#4

DRAFT
Overfishing Definitions and Control Rules for the Sea Scallop Fishery Under Rotation Management

prepared by

John M. Hoenig
Virginia Institute of Marine Science
P.O. Box 1346
Gloucester Point, VA 23062

And discussions within the Scallop Plan Development Team

9 May 2002

Proposed Definition for the Complex of Areas Under Area Rotation

For each of the three stocks currently recognized (Gulf of Maine, Georges Bank and Mid-Atlantic Bight) the proposed definition of overfishing will comprise two parts: 1) a biomass criterion that applies to the whole stock as described below, and 2) separate fishing mortality criteria for a) the complex of areas under area rotation, b) the areas under the ordinary management system, and c) areas subject to permanent or long-term closures.

1) The target biomass for an entire stock remains, as before, at B_{msy} proxy and is defined to be the conventional B_{max} per recruit multiplied by the average number of recruits per tow over the entire stock area surveyed by NMFS. (Scallops in the shallow water unsurveyed areas are not included). There is no specific target biomass for a) the complex of areas under rotation management (either singly or in aggregate), b) the areas under ordinary management, or c) areas under long-term closure. This is because the purpose of biomass targets and thresholds are to insure that reproductive capacity is not seriously reduced and, given the widespread dispersal of larval scallops, this only makes sense when biomass is considered on an appropriately large scale.

2) The biomass threshold, i.e., the stock biomass defining when a stock is overfished (thus triggering a formal rebuilding program to allow the stock to recover to B_{max}), is 25% of B_{target} (i.e., 25% of B_{msy} proxy).

3) The control rule for fishing mortality thresholds is as follows.

a) For each area under area rotation management: provided that stock-wide biomass exceeds 75% of B_{target}, the fishing mortality limit for each open area is that fishing mortality which, when averaged over the fishing mortalities that have occurred in the area since area rotation was declared (or over the past 10 years, whichever is a shorter period of time), will result in a time-averaged mortality equal to F_{max} where F_{max} is computed according to the existing method. (For areas under area rotation management that are scheduled to be closed to fishing, the fishing mortality limit is zero.) When biomass for the stock is between 0.25 B_{target} and 0.75 B_{target}, the limit for each area under area rotation is $F = (2B/B_{target} - .5) F_{limit}$ where F is the limit fishing mortality for the area, B is the stock biomass, and F_{limit} is the fishing mortality that would be the limit fishing mortality if the stock were above 0.75 B_{target}. This simply ramps the fishing mortality down linearly to zero as the stock biomass declines to 25% of B_{target}.

b) For the area under general management, provided that biomass exceeds 75% of B_{target}, the limit fishing mortality is F_{max}. When biomass for the stock is between 0.25 B_{target} and 0.75 B_{target}, the limit for the area is $F = (2B/B_{target} - .5) F_{max}$ where the symbols are as defined in (a) above.

c) For areas that are under long-term closure, the fishing mortality is (by definition) zero.

4) For determining compliance with the overfishing definition in areas under area rotation management, current fishing mortality averaged over all the areas is compared to an overall fishing mortality threshold determined as an average over all areas. That is, the determination of overfishing is made for the entire, aggregate area under rotation management rather than for each specific area separately. For the entire complex of areas under area rotation (within a stock), the threshold is the average of the fishing mortality limits in the rotation areas computed as a numbers-weighted average. Overfishing occurs if the number-weighted fishing mortality averaged over the rotation areas exceeds the threshold fishing mortality. Overfishing does not occur if the fishing mortality in a particular area under rotation management exceeds the limit fishing mortality for that area provided the average mortality over all areas under rotation management does not exceed the area-wide threshold. (However, if the mortality in an area under area rotation exceeds that area's limit, the limit for the next year will be reduced because the limit is an average of time-specific mortality rates.) For the area under general management, the fishing mortality in the area is compared to F_{max} for purposes of determining compliance.

6) The target fishing mortality in any area under area rotation can be any value not exceeding the area's limit fishing mortality, subject to the restriction that the numbers-weighted average of the target fishing mortalities does not exceed 90% of the threshold fishing mortality. Note that the managers have the flexibility to choose less than the maximum allowed fishing mortality rate. This might make sense if, upon reopening an area, there are a substantial number of small scallops. It might also make sense to choose a fishing mortality rate less than the maximum allowed if it is anticipated that few areas will be opened in the next few years so that the pool of scallops in the open areas must carry the fishery for a few years. That is, the desire for stability of yields may affect how the managers choose fishing mortality rates.

7) For the areas not under rotation management, the limit and target fishing mortalities remain as before, i.e., are calculated as if the areas under rotation management were a separate stock.

1. Introduction – Rationale for Area Rotation

Sea scallops are an essentially sedentary resource; consequently, the spatial distribution of the resource and the spatial pattern of exploitation can have important consequences for the dynamics of the population and the stability and yield of the fishery (Hart 2001). A uniform distribution of fishing effort over space would not have the same effects and results as, say, harvesting local concentrations of scallops and moving from location to location to maximize catch rates. Not only can the latter strategy be profitable to the industry but it can enhance the productivity of the stock and have conservation benefits, as will be discussed below. In this section, we define periodic rotation schemes and describe their benefits, discuss why spatially-averaged fishing mortality rates are inappropriate while time-averaged rates are appropriate, and then introduce adaptive rotation schemes. We conclude the section with a description of the contents of the rest of the document which define a possible definition of overfishing for sea scallops.

Periodic Rotation. As used here, a periodic rotation scheme involves defining a rotation period of $p = x + y$ years for an area, with the fishery being closed in the area for x consecutive years, then opened for y successive years, then closed for x years, etc.; the fishing mortality in the area averaged over any consecutive p years is F_{max}. (The average is a simple mean of p annual fishing mortality rates.) Thus, in a four year rotation period, if the fishery is closed for three years and open in the fourth, a fishing mortality of (approximately) $4F_{max}$ will maximize yield per recruit in the long term from that area (i.e, the simple arithmetic average of 0, 0, 0, and 4 F_{max} is F_{max}). This harvesting strategy is called a rotation because if there are p areas under a p-year rotation scheme then each year a different one of the p areas can be open.

It can be demonstrated mathematically that a periodic area rotation can achieve the following (Hart in review):

- increased yield per recruit over that achieved by a uniform distribution of fishing effort over space for any given level of fishing mortality
- protection of yield per recruit from errors in the assessment of the fishing mortality (i.e., yield per recruit drops off more slowly as F increases beyond F_{max} when a periodic rotation scheme is used instead of a uniform distribution of fishing effort)
- a higher level of spawning biomass for a given level of fishing effort.

