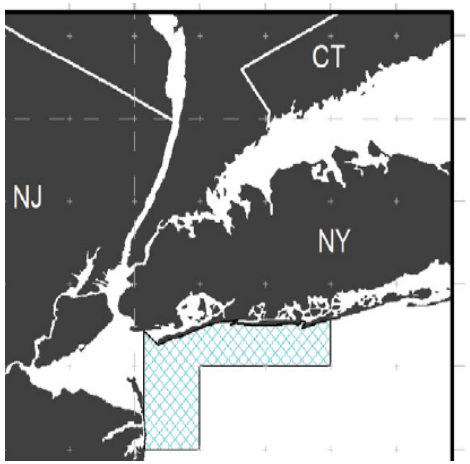
Murphy et al. 2014

Windowpane Flounder

- Windowpane is a discarded bycatch species in multiple demersal fisheries, with a stock that is greater than the rebuilding target in the southern management area (i.e., not overfished).
- Accountability for exceeding the 2012 Annual Catch Limit based on a data-limited assessment is limiting many fisheries at costs of ~$5-10Mil per year in the groundfish fishery and more in other fisheries. (e.g., scallops, worth $550Mil/year)







Groundfish Closed Areas

Northern Windowpane Flounder (NWF) Accountability Measure (AM) Areas

NWF Large AM Area

Southern Windowpane Flounder (SWF) Accountability Measure (AM) Areas

SWF Large AM Area 1

SWF Large AM Area 2

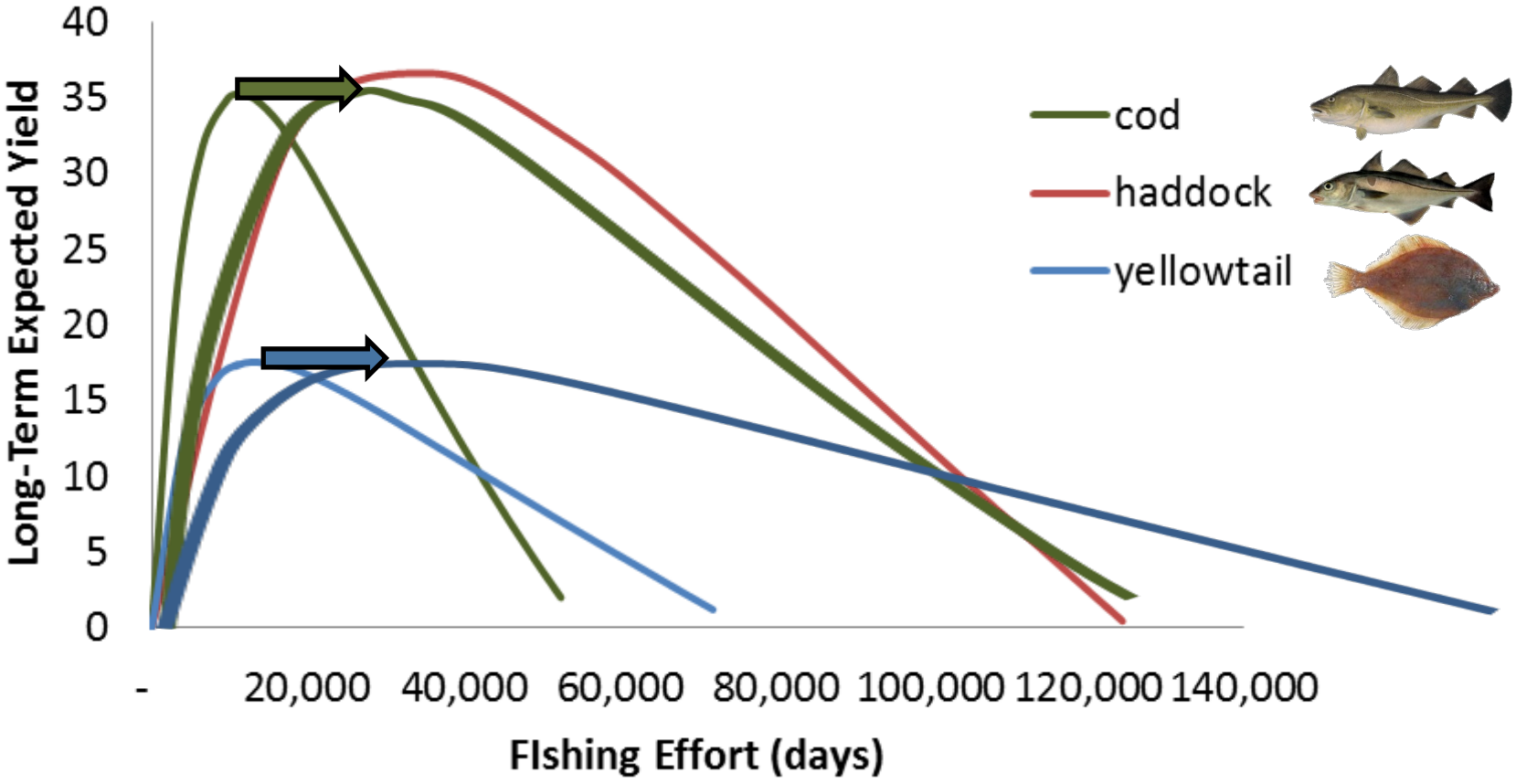
Achieving Optimum Yield

- Improving scientific support
  - More frequent stock assessments
    - Most New England groundfish are assessed every 3-4 years
