Effects of spatial heterogeneity and area management on fishery reference points

or

Why the overfishing definition for sea scallops needs to be revised

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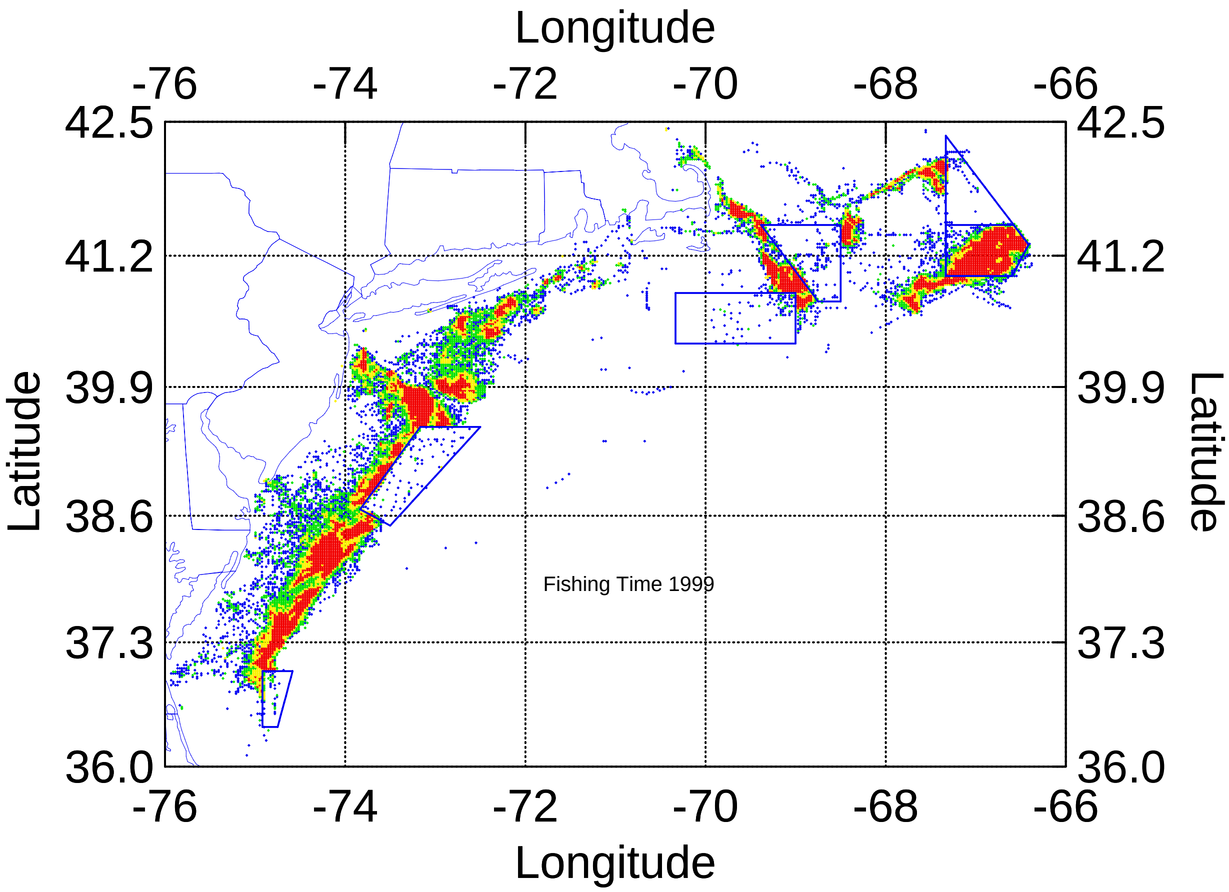
Standard fishery theory assumes that fishing mortality is uniform spatially