We note that, if an area is closed for a long period of time, then the fishing mortality in that area can be extremely high when the area is reopened. This means that the recruited biomass can essentially be eliminated quite quickly in that area. This is appropriate because much of the biomass will be comprised of large, slow-growing animals which have little growth potential; elimination of this biomass would leave the pre-recruits which would then be protected by a new closure and allowed to grow.

Biomass Considerations. The above discussion is in terms of yield per recruit rather than total yield. If we imagine that we are dealing with the right side of a Beverton-Holt stock recruitment curve, then the spawning biomass is largely irrelevant and maximizing yield per recruit is an appropriate goal. Thus, a reasonable definition of overfishing based on yield per recruit in a rotational context must consider what fishing level is appropriate above and what is appropriate below a relevant spawning biomass reference point.

In the case of the sea scallop resource, there are areas closed to fishing for groundfish conservation. These are long-term closures. Similarly, there are shallow water areas, areas with unfishable bottom, and areas with low concentrations of scallops that are not fished and these areas, therefore, may serve to maintain the spawning biomass. These considerations go a long way towards assuring the spawning biomass will not dip below the level where recruitment is likely to be affected and thus make the yield per recruit criterion appropriate.

Spatially Averaged Fishing Mortality. A key feature of the area rotation scheme described above is a time-averaging of the fishing mortality. This is in contrast to the current practice of assuring that the fishing mortality in a year (when averaged over the entire population in space) does not exceed F_{max} (or whatever operational limitation is in effect). It turns out that spatially averaging the fishing mortality each year may not be optimal as the following example shows (see also Hart 2001). Consider the consequences of a situation where a large biomass is persistently distributed over a wide area at low density and a high biomass also occurs at high density in some smaller region. It may be the case that it is never profitable to fish for scallops in the low density zone. Under the spatially-averaged fishing mortality scheme, the permissible fishing mortality in the high-density zone can be persistently above the F_{max} level because, when averaged over the entire stock, the fishing mortality is below F_{max}. But the yield per recruit in the high density zone does not depend on the abundance of scallops elsewhere (by definition); therefore, adjusting the fishing mortality in the high density zone by the abundance elsewhere cannot achieve maximum yield per recruit. (The yield per recruit for the entire stock, as opposed to the part of the stock in the high-density zone, depends entirely on the high density zone because the yield from the low-density zone is zero; consequently, to achieve maximum yield per recruit in the high density zone the fishing mortality has to be F_{max} (or F_{max} on time-average) in the high density zone.) Hart (in review) also shows that spatially averaged fishing mortalities can have peculiar properties. For example, in the case where a portion of the stock area is permanently closed to fishing, an increase in the fishing mortality in the open area can result in a decrease in the overall fishing mortality calculated for the entire stock. This is because the increase in fishing mortality in the open area can reduce the abundance in the open area so that when the fishing mortality in the closed area (= 0) is averaged (on a numbers basis) with the high fishing mortality exerted on the small population in the open area the result is a low overall fishing mortality. In essence, the population in the open area can be so small that the weight given to the fishing mortality in the open area is small.

Thus, it can be concluded that use of a spatially averaged fishing mortality does not lead to maximum sustainable yield - on a per recruit basis – whereas use of time-averaged fishing mortalities in a rotational scheme can lead to a higher maximum yield per recruit over that achievable from a uniform fishing mortality over space.

Fixed Boundary Adaptive Area Rotation. The periodic rotation scheme described above is attractive because its properties can be studied analytically. But, the requirement for a fixed schedule of closures and openings, with openings rotating through the various areas, can be inconvenient and may not provide the largest yield per recruit. An adaptive rotation scheme is therefore likely to be preferred. Under such a scheme, the managers can decide to close an area for a period of time (the duration of the closure is up to the managers). Upon reopening the area, the managers can choose any fishing mortality so long as the time-averaged fishing mortality does not exceed F_{max}. In particular, it would be reasonable to close areas with many small scallops and open those with many large animals. A fixed schedule of openings and closings might require an area to be opened just as a pulse of recruitment of small animals occurs which obviously would not maximize the yield per recruit. Unpublished simulations by Hart indicate that adaptive rotation can work even better than the periodic rotation scheme in terms of increasing yield and spawning biomass. It might be asked what schedule of fishing mortalities over time will provide the global maximum yield from an area. The precise answer is not known but simulations suggest that a time-averaged fishing mortality of approximately F_{max} will provide close to the maximum. Thus, it appears there is room for flexibility in the managers' decision making. A departure from the global maximum yield in order to, say, promote stability in days at sea would be acceptable under the law provided the biomass is on the high side of B_{msy} rather than on the low side; this is likely to be met for sea scallops because of the biomass refuges described above.

Outline of Material Presented. In Section 2 of this document, we describe some examples of rotation schemes to make the general features of such a system clear. In Section 3 we discuss issues associated with the specification of a definition of overfishing and control rules. These include a) legal issues associated with time-averaging and the need to manage for maximum sustainable yield, b) the appropriateness of aggregating areas for the purposes of assessing compliance, and c) appropriate windows of time and methods for calculating time-averaged mortality rates. In Section 4, we specify a possible definition and control rule. Section 5 provides a discussion of the options.

2. Examples of Rotation Schemes

Under the rotation scheme adopted by the PDT, a clock starts ticking when an area is closed to fishing and designated as a rotational management area. In every subsequent year (up to a maximum of 10 years), the time-averaged fishing mortality must be less than or equal to F_{max}. At any point, the managers can end the special status of the area and the area is then subject to the normal limit to fishing mortality, F_{max}. The examples below should make this clear.

Closed three years followed by the maximum pulse fishing. We consider first the simple case where an area is closed for three areas and then opened for one year. In that fourth year, a fishing mortality up to 4 F_{max} can be adopted. If 4 F_{max} is chosen, the average over the four years will be $(0+0+0+4\ F_{max})/4 = F_{max}$. In the fifth year, all the "credit" for having closed the fishery has been spent so the maximum fishing mortality allowed is the usual limit, F_{max} $((0 + 0 + 0 + 4\ F_{max} + F_{max})/5 = F_{max})$. In each subsequent year, the limit is F_{max} so the managers might as well end the special status of the area. If the area is closed again, the clock is reset to zero.