    - Considerable changes in resource conditions and substantial changes in perceived stock status ('retrospective patterns') have occurred over 3 years.
  - In-season monitoring
    - Fishermen can optimize their catch if given timely information.
    - Availability of observer data in New England is lagged up to three months after the trip.

Achieving Optimum Yield

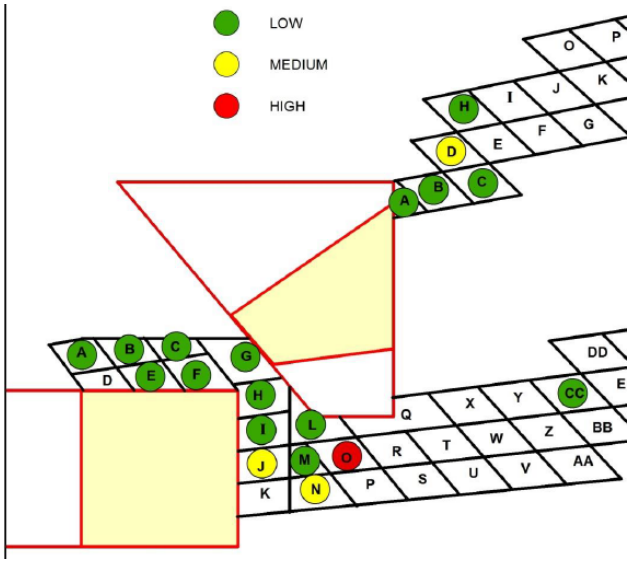
- Mixed-species catch allocations can be achieved by managing species catchabilities.

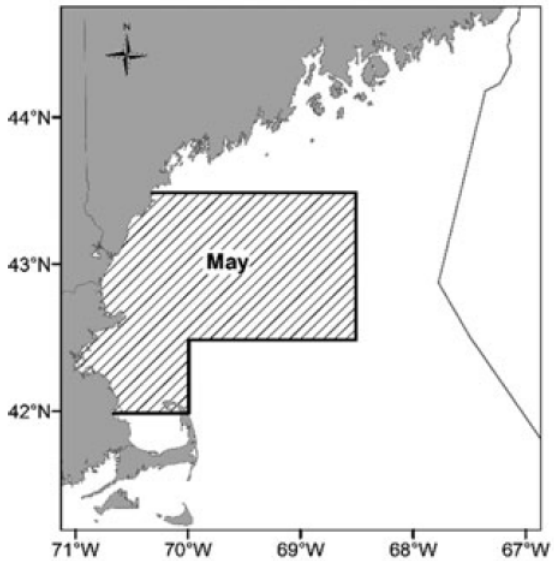
$$\blacksquare Fishing\ mortality = catchability \cdot fishing\ effort @ F{\downarrow}cod = q{\downarrow}cod \cdot E$$



Achieving Optimum Yield

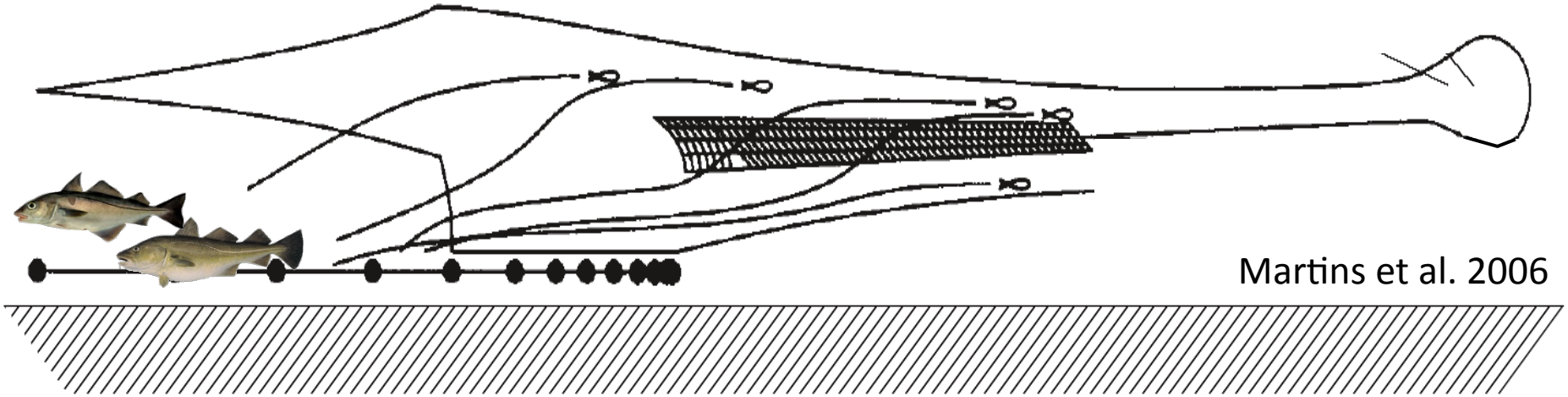
- Species catchabilities in mixed-stock fisheries can be managed several ways:
  - Conservation engineering
  - Transferability
  - Regulating time-area fishing patterns
  - Bycatch avoidance