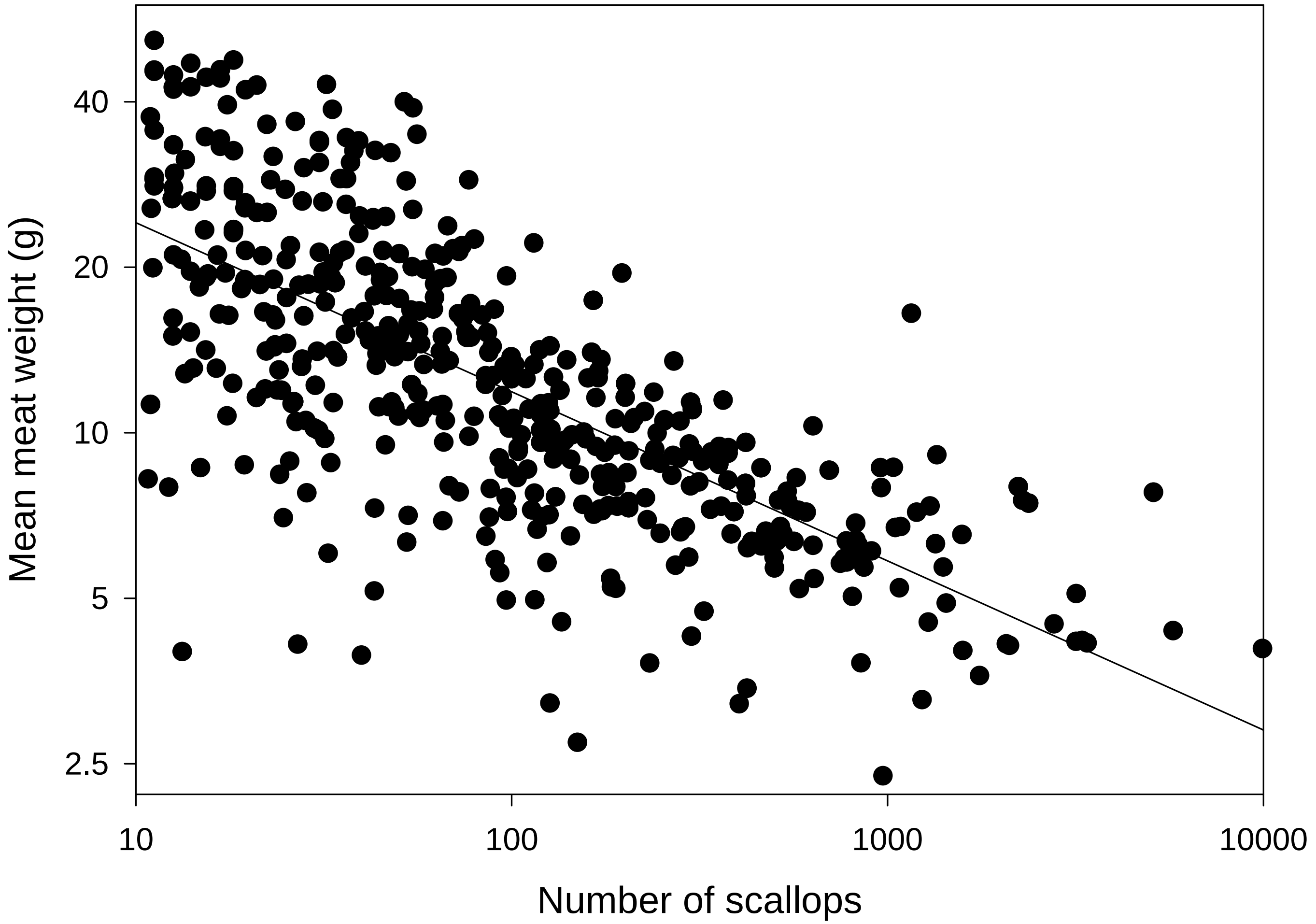
This assumption is strongly violated in the sea scallop fishery



Mean meat weight by tow of Georges Bank sea scallops

Groundfish closed areas, preclosure (1982-1994)