Closed three years followed by a prolonged pulse of fishing. Suppose the fishery is closed for three years and, upon reopening the fishery, the managers decide to set $F = 2\ F_{max}$. Then, after the fourth year the time-averaged F will be $(0+0+0+2\ F_{max})/4 = ½\ F_{max}$, which is acceptable. Now, in year 5, the maximum F that can be accepted is the solution to $(0+0+0+2\ F_{max} + F)/5 = F_{max}$; clearly, F can't exceed 3 F_{max}. If 3 F_{max} is chosen, then in year 6 the fishing mortality cannot exceed F_{max} so that $(0+0+0+2\ F_{max} +3\ F_{max} + F_{max})/6 = F_{max}$. If, however, 2 F_{max} is chosen for year 5, then in year 6 F can be as high as 2 F_{max}.

Rationale for a fixed time horizon. In the above schemes, the managers first gain "credit" for a closure; then they are able to "spend" that credit on higher fishing mortalities. They are not allowed to spend that credit first and then "pay" for the higher fishing mortalities with future closures. The amount of credit obtained from a closure depends on the time horizon. Obviously, if fishing mortality were time-averaged over the last 10,000 years then virtually unlimited fishing mortality would be acceptable for decades. This is unreasonable, of course, because the scallops present long ago contribute nothing to the current population. Therefore, the time window has to reflect the lifespan of the organism. It appears reasonable for a long-lived species like sea scallops to use a 10-year window. However, it is also necessary to consider the initial conditions. Therefore, the fishing mortality should be averaged over the number of years since the area was designated for rotational management, up to a maximum of 10 years.

3. Issues Associated with Defining Overfishing and Specifying Control Rules

a) *legal issues associated with time-averaging and the need to manage for maximum sustainable yield.* The existing law and guidelines do not deal explicitly with the concept of time averaging of fishing mortality. They do, however, specify that the goal is maximum sustainable yield with fishing mortality modified downward by any relevant social, economic, etc. considerations. Areal rotations can result in a higher value of msy than that calculated by traditional means (which assume uniform risk of dying from fishing over all members of a given age class). Thus, it can be argued that areal rotation (with time-averaged fishing mortality criteria) is consistent with the law.

A minor technicality is that it is not clear at this point in time exactly what areal rotation scheme will produce the global maximum sustained yield. But, strictly speaking, it would be hard to find any stocks that are managed for a global maximum sustainable yield. This is because the value of msy under current management paradigms depends on the pattern of exploitation with age but for purposes of computing msy the exploitation pattern is held constant or just a few possible exploitation patterns are considered. Thus, it would be unreasonable to hold a proposed areal rotation scheme to a technical standard that is not met by current management schemes. It would be absurd to argue that an areal rotation scheme that produces higher yield than the current management scheme cannot be used simply because the areal scheme does not produce the highest possible yield.

In addition, there may be some precedent for having temporary fishing mortalities above F_{msy}. The original guidelines referred to the possibility that fishing mortality might exceed F_{msy} in a new fishery where biomass was considerably above the B_{msy} level. The technical analyses conducted by Hart now give support to this idea.

b) *appropriate windows of time and methods for calculating time-averaged mortality rates.* The optimum window of time over which to average fishing mortality rates is not entirely clear at present. However, this is not likely to be a serious impediment to operations. The idea behind the adaptive rotation scheme is to close areas to allow scallops to grow – this may be on the order of five years – and then to fish the opened areas hard. How hard a reopened area will be fished depends on how long the managers want to make the pool last. If there are other areas waiting to be reopened then the managers can let the pool in the reopened area be largely depleted within a year (assuming the area has been closed long enough to justify a high fishing mortality); if, on the other hand, the area needs to supply the industry for two or more years then the managers can and likely will set the fishing mortality lower than the maximum to promote stability of yields. The time averaging clock starts when an area is declared an areal rotation unit and closed to fishing. The entire cycle of closure and open is likely to take less than 10 years so the 10 year limit to the window will rarely come into play. The limit is nonetheless part of the management scheme in case an area has been closed for a very long time and is then opened.

Note that every time an area is closed to fishing and declared to be under area rotation the clock is reset.

A simple average of mortality rates over time was evaluated in simulations by Hart and found to provide higher yields relative to non-rotational management. It is possible that a weighted average of the fishing mortalities over time could provide better results (in terms of, say, yield or stability); however, no information is available on the properties of alternative averaging schemes.

c) *the appropriateness of aggregating areas for the purposes of assessing fishing mortality compliance*. The Magnuson-Stevens Act requires (or is being generally interpreted as requiring) that fishing mortality not exceed F_{MSY} in any fishery. In order to monitor the fulfilment of that requirement, NMFS prepares an annual report to Congress detailing which fisheries currently meet this requirement and which are experiencing "overfishing". Meanwhile, most alternatives currently before the Council for potential implementation in Amendment 10 would result in much of the scallop fishery remaining under unitary management, such that the fleet will be free to direct most of its effort anywhere across a broad "open" area (even when certain parts of the grounds have special controls). In order to best match such a fishery to the legislated reporting requirement, while obtaining the yield advantages of area-based management, a single fishery-wide mortality threshold could be set annually as a weighted average of area-specific limit mortalities (F_{limit}) for each area within the fishery that is open to scalloping in that year. Essentially, if one or two areas having fishing mortalities slightly in excess of the limit fishing mortality and the rest have mortalities below the respective limits, it would not make sense to declare overfishing is occurring; in order to avoid any areas from being declared to have overfishing, one would have to set all the targests very conservatively. Therefore, the proposed definition of overfishing involves setting targets and thresholds for each area but determines compliance with the Sustainable Fisheries Act by looking at an overall (averaged) fishing mortality. Because area rotation management is new, it makes sense to make two determinations per stock – one for whether overfishing is occurring in areas under rotation management and one for areas under general (traditional) fishing.

Thus, assessing specific areas separately by monitoring area-specific fishing mortality rates would require area-specific abundance estimates; these would be imprecise if the current survey design were continued. It would also be necessary to prepare, present and evaluate multiple assessments of what might be considered subcomponents of a single fishery resource. The more areas that are assessed the greater the chances that at least one area will be found to have excessive fishing mortality because of random sampling error. It would not be reasonable to react to an estimated high fishing mortality on a portion of the stock when the stock as a whole is being managed appropriately. It does not make sense to penalize the fishery with ultraconservative regulations just because the managers try to increase yield and stability by defining more subareas; insisting that measured fishing mortality must be at or below the threshold in each subarea would do exactly that.