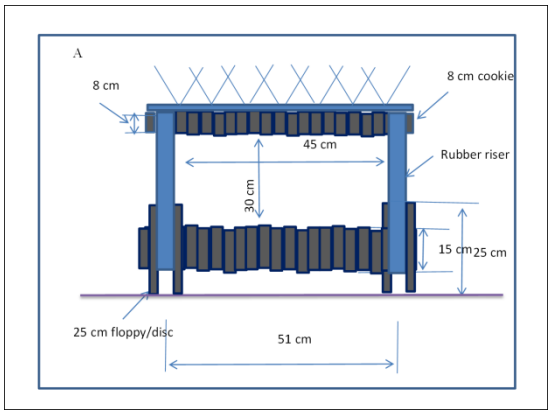
Conservation Engineering

- Alternative fishing technologies can alter the relative efficiency of catching different species.
- Haddock separator trawl:



Martins et al. 2006

- Flatfish escapement windows:



Roman et al. 2012

Transferability

- The conceptual justification for 'catch shares' is that catch allocations can be traded to fishing operations in which it is most valuable.
  - Different fishermen use different gears and fish in different areas (i.e., have difference species catchabilities).
  - If a fisherman cannot catch his haddock allocation because of bycatch, he might lease it to another fisherman who can.

West Coast Groundfish Trawl Catch Share Program

- In 2011, NMFS implemented a catch shares management system for the West Coast Groundfish Trawl Fishery.
- An Individual Fishing Quota (IFQ) is allocated to the shore-based trawl fleet and cooperative programs for the at-sea mothership and catcher/ processor trawl fleets.
- Shares are controlled by individual fishermen or groups of fishermen (cooperatives) and can be harvested at the fishermen's discretion, ideally more efficiently and at more profitable marketing times.
- The program holds fishermen accountable for their deliberate catch as well as bycatch.

www.westcoast.fisheries.noaa.gov/fisheries/groundfish_catch_shares

Risk Pools

- Yelloweye and canary rockfish are rebuilding slowly and have low Annual Catch Limits, but they form aggregations such that the catch limits can be exceeded in a single accidental haul.
- Individuals pay or contribute their quota for the species so that the collective catch allocation can be used to cover accidental catches.
- Membership usually requires the use of selective fishing gear and avoiding bycatch areas.

NORTHEAST MULTISPECIES - SECTOR MANAGEMENT

- In 2010, the Northeast groundfish fishery implemented “sector management.”
- A "sector" is a group of fishermen with groundfish permits who voluntarily entered into a sector contract for a specified period of time.
- Groundfish sectors are allocated a total allowable catch in order to achieve management objectives, and catch allocations can be leased from one sector to another.

www.nero.noaa.gov/sfd/sfdmultisector.html

Foregone Yield

- Transferability is not solving the problem of 'underfishing' in New England because of design constraints.