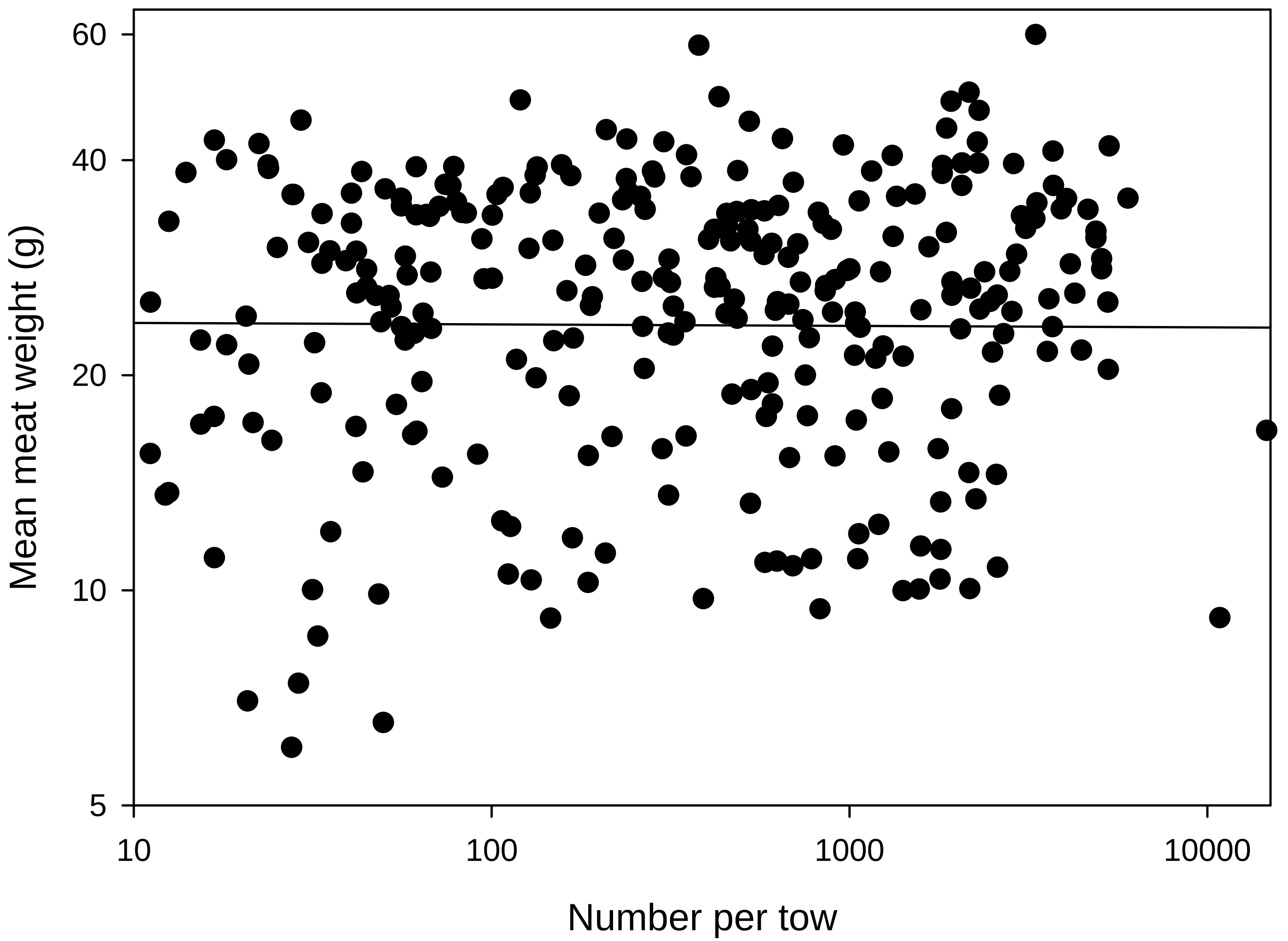
Excludes CLII-S which was heavily fished in 1999-2000