In discussions about the method of determining compliance, there was confusion about the role of areas closed to fishing. It does not matter whether the areas under rotation management that are currently closed to fishing are included in the determination of overfishing. For example, suppose that there are 5 areas under area rotation management, two of which are currently closed, and suppose that the number of scallops is the same in each area and the limit fishing mortalities are 0.0, 0.0, 0.2, 0.4, and 0.4. Then, if we include the closed areas the overall fishing mortality for determining overfishing is (0 + 0 + 0.2 + 0.4 + 0.4)/5 = 0.2. If the measured fishing mortalities during the year were 0, 0, 0.3, 0.4, and 0.3 then the average is 0.2 and overfishing is not occurring. On the other hand, suppose we disregard the two closed areas. Then the overall fishing mortality for determining overfishing is (0.2 + 0.4 + 0.4)/3 = 0.333. The average of the measured fishing mortalities in those areas is 0.333 so we reach the same conclusion – overfishing is not occurring. In other words, by including the closed areas we lower the average fishing mortality that occurred but we also lower the permissible limit so there is no change in the conclusions.

For areas under area rotation, it may seem inconsistent to reject spatial averaging for the purposes of setting targets and then use spatial averaging for the purposes of assessing compliance. However, this is a false issue precisely because the objectives are different for the two exercises. The former aims to set appropriate limits based on production considerations and thus requires time averaging. The latter aims to evaluate at a particular point in time whether the overall objectives have been met. However, in terms of setting the following year's limits to fishing mortality, the history of the fishery in each area is considered separately so that the time-averaged fishing mortality limit for *each* area is set to the appropriate value. Hence, for each area under area rotation, if the fishing mortality for the current year exceeds the target, the limit to the fishing mortality for the subsequent year is reduced.

d) *Method of averaging over space*. There are two choices for averaging the fishing mortality over the areas under rotation management for assessing compliance: averaging with weights proportional to the biomass in the areas or averaging with weights proportional to the numerical abundances. At present, there are no analytical results or simulation studies to shed light on issue. We note that fishing mortality rates are generally defined, and estimated, in terms of numbers (e.g., in the equation describing the decay over a cohort over time and in the yield per recruit formulations F is used to describe changes in numbers.) It therefore seems advisable for now to adopt a numbers-weighted approach. An intuitive explanation for this is as follows. In an area with large scallops one would want a high fishing mortality rate because these scallops are not growing quickly and one might as well harvest them; the consequence of a fishing mortality above that intended would be a more rapid depletion of this pool of scallops but not necessarily a significant reduction in yield. In contrast, in an area with small scallops, the goal is to have lower mortality so that some of the scallops can grow larger; the consequences of a fishing mortality higher than intended would be not only a more rapid depletion but also a reduction in the yield per recruit from that pool of scallops. Thus, it would appear that from a yield per recruit perspective, it would be worse to have higher than intended fishing mortality on small scallops than on large scallops. However, averaging with weights proportional to biomass might treat high fishing mortality in the areas with large scallops as more important. We emphasize that the method of calculation could be modified if more definitive results are obtained.

4. Definition and Control Rule

For each of the two stocks currently recognized (Georges Bank and Mid-Atlantic Bight) the proposed definition of overfishing will comprise two parts: a biomass criterion that applies to the whole stock as described below, and separate fishing mortality criteria for the complex of areas under area rotation and for the areas under the ordinary management system.

a) ***Target biomass***. The target biomass, defined as a B_{MSY} proxy, is of primary importance as a step towards setting the biomass threshold. The latter is the ultimate decision point preventing long-term damage to the resource through excess fishing. As such, it should be defined relative to resource units rather than management ones and hence the same is true of the target biomass. Thus:

There will be a single defined target biomass, set as a B_{MSY} proxy, for each of the recognized "stocks" of sea scallops, *viz.* Georges Bank, Mid-Atlantic Bight. Due to the lack of regular survey data, the Gulf of Maine "stock" will not be considered when setting the target biomass nor when comparing existing biomasses to the target level. Areas of low scallop density within other "stock" areas that are not included in the regular NMFS scallop survey will likewise be excluded from consideration.

To facilitate monitoring of scallop biomass relative to the target, the present system will be maintained and the biomass target will be defined in terms of an average catch per standard tow in the NMFS scallop survey.

The B_{MSY} proxy will be set as an estimate of conventional B_{MAX} per recruit multiplied by the average number of recruits in a standard survey tow over the entire stock area surveyed by NMFS.

There is no specific target biomass for the areas under rotation management (either singly or in aggregate). This is because the purpose of biomass targets and thresholds are to insure that reproductive capacity is not seriously reduced and, given the widespread dispersal of larval scallops, this only makes sense when biomass is considered on an appropriately large scale.

b) Biomass Threshold. The biomass threshold is 25% of B_{target} (i.e., 25% of B_{msy} proxy). Thus, fishing mortality in the entire stock area should be as close to zero as possible if the biomass falls below $B_{threshold}$.

c) Mortality Threshold and Target at High Biomass

Area-Specific Mortality Limits

Application of rotation management requires the definition of an area-specific fishing mortality limit (F_{limit}) for each of the J areas included in the calculations. When the biomass in the stock area is greater than 0.75 x B_{target}, F_{limit} for the jth area in the nth year after rotation management begins (n <11) will be defined as:

$$F_{limit\ jn} = 0, \text{ if the area is closed to fishing}$$

$$F_{limit\ jn} = K_{jn}\ F_{MAX}, \text{ otherwise}$$

where F_{MAX} is calculated conventionally and K_{jn} is defined as

$$K_{jn} = n - \sum_{t=1}^{t=n-1} (F_{jt} / F_{MAX})$$

where F_{jt} is the realized fishing mortality in area j in year t, and t = 1 refers to the year in which rotation management begins (thus $F_{jt} = 0$); if area rotation began 10 or more years ago, then only the previous 9 fishing mortalities are used in the summation (n is set equal to 10).

Closing areas for area rotation reduces the overall DAS allocation by the amount of scallop grounds taken out of the fishery; this is offset by the higher fishing mortalities allowed when areas are reopened. Managers will presumably want to consider various scenarios for closings and openings in terms of stability of yield and days at sea.

Note that F_{MAX} is calculated conventionally and applied in the above equation, even though the F generating maximum yield per recruit is somewhat higher under a rotation scheme than in a scheme with uniform fishing intensity over space. That is: ${}^{AVG}F_{MAX}$ (i.e. F_{MAX} calculated as an average over time) under rotation is greater than F_{MAX} in the absence of rotation. Yet the degree of difference cannot be calculated using conventional models for adaptive rotation systems. This is one area where improvements in modelling could lead to improved knowledge of F_{max}.