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E Georges Bank cod	349,326	146,887	42%
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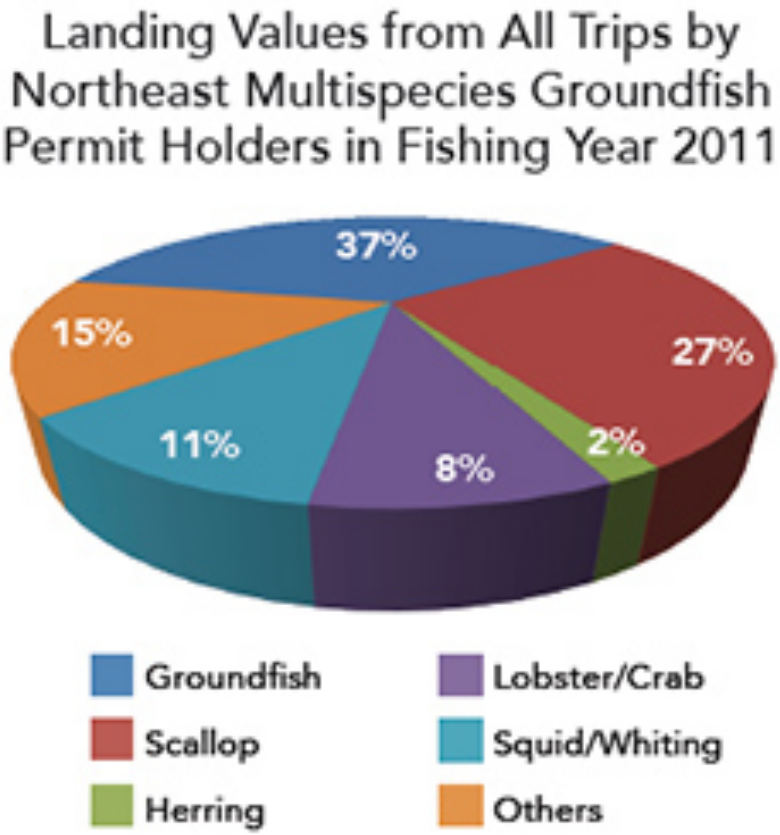
All Stocks	165,934,971	53,195,860	32%

Murphy et al. 2014

Flexibility

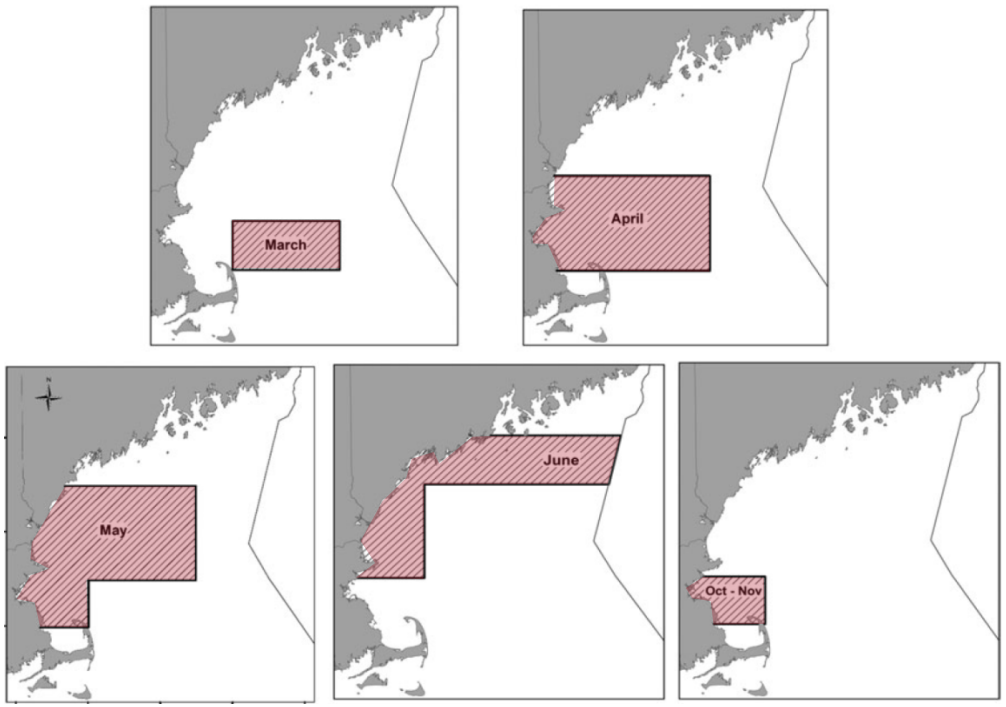
- Transferability among New England groundfish sectors has not achieved catch allocations, but flexibility to harvest other resources is helping to sustain profitability of groundfish operations, but multi-fishery flexibility is difficult to manage.