Mean meat weight by tow of Georges Bank sea scallops

Groundfish closed areas, post-closure (1999-2003)

Excludes CLII-S which was heavily fished in 1999-2000

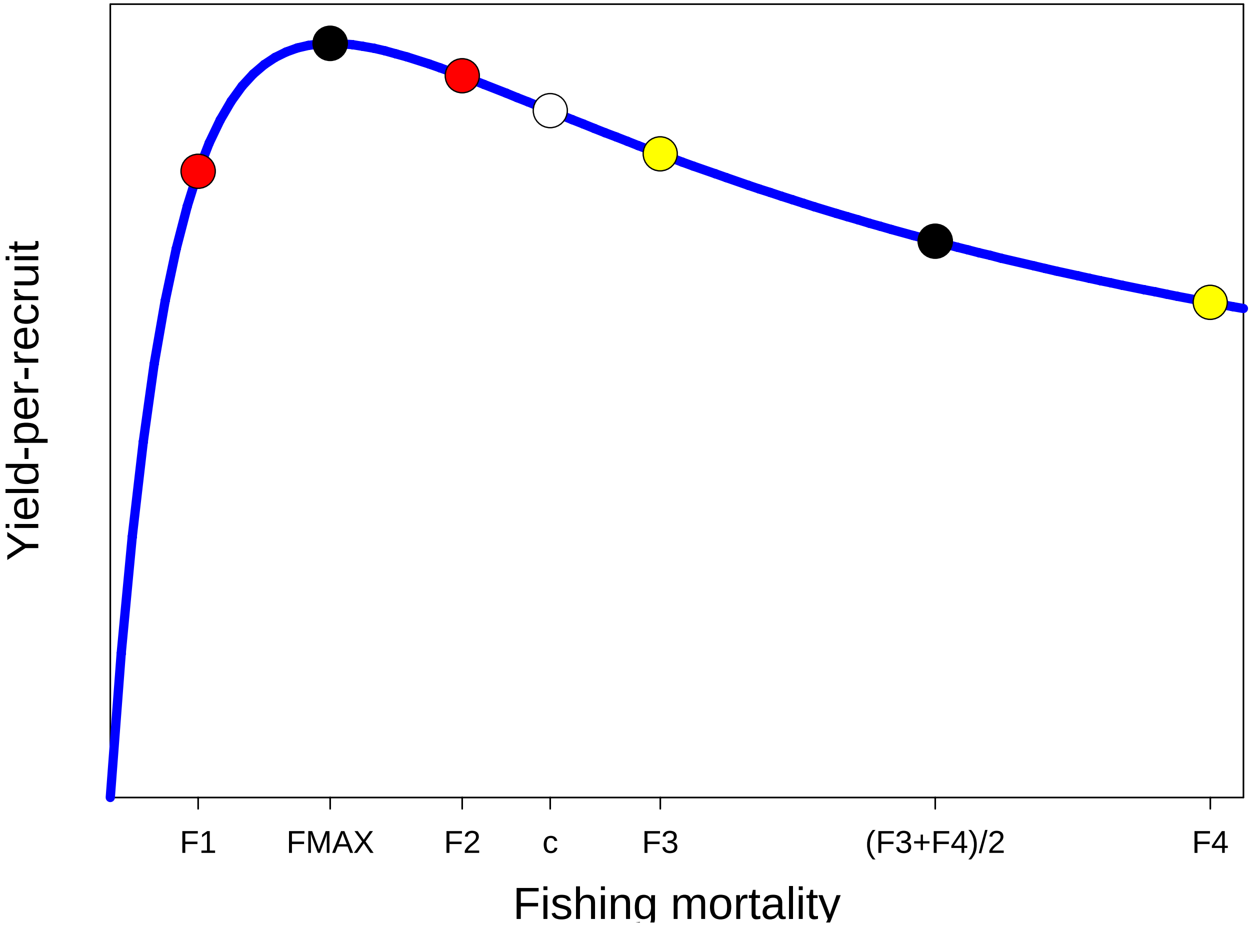


Sea scallop fishing mortality is highly variable in space even without any specific area management. Fishing mortality is higher in areas of higher scallop density.