Mortality Threshold for the Complex of Areas Under Rotation

The Magnuson-Stevens Act requires (or is being generally interpreted as requiring) that fishing mortality not exceed F_{MSY} in any fishery. In order to monitor the fulfilment of that requirement, NMFS prepares an annual report to Congress detailing which fisheries currently meet this requirement and which are experiencing "overfishing". Meanwhile, most alternatives currently before the Council for potential implementation in Amendment 10 would result in much of the scallop fishery remaining under unitary management, such that the fleet will be free to direct most of its effort anywhere across a broad "open" area (even when certain parts of the grounds have special controls). In order to best match such a fishery to the legislated reporting requirement, while obtaining the yield advantages of area-based management, there will be a single mortality threshold for the complex of areas under rotation management, set annually as a numbers-weighted average of area-specific limit mortalities (F_{limit}) for each area under area rotation management.

Areas under area rotation that are closed to scalloping in the particular year will be included in the calculation of the fishing mortality threshold.

When the biomass is high, the weighted average of J area-specific limit mortalities will be calculated as:

$$F_{threshold} = \sum_j N_j F_{limit\,j} / \sum_j N_j$$

where N_j is the number of exploitable scallops in area j.

One weakness with this approach is that it means that $F_{threshold}$ will change, in numerical value, from year to year as various areas are opened and closed to scalloping (if such areas have different area-specific but time-independent "general" mortality limits), as freshly re-opened areas progress through any post-closure time-specific variations in mortality limit (if such variations are used), and as the relative biomasses or abundances change in areas open to fishing that have different mortality limits.

Area-Specific Mortality Targets

The target fishing mortality in any area under area rotation can be as high as the limit fishing mortality for that area, providing the numbers-weighted average of the target fishing mortalities (averaged over all areas under area rotation) does not exceed 90% of the mortality threshold for the complex under area rotation management. The rationale for this is as follows. A fishing mortality target is a declaration of intention. The fishing mortality that is actually realized may be somewhat higher or lower than that intended. The fishing mortality threshold is a value that should not be exceeded. Therefore, if the target is set too close to the threshold, there will be an appreciable chance of exceeding a value that shouldn't be exceeded. One could argue that the threshold and target should pertain to the entire population and not be computed separately for areas under and for areas not under area rotation. However, because area rotation is new, it is reasonable to evaluate how well it works, which suggests that the target and threshold for area rotation areas should be computed separately from those computed for areas not under area management. Note that, as this pertains to the case where biomass is high, a value of 90% seems reasonable because the stock is not at threat.

Examples. Suppose there are three areas under area rotation, and the abundance is the same in all areas. Suppose further the limit fishing mortality for each area is .30. Then, the target fishing mortality for the complex of three areas cannot exceed .9 x .3 = .27. Thus, any area can have a target fishing mortality of .3 (because that is the limit) but they can't all have .3 (because that would bring the average above .27). Some possibilities are:

Area	limit F	target	target	target
A	.30	.27	.30	.27
B	.30	.27	.30	.30
C	.30	.27	.21	.24
Avg.	.30	.27	.27	.27

In all cases, the numbers-weighted fishing mortalities do not exceed the target for the complex of .27.

d) Mortality Threshold and Targets at Low Biomass

The limits to fishing mortality described in this document have been predicated on the assumption that spawning biomass is high enough that recruitment is not sensitive to stock size, i.e., that we are operating at the right-hand side of a Beverton and Holt stock recruitment curve. If biomass falls below a threshold, then it will be necessary to limit the fishing mortality according to the current level of biomass. The recommended procedure is:

When biomass for the stock is between .25 B_{target} and .75 B_{target}, the limit for each area under area rotation is $F = (2B/B_{target} - .5)\ F_{limit}$ where F is the limit fishing mortality for the area, B is the stock biomass, and F_{limit} is the fishing mortality that would be the limit fishing mortality if the stock were above .75 B_{target}. This simply ramps the fishing mortality down linearly as the stock biomass declines. When stock is below 0.25 x B_{target}, the fishing mortality is set as close to zero as possible.

The 25% B_{target} criterion is consistent with what has been adopted for the stock in the past but somewhat lower than what is advised in the National Standards Guidelines. However, there may be significant portions of the stock in refuges that are not surveyed by NMFS (e.g., in shallow waters) so the 25% value may be more conservative than it appears.

The target fishing mortalities are constrained to have numbers-weighted average equal to 90% of the threshold fishing mortality. Because the stock is below Btarget, it might seem that the value of 90% should be reduced. However, because there are some scallop refuges not surveyed by the NMFS survey (e.g., shallow water areas), it might be argued that the 90% value affords adequate protection to the stocks reproductive capacity and the real issue is whether a target of 90% of $F_{threshold}$ will create management problems by causing frequent declarations that the stock is overfished.

5. Discussion

The PDT accepted that area rotation, including adaptive area rotation, is a scientifically valid approach to management that can accomplish the intent of the Magnusson Act, to wit, to ensure close to maximum sustainable yield is achieved while affording the stock protection from too low a biomass or too high a fishing mortality. There are numerous issues about the optimum implementation of such a scheme that cannot be resolved at this time for lack of knowledge of the properties of area management programs. Nonetheless, it is clear that area rotation can be made viable now and lack of evaluation of various options should not prevent its use. By the same token, our knowledge of area rotation systems is likely to advance quickly and it would be a pity if the definition of overfishing were constructed so rigidly that future methodological improvements could not be incorporated into the management of the resource.

Below, we describe some of the options that were suggested during development of this plan. These options were rejected merely because there wasn't enough evaluation to adopt them or they were suggested too late in the process to be discussed.

Closing areas instead of reducing fishing mortality when biomass is too low. If biomass goes below $0.75B_{max}$, the proposed control rule indicates that fishing mortality must be reduced in open areas. Another possibility would be to close more areas, which is consistent with the existing definition of overfishing. Time precluded discussing how this should be done and this is an area where modifications might be made to the proposed plan.

Adjusting limits to fishing mortality according to mean weight of the scallops. The idea here was that the larger the scallops in a reopened area the slower growing the pool would be. Thus, fishing mortality should depend on the mean weight present. This idea is partly inherent in the scheme proposed here: the longer an area has been closed the larger the scallops are likely to be and the higher the permitted fishing mortality. However, it is possible that a large year class appears towards the end of a closed period and thus there might be many small scallops when the area is opened and these could profitably be protected. Two approaches were discussed. The first simply modified F_{max} by the ratio of mean weight to maximum yield per recruit. The second modified the F_{limit} calculated by the method proposed in this document by a factor depending on the mean weight in the area. The PDT simply did not have any way to evaluate the performance of a body weight-adjusted fishing mortality limit. It is not yet clear whether these alternatives, or some modification of them, would lead to an "MSY Control Rule" in the sense meant by the National Standards Guidelines, which is to say a control rule that, if applied, would lead to the harvest of MSY. The Guidelines require that the threshold mortality rates follow such an MSY Control Rule. This alternative would also lead to some values of F_{limit} that far exceeded anything that could be called "F_{MSY}", potentially causing the threshold mortality rate to be set so high as to violate the Magnuson-Stevens Act. The behaviour of this alternative therefore needs to be explored by simulation modelling to ensure that these potential defects are not severe enough to prevent the use of this approach.