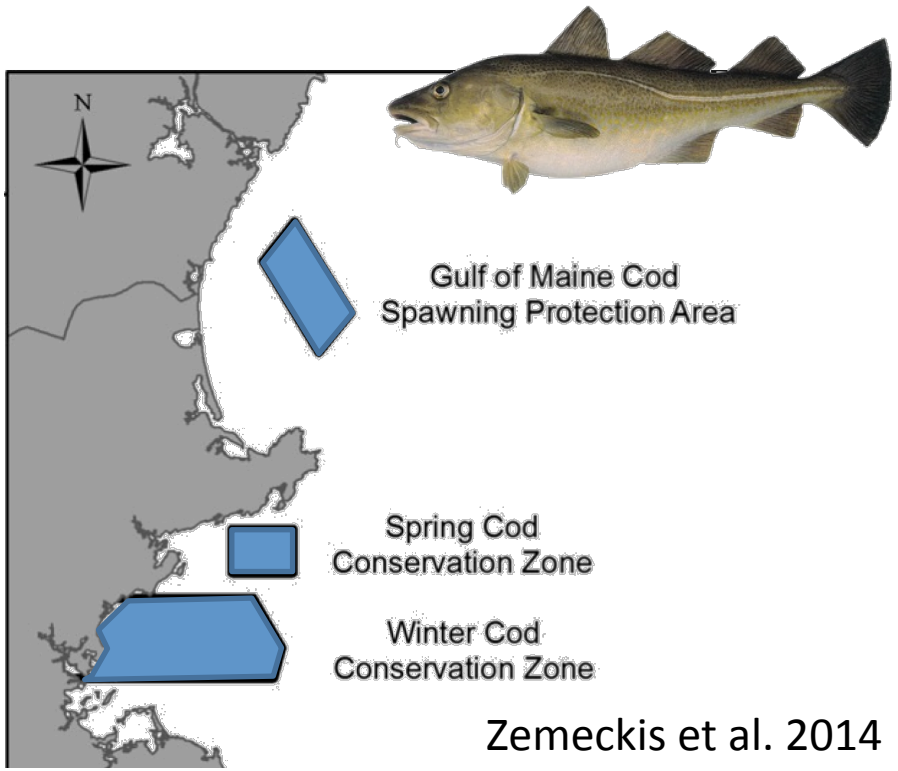


Sun et al. 2013

Time/Area Fishing Patterns

- Fishing on aggregations increases fishery catchability, so protecting persistent spawning aggregations conserves discrete spawning components (e.g., cod rolling closures, inshore cod conservation zones).