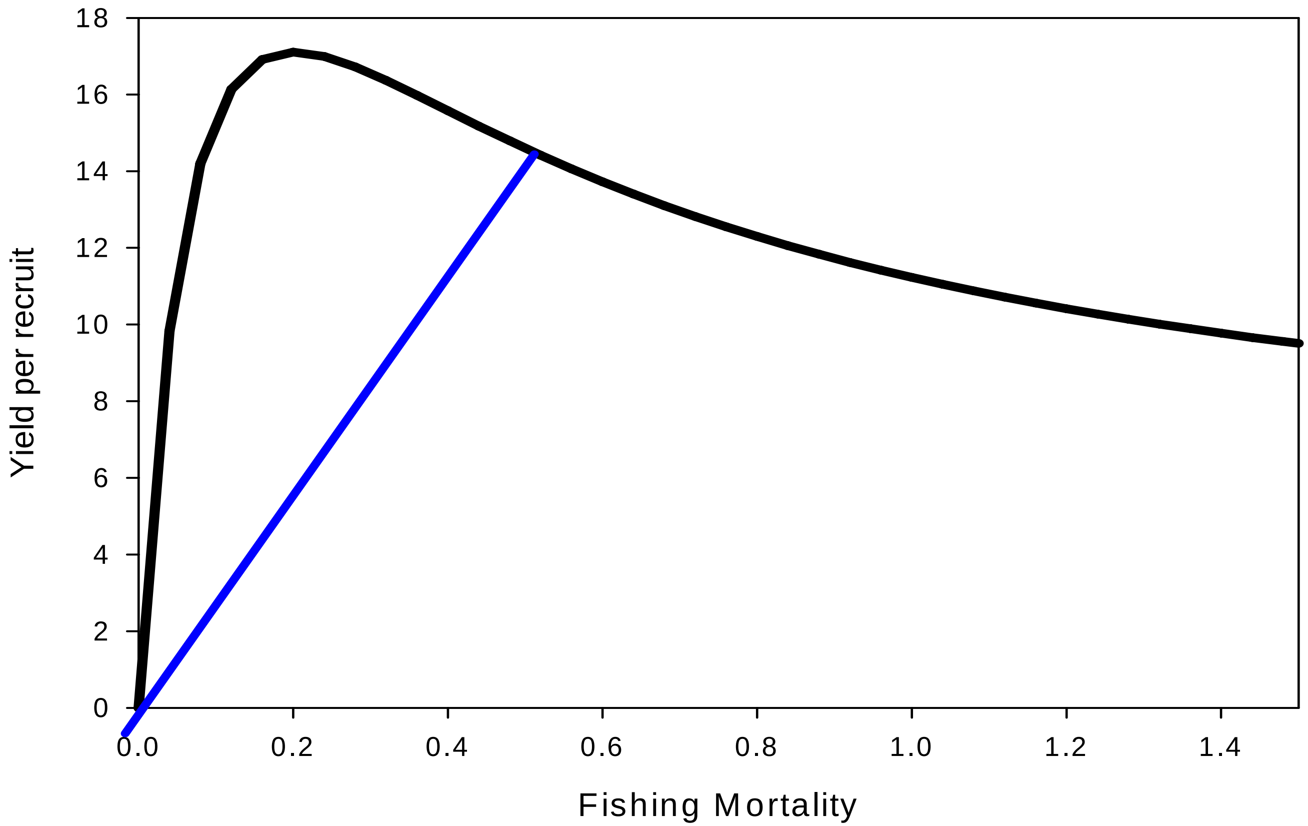
Rotational and long-term area closures further increase the spatial variability in fishing mortality.