Defintions of $F_{threshold}$. Two possible approaches proposed were:

$F_{threshold}$ will be equal to F_{limit} when the biomass is equal to or greater than the target biomass. As biomass falls below the target biomass, $F_{threshold}$ will decrease linearly until it approaches zero as biomass approaches 25% of the target level. At still lower biomass levels, $F_{threshold}$ will be as close to zero as is practicable.

$F_{threshold}$ will be equal to F_{limit} when the biomass is equal to or greater than 75% of target biomass. As biomass falls below that level, $F_{threshold}$ will decrease linearly until it approaches zero as biomass approaches zero.

The relative merits of these alternatives have not been discussed by the PDT. The first follows the principles used in the 1998 overfishing definitions for the Northeast Region. The second approximates to the default recommendations of the NMFS Technical Guidance document concerning the design of control rules under the National Standards Guidelines. It differs from those in setting the break point at 75% of target biomass, rather than at (1-M) (i.e. 90%) times that biomass. The intent of the offset is to allow biomass to fluctuate around the target level in response to natural inter-annual variability without requiring management action to adjust the mortality rate. A finfish with M=0.1 would have a high life expectancy, a large accumulated biomass of older animals, and so limited natural fluctuations in biomass when under optimum management. It has been argued, however, that scallops are opportunistic animals which respond to a changing environment through major variations in abundance. As such, it would be sensible to allow more scope for fluctuation without requiring reduced DAS allocations.

Biomass Threshold. At least four alternatives were suggested:

$B_{threshold}$ will be set at 25% of B_{target};

$B_{threshold}$ will be set at 50% of B_{target}

$B_{threshold}$ will be set at 75% of B_{target}

$B_{threshold}$ will be set at that level from which modelled biomass could increase to B_{target} in ten years while the resource is subject to the $F_{threshold}$ applying to the biomass present in a given year

The relative merits of these alternatives have not been discussed by the PDT. The first follows the principles used in the 1998 overfishing definitions for the Northeast Region but would be a direct violation of the National Standards Guidelines requiring special justification. It is consistent with the first option for adjusting fishing mortality for low biomass.

The fourth is a direct application of the National Standards Guidelines. However, it was suggested that unless the mortality threshold at high biomass is set below F_{MSY}, it is likely to result in a biomass threshold close to the biomass target and hence to "overfished" designations being triggered by natural inter-annual fluctuations, which would be directly contrary to the expressed intent of the Guidelines

The second and third are partially (though not fully) consistent with the letter of the National Standards Guidelines and might be reasonable implementations of their intent where the particular dynamics of sea scallops are concerned.

Summary of Amendment 10 Overfishing Definition Options Considered by the Scallop PDT

PDT reviewed the present overfishing definition and determined that it is clear that the definition is inconsistent with area based management, whether or not it includes area rotation. The present overfishing definition allows for excessive localized overfishing in open fishing areas. This localized overfishing prevents the plan from meeting its maximum yield objectives, whether the closed areas are permanent (i.e. HAPC) or temporary (area rotation). In addition, area rotation introduces variations in fishing effort that need to be taken into account to maximize yield when closed areas re-open to fishing. The three options considered by the Scallop PDT take different approaches on this point. In all cases, the annual day-at-sea allocations would depend on the combined product of the number of open fishing areas, the annual fishing mortality threshold within each area, the expected average catch per day-at-sea (constrained by crew limits), the number of active fishing vessels, and either the general category TAC or the expected landings by vessels fishing under general category rules.

Although the application of the current overfishing definition has problems (i.e. including unexploitable biomass in permanently closed areas to allow overfishing in open areas; the inflexibility to allow fishing mortality to temporarily exceed Fmax after rotational closures), none of the options for revising the overfishing definition suggest that F_{max} and B_{max}, the current proxies for F_{msy} and B_{msy} respectively, are inappropriate. In addition, the current estimate of F_{max} (F=0.24) and a target F (F=0.2) are also deemed acceptable. The options for redefining overfishing do not suggest that the current B_{max} as a target and proxy for B_{msy} are inappropriate for the scallop stocks as currently defined.

The PDT reviewed all three options presented to it and agreed to recommend proposal one as the most appropriate approach to defining overfishing in a way that is consistent with area based management. A draft report containing this recommendation is under development and we will circulate this report to the PDT for review and comment, before making it available to the Council and others.

During the discussion, the PDT agreed to use the following six principles to judge the suitability for any overfishing definition developed to be compatible with area based management or rotation:

1. Overfishing definitions <u>must</u> be based on <u>current</u> fishing mortality, not past events (i.e. mistakes).
2. Area specific TACs can take into account past mortality history (i.e. closures).
3. The reference points and TACs cannot take 'credit' for future, planned management that may not be guaranteed.

Summary of Amendment 10 Overfishing Definition Options Considered by the Scallop PDT

PDT reviewed the present overfishing definition and determined that it is clear that the definition is inconsistent with area based management, whether or not it includes area rotation. The present overfishing definition allows for excessive localized overfishing in open fishing areas. This localized overfishing prevents the plan from meeting its maximum yield objectives, whether the closed areas are permanent (i.e. HAPC) or temporary (area rotation). In addition, area rotation introduces variations in fishing effort that need to be taken into account to maximize yield when closed areas re-open to fishing. The three options considered by the Scallop PDT take different approaches on this point. In all cases, the annual day-at-sea allocations would depend on the combined product of the number of open fishing areas, the annual fishing mortality threshold within each area, the expected average catch per day-at-sea (constrained by crew limits), the number of active fishing vessels, and either the general category TAC or the expected landings by vessels fishing under general category rules.

Although the application of the current overfishing definition has problems (i.e. including unexploitable biomass in permanently closed areas to allow overfishing in open areas; the inflexibility to allow fishing mortality to temporarily exceed Fmax after rotational closures), none of the options for revising the overfishing definition suggest that F_{max} and B_{max}, the current proxies for F_{msy} and B_{msy} respectively, are inappropriate. In addition, the current estimate of F_{max} ($F=0.24$) and a target F ($F=0.2$) are also deemed acceptable. The options for redefining overfishing do not suggest that the current B_{max} as a target and proxy for B_{msy} are inappropriate for the scallop stocks as currently defined.