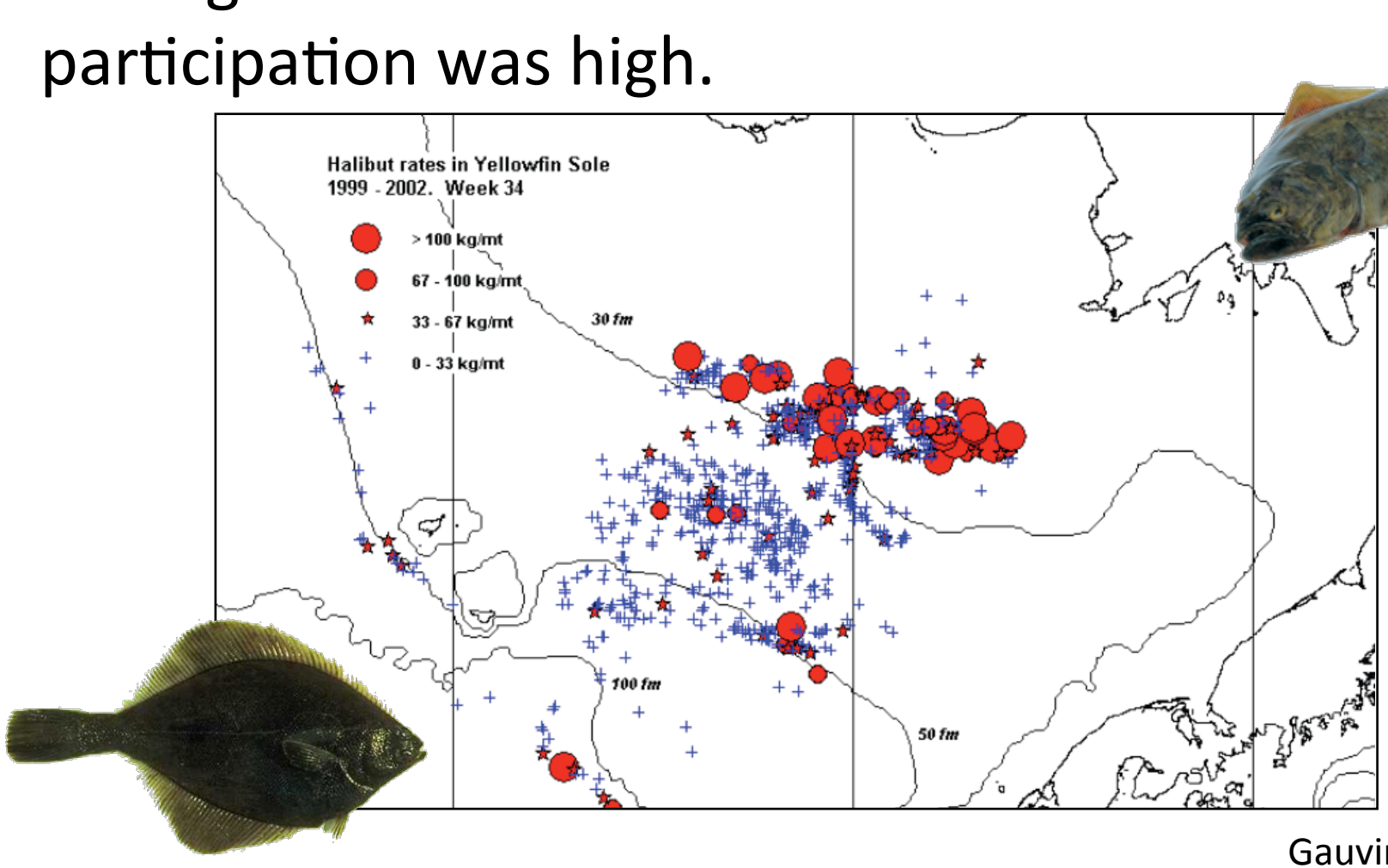




Zemeckis et al. 2014

Bycatch Avoidance

- Alaskan fisheries have successfully reduced bycatch through satellite communications when participation was high.



Gauvin et al. 1995

Bycatch Avoidance

- Yellowtail flounder occur as bycatch in the scallop fishery, and bycatch limits have prevented the scallop fleet from achieving it's target species allocation.

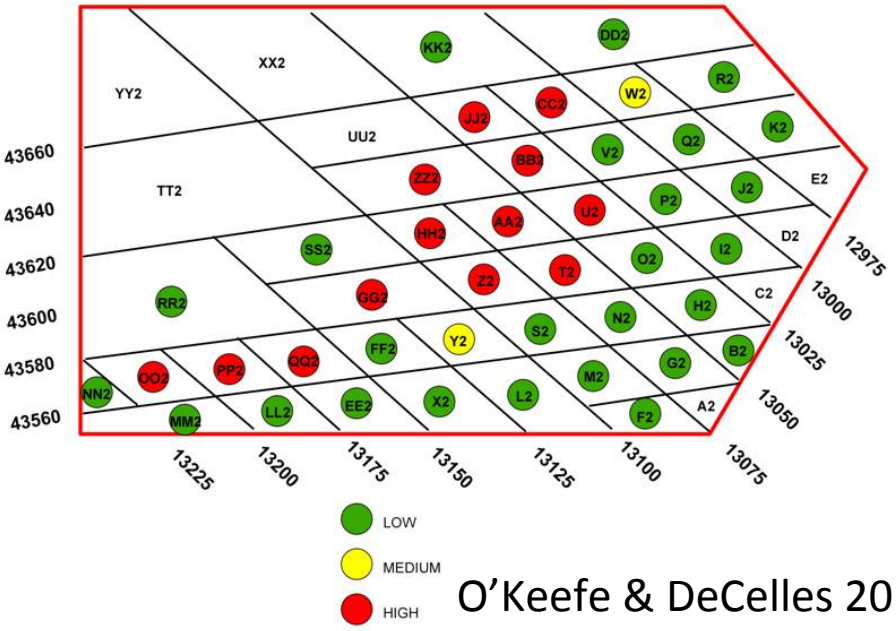
UMass School for Marine Science & Technology

Year	2006	2006	2008	2009
Area	Nantucket	Closed Area II	Nantucket	Closed Area II
Days Open	32	82	49	15
% Yellowtail TAC Caught	176%	103%	98%	81%
% Scallop Target Caught	78%	82%	75%	61%
Forgeone yield ($)	$17,850,000	$21,000,000	$11,100,000	$16,000,000