What are the consequences of fishing mortality heterogeneity for fishing mortality and reference point calculations?

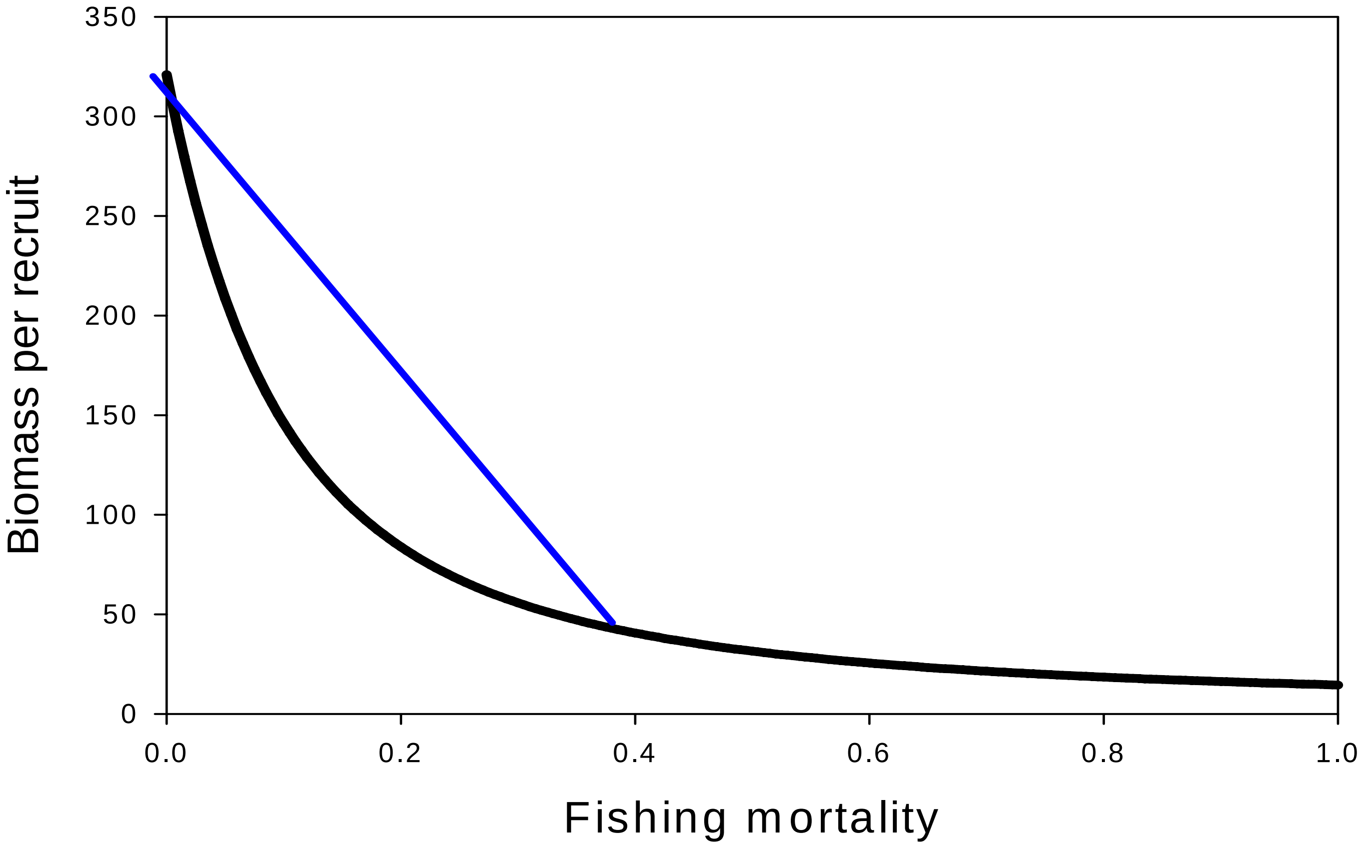
Variation in fishing mortality cause YPR to be overestimated for except possibly at very high (mean) fishing mortalities, and underestimation of BPR at any fishing mortality (see Hart 2001).