The PDT reviewed all three options presented to it and agreed to recommend proposal one as the most appropriate approach to defining overfishing in a way that is consistent with area based management. A draft report containing this recommendation is under development and we will circulate this report to the PDT for review and comment, before making it available to the Council and others.

During the discussion, the PDT agreed to use the following six principles to judge the suitability for any overfishing definition developed to be compatible with area based management or rotation:

1. Overfishing definitions <u>must</u> be based on <u>current</u> fishing mortality, not past events (i.e. mistakes).

2. Area specific TACs can take into account past mortality history (i.e. closures).

3. The reference points and TACs cannot take 'credit' for future, planned management that may not be guaranteed.

Table 2. Example of time-averaged fishing mortality overfishing definition with a two-year closure, followed by a three-year period of re-opened management status.

Year	Year N	1	2	3	4	5	6	7 - N	1	All
Status	Open	Closed	Closed	Closed	Re-opened	Re-opened	Re-opened	Open	Closed	Average
No rotation	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Simple rotation	0.20	0.00	0.00	0.30	0.30	0.30	0.30	0.20	0.0	0.20
Ramped rotation	0.20	0.00	0.00	0.21	0.27	0.33	0.39	0.20	0.0	0.20

2. **Size mitigated fishing mortality targets**
   A method to determine area-specific fishing mortality thresholds based on current scallop size frequencies

Like the time-averaged mortality threshold in Proposal 1, this method allows for area-specific fishing mortality targets that are higher than the stock-wide target. On the other hand, the annual mortality target for an area would depend on the size of scallops, compared to the average size of scallops when fished constantly at F_{max}. Larger scallops in a re-opened fishing area would mean that the annual mortality target for that area would be greater than F_{max} and vice versa. The annual target would be determined from the ratio of the average size of exploitable scallops in an area to the average size of exploitable scallops when fished constantly at F_{max}. Overfishing in this case would be determined from a biomass-weighted average of open fishing areas.

Thus, the mortality target in an area would depend not on the length of time in which the area was closed or the actual past fishing mortality history, but on the size of scallops occurring there when re-opened and in each year the area remains open. If high recruitment occurs in an area during its closure, this method would reduce mortality and protect the smaller scallop, even though the area might have been closed for a long period. Conversely, an area that closes late (i.e. the scallops are intermediate size, rather than small when the closure occurs) and recruitment is low, this method would allow a higher annual fishing mortality target even if the closure duration is short.

3. **Synthetic F_{max}**
   A method to determine resource-wide fishing mortality thresholds through projections of future fishing mortality and area rotation policy

A third alternative would modify the F_{max} threshold based on the amount of closed areas and the size of scallops in the resource. Thus, the synthetic F_{max} (the fishing mortality threshold) would vary from year to year and the fishing mortality target would be a fraction (80%?) of the synthetic F_{max} value.

In some ways, this is similar to Proposal 2 above, but the change in F_{max} is calculated by a dynamic yield per recruit model or simulation, rather than a ratio of size method. On the other hand, it is conceptually a little different from Proposal 2 in that the long-term threshold F is undefined and allows for specification of an annual synthetic F_{max} for the entire resource instead of an area-specific fishing mortality threshold as proposed under proposals 1 and 2.

It also requires a iterative simulation to determine the synthetic F_{max} value that maximizes future yield based on the current size structure, assumed recruitment, size selectivity of the current and future fishery, and future fishing mortality and area management policy. The projected synthetic F_{max} could be a single value through time (which may vary in the future) or a time-stream of fishing mortality rates that vary through time to maximize yield. Although not part of the original proposal, this could be taken one step further by calculating net benefits and discounting for time, or F_{npv}.

Table 1. Current scallop status and long-term potential yield for fixed boundary area rotation options and time-averaged fishing mortality (F=0.2) by area. Shaded blocks indicate areas where the current conditions exceed the long-term conditions when fished at the fishing mortality target.

Stock	Rotation area	Realized F with 26,000 day-at-sea use	Total area (nm²)	Scallop survey stratum approximate area (nm²)	2000 biomass (mt)	2001 yield (mt) @ F=0.2	Expected average biomass @ F=0.20	Potential long-term yield (mt) @ Bmax	Percent of total long-term potential yield	Productivity (mt/nm²)	DAS @ long-term potential yield	Percent of total effort	Landings per day-at-sea used	Average meat count	Area swept
GB	9 (CL-1 FW13)	0.20	357	384	6433	990	4866	490	2.0%	1.28	471	2.1%	2285	15.4	91
GB	10+11 (CL-1)	0.20	793	287	14983	2148	19569	1475	6.1%	5.14	1250	5.5%	2601	15.6	68
GB	14 (CL-2 FW13)	0.20	1124	994	43315	7560	17598	4590	18.8%	4.62	3870	17.0%	2615	15.5	237
GB	15 (CL-2 N)	0.20	673	862	4496	655	4372	990	4.1%	1.15	966	4.2%	2259	15.6	205
GB	12 (NLS FW13)	0.20	330	123	3732	621	10835	345	1.4%	2.79	298	1.3%	2553	15.5	29
GB	13 (NLS)	0.20	1488	704	3889	565	2819	521	2.1%	0.74	597	2.6%	1923	15.4	168
GB	*CLOSED*	*0.20*	*4966*	*3354*	*76848*	*12383*	*9551*	*8410*	34.5%	*2.51*	*7451*	32.7%	*2488*		
GB	8	0.20	749	138	245	36	2136	77	0.3%	0.56	102	0.4%	1670	15.5	32
GB	7	0.20	601	710	1147	159	4768	888	3.6%	1.25	653	3.7%	2295	15.5	169
GB	6	0.20	849	567	2262	372	3643	561	2.3%	0.98	577	2.5%	2145	15.6	139
GB	5	0.20	1701	1198	3079	467	1479	465	1.9%	0.39	775	3.4%	1322	15.6	265
GB	4	0.20	905	461	2188	336	2566	324	1.3%	0.67	382	1.7%	1667	15.6	114
GB	3	0.20	504	255	2768	441	5793	388	1.6%	1.52	357	1.6%	2395	15.6	60
GB	2	0.20	459	404	6871	1576	33908	3595	14.8%	8.90	3028	13.3%	2619	15.6	96
GB	1	0.20	487	115	110	17	4216	127	0.5%	1.10	129	0.6%	2188	15.3	27
GB	*OPEN*	*0.20*	*6494*	*3886*	*20668*	*7560*	*6297*	*6424*	*26.4%*	*1.65*	*6201*	*27.2%*	*2284*		
GB	TOTAL	0.20	11400	7240	96446	15790	7806	14834	60.9%	2.05	13653	59.8%	2395	15.4	1726
MA	9	0.20	1830	1182	784	141	2161	479	2.0%	0.41	678	3.0%	1561	16.0	228
MA	8	0.20	2465	2677	5964	1039	3581	1798	7.4%	0.67	1958	8.6%	2026	16.0	517
MA	7	0.20	2697	1431	5142	950	6833	1833	7.5%	1.28	1697	7.4%	2382	16.0	276
MA	6	0.20	2056	746	5928	1107	9589	1341	5.5%	1.80	1185	5.2%	2474	16.0	144
MA	5	0.20	2124	1036	15594	2867	9424	1631	7.5%	1.77	1634	7.2%	2471	16.0	200
MA	4	0.20	1859	530	2453	421	8393	834	3.4%	1.57	753	3.3%	2443	16.0	102
MA	3	0.20	1433	457	3104	567	6476	726	3.0%	1.59	654	2.9%	2447	16.0	88
MA	2	0.20	668	173	489	80	13166	428	1.8%	2.47	373	1.6%	2530	15.9	33
MA	1	0.20	500	130	220	36	10633	259	1.1%	1.89	229	1.0%	2486	15.9	25
MA	*TOTAL*	*0.20*	*16133*	*8363*	*39638*	*7213*	6075	*9529*	39.1%	*1.14*	*9166*	40.2%	*2292*	*16.0*	*1617*
ALL	***TOTAL***	***0.20***	***27533***	***15603***	***136082***	***23003***		***24363***	100.0%	***1.58***	***22818***	***100.0***	***2354***		