O'Keefe & DeCelles 2013

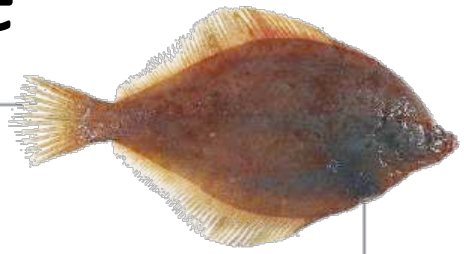
Bycatch Avoidance

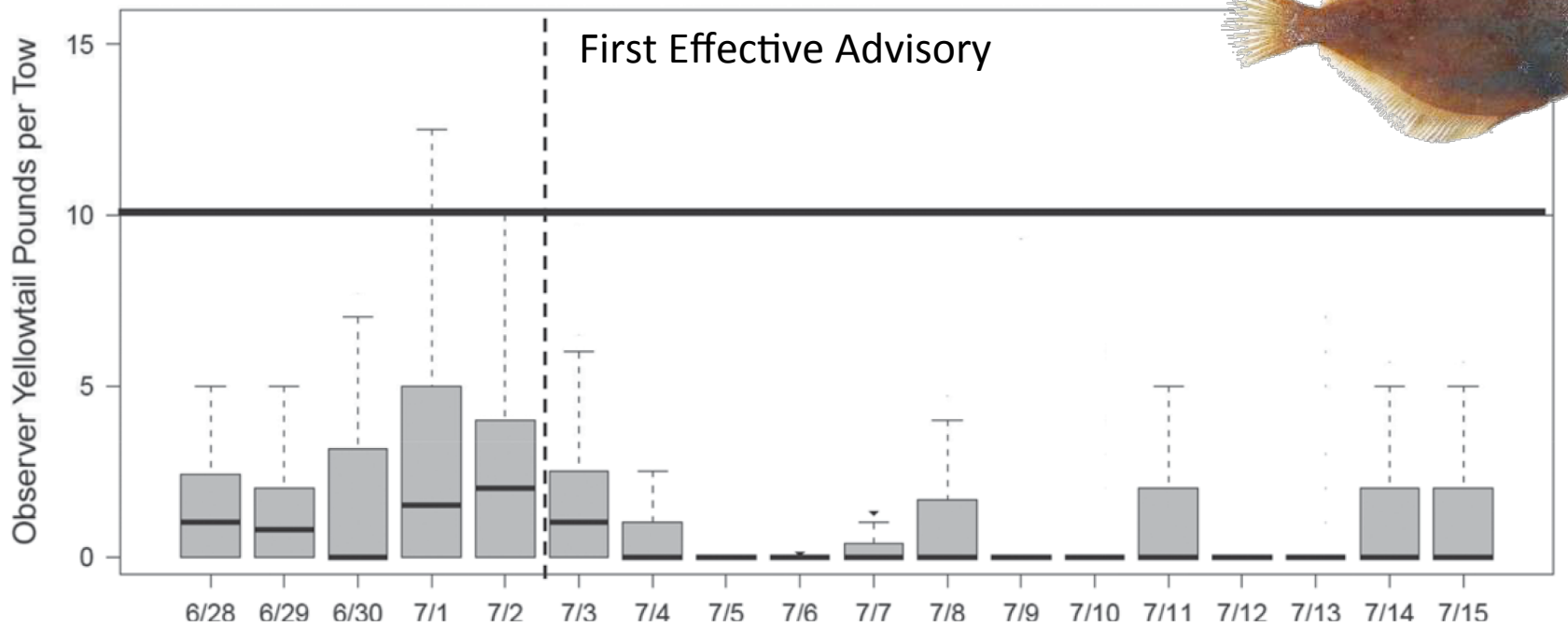
- A data-sharing program was developed in which fishermen email SMAST daily with their position and catch rates, SMAST compiles the data and sends a bycatch advisory to the fleet.



O'Keefe & DeCelles 2013

Bycatch Avoidance





- In 2009, only 32% of the yellowtail bycatch limit was caught, but the entire scallop allocation was achieved, valued at $40 million.

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Bycatch Avoidance

BYCATCH MITIGATION PROGRAM	Reduced Bycatch	Min. Effect on Target Catch	Min. Effect on Non-Target	Min. Effort Impacts	Economic Viability
TIME/AREA CLOSURES					
Shrimp in Kuwait (Ye et al 2000)	✔	✔	✔		✔
Porpoise in Gulf of Maine (Murray et al 2000)			✔		
Juvenile plaice in North Sea (Pastoors et al 2000)	✔				
QUOTAS/CAPS					
Sea scallop bycatch cap (O'Keefe et al 2010)	✔				
New Zealand quota system (Diamond 2004)	✔	✔		✔	✔
British Columbia halibut ITQ (Ackerson & Turris 2011)	✔		✔	✔	✔
FLEET COMMUNICATION					
SeaState Inc. AK trawl (Gauvin et al 1995)	✔	✔	✔		✔
Capt. Communication swordfish (Gilman et al 2006)	✔	✔	✔	✔	✔
Fishery Information AK longline (Gilman et al 2006)	✔	✔	✔	✔	✔
Yellowtail Avoidance US scallop (O'Keefe et al 2010)	✔	✔	✔	✔	✔

O'Keefe et al. 2013

Morro Bay Groundfish Fishery

- From 1987 to 2003 gross revenues from Pacific groundfish trawling decreased by two-thirds.
- Fishermen partnered with the conservation groups to form "conservation fishing agreements" lease catch to fishermen with restrictions on fishing gear, fishing areas, fleet communication and electronic monitoring.