If fishing mortality is constrained to be zero in some areas (e.g., EFH closures), YPR will be maximized by setting F in the remainder of the areas to FMAX, rather than the overall fishing mortality to FMAX. For example, if FMAX = 0.29, and half the scallops are in EFH closures, the remainder should be fished at 0.29 rather than 0.58.



Heterogeneity in fishing mortality induces higher BPR than would occur at the same mean F if all individuals were subject to the same fishing mortality risk.
The example below shows that BPR at F = 0.2 is less than half that of the average of F = 0 and F = 0.4



F	%of stock	YPR	BPR
0	56	0.00	365.2
0.2	19	17.11	89.9
0.4	11	15.58	43.3
0.6	8	13.72	27.1
0.8	6	12.30	19.5
	Mean	**11.74**	**109.0**

***n*-weighted *F* = 0.18 < F_{MAX}**

YPR(0.18) = 17.06, BPR(0.18) = 99.2

The stock appears to be underfished, even though the true YPR is well less than Y_{MAX}, and (uniform) reductions in fishing mortality would increase YPR.

Individual variations in fishing mortality cause conventional estimators of fishing mortality to be biased low when compared to conventional per-recruit calculations

Effects of fishing mortality heterogeneity

(1) Causes number-weighted calculations of fishing mortality to be biased low when compared to standard per recruit reference points

(2) Induces reductions in YPR and increases in BPR

(3) When fishing mortality in some areas is constrained to be zero, fishing mortality in the remainder of the areas need to be set to FMAX in order to maximize YPR given the constraint, rather than be spatially averaged with the closed areas.

Time-averaging principle for rotational (or time-varying) fishing

Strategies that have the same time-averaged fishing mortality will have (to a first approximation) similar yields and biomasses (see Hart 2003)

For example,

F,F,F,…   will have similar yields and biomasses to

0,2F,0,2F,…

0,0,3F,0,0,3F,…

0,0,0,F,2F,3F,0,0,0,F,2F,3F,…

½ F, 3/2 F, ½ F, 3/2 F,…

In summary:

Averaging fishing mortality over time is appropriate

Averaging fishing mortality over space is not

A10 proposed overfishing definition

Recognized three types of areas:

(1) Closed Areas

(2) Rotational Access Areas that had been closed in the recent past

(3) “Open” areas, that do not qualify as (1) or (2)

Procedure for determining overfishing

Closed areas (both long-term and rotational) are not included in the fishing mortality calculation

The threshold for access areas is set using the time-averaging principle (typically higher than for open areas)

The threshold for the open areas is the conventional F_{MAX} threshold

The stock is overfishing if the fishing mortality in the non-closed areas is higher than the number-weighted average of the targets for the access and open areas

Some potential updates to the proposed A10 OFD:

(1) Growth estimates had been similar on Georges Bank and Mid-Atlantic, leading to similar target fishing mortality rates. New estimates of growth imply a higher fishing mortality threshold (0.36) in the Mid-Atlantic than on Georges Bank (0.24). For this reason, it may make sense to use separate target Fs in the two areas (rather than a spatially averaged 0.29), in both open and access areas.

Some potential updates to the proposed A10 OFD:

(2) Instead of setting the target to be 80% of the threshold, a higher percentage can be used when there are long-term closures (e.g., if 10% of all scallops were in EFH closures, the target in the open areas can be 90% of the threshold, rather than 80%). The target still probably needs to be set less than the threshold, but perhaps only 10% less if more than 10% are in closures.