Non-surveyed areas

	Mean Landings (MT)	Compared to status quo:
Gulf of Maine[1]	472	
S. New England[2]	64	

[1] High percentage in state waters within three miles of shore
[2] West of NLS area

Table 2. Current scallop status and long-term potential yield for fixed boundary area rotation options and current day-at-sea use. Shaded blocks indicate areas where the current conditions exceed the long-term conditions when fished at the fishing mortality target.

Stock	Rotation area	Realized F with 26,000 day-at-sea use	Total area (nm²)	Scallop survey stratum approximate area (nm²)	2000 biomass (mt)	2001 yield (mt) @ F=0.2	Expected average biomass (g/tow) @ F=0.13 with long-term area closures	Potential long-term yield (mt) @ F=0.13 with long-term area closures	Percent of total long-term potential yield	Productivity (mt/nm²)	Day-at-sea use @ long-term potential yield	Percent of total effort	Landings per day-at-sea used	Average meat count	Area swept
GB	9 (CL-1 FW13)		357	384	6433	930	22623	0	0.0%	0.00	0	0.0%	3165	10.4	0
GB	10+11 (CL-1)		793	287	14983	2148	88325	0	0.0%	0.00	0	0.0%	3192	10.5	0
GB	14 (CL-2 FW13)		1124	994	43315	7560	80734	0	0.0%	0.00	0	0.0%	3208	10.4	0
GB	15 (CL-2 N)		673	862	4496	655	19945	0	0.0%	0.00	0	0.0%	3148	10.4	0
GB	12 (NLS FW13)		330	123	3732	521	47203	0	0.0%	0.00	0	0.0%	3197	10.4	0
GB	13 (NLS)		1488	704	3889	585	13407	0	0.0%	0.00	0	0.0%	3100	10.4	0
GB	*CLOSED*	*0.00*	*4966*	*3354*	*76848*	12383	*49744*	*0*	0.0%	*0.00*	*0*	0.0%			*0*
GB	8		749	138	245	38	821	83	0.8%	0.46	177	0.7%	762	20.4	69
GB	7		801	710	1147	159	1385	850	8.3%	0.92	1465	5.7%	957	24.4	528
GB	6		849	567	2262	372	1227	441	4.3%	0.75	1055	4.1%	928	23.5	397
GB	5		1701	1196	3079	467	818	424	4.1%	0.35	1299	5.0%	715	19.4	529
GB	4		905	481	2168	306	1079	276	2.7%	0.57	711	2.7%	874	22.1	280
GB	3		504	255	2768	441	1534	278	2.7%	1.09	599	2.3%	1030	26.1	211
GB	2		459	404	8871	1578	3448	1475	14.4%	3.85	2859	11.4%	1080	38.9	656
GB	1		467	115	110	17	1137	80	0.8%	0.70	195	0.8%	817	21.8	70
GB	*OPEN*	*0.59*	*6434*	*3886*	*20668*	7660	*1345*	*3690*	36.0%	*0.95*	*8462*	32.7%	984	*29.2*	*2739*
GB	TOTAL	0.04	11400	7240	98446	15790	20869	3690	36.0%	0.51	8462	32.7%	984	29.2	2739
MA	9		1630	1162	764	141	817	408	4.0%	0.35	1325	5.1%	680	22.5	536
MA	8		2485	2877	5984	1039	1077	1462	14.3%	0.55	4019	15.5%	817	25.8	1564
MA	7		2897	1431	5142	950	1463	1315	12.8%	0.92	3140	12.1%	921	29.8	1105
MA	6		2058	746	5928	1107	1754	913	8.9%	1.22	2073	8.0%	956	32.3	872
MA	5		2124	1036	15594	2867	1725	1227	12.0%	1.16	2769	10.7%	944	31.5	898
MA	4		1659	530	2453	421	1149	484	4.7%	0.91	1611	6.2%	652	36.0	593
MA	3		1433	457	3104	667	1145	416	4.1%	0.92	1412	5.5%	680	36.7	524
MA	2		868	173	469	60	1416	207	2.0%	1.20	657	2.5%	674	38.7	228
MA	1		800	130	220	36	1235	130	1.3%	1.00	439	1.7%	646	37.0	157
MA	*TOTAL*	*0.68*	*16133*	*8363*	*39638*	7213	1265	*6569*	64.0%	*0.79*	*17451*	*67.3%*	831	*30.8*	*6274*
ALL	*TOTAL*	*0.13*	*27533*	*15603*	*138082*	23003		*10260*	100.0%	*0.66*	*25913*	*100.0*	*877*	*30.5*	*9013*

Table 3. Comparison of long-term biomass, yield, and day-at-sea use estimates for the current and proposed overfishing defintions

			Expected average biomass (g/tow)			Potential long-term yield (mt)			Allowable day-at-sea use		
Stock	Rotation area	Scallop survey stratum approximate area (nm2)	Current definition (26,000 DAS, F=0.13)	Revised definition (F=0.2 in all areas)	Change	Current definition (26,000 DAS, F=0.13)	Revised definition (F=0.2 in all areas)	Change	Current definition (26,000 DAS, F=0.13)	Revised definition (F=0.2 in all areas)