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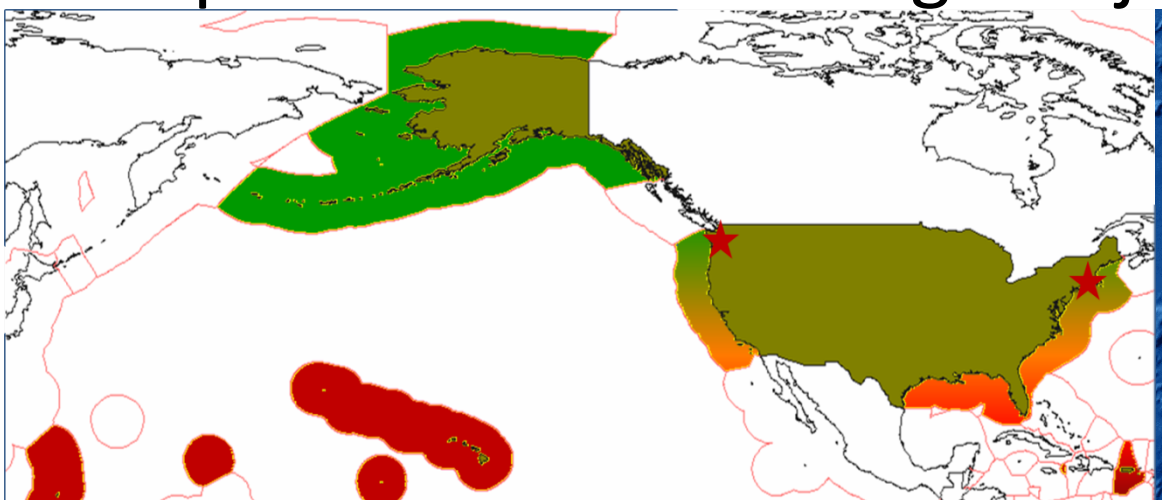
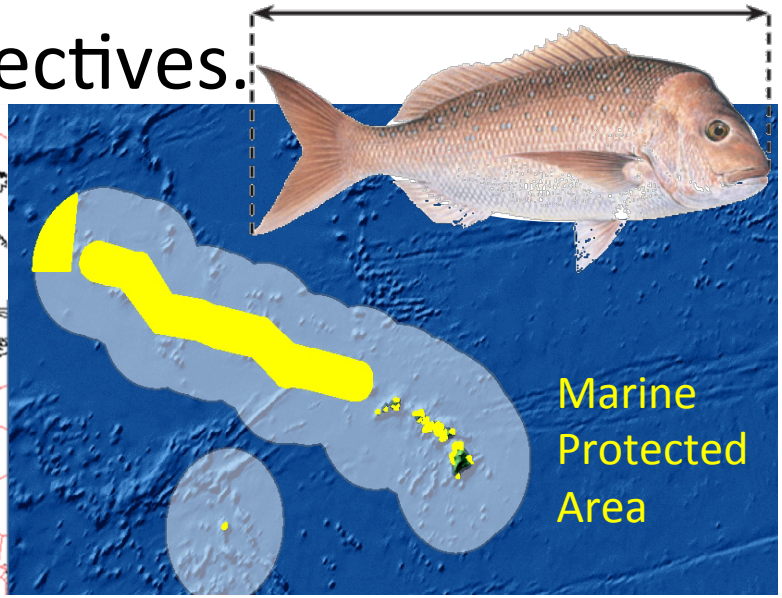
Conclusions

- Annual Catch Limits and Accountability Measures should effectively avoid overfishing, **if…**
  - catch estimation and stock assessments are accurate and timely and transparent, and
  - stocks can be targeted individually.
- Achieving optimum yield in mixed-stock fisheries requires modification of species catchabilities:
  - Transferability
  - Conservation engineering
  - Time-area patterns
  - Bycatch avoidance
- Some 'input controls' can be voluntary rather than regulated.

Recommendation #1

- Annual Catch Limits should not be required for fisheries that do not have reliable annual catch estimates or catch monitoring information is not timely available on a enough to support in-season fishing decisions or the benefits of catch shares.
- Alternative management approaches should be required to meet strategic objectives.





Recommendation #2

- A more explicit legal exemption from the Maximum Sustainable Yield harvest rate limit and rebuilding to Maximum Sustainable Yield stock level for each stock would ease the challenge of achieving optimum yield from mixed-stock fisheries.
  - Optimum Yield is mandated for fisheries (not stocks).
  - National Standard 1 Guidelines include a 'mixed-stock exemption', but without a mandate for the exemption it is too limiting and has not been applied.
    - "Harvesting one stock at its optimum level may result in overfishing of another stock when the two stocks tend to be caught together", if all of the following conditions are satisfied:
      1. Such action will result in longterm net benefits to the Nation;
      2. A similar level of long-term net benefits cannot be achieved by modifying fleet behavior, gear selection/configuration, or other technical characteristic in a manner such that no overfishing would occur; and
      3. The resulting rate of fishing mortality will not cause any stock or stock complex to fall below its 'overfished' threshold more than 50% of the time (NMFS 2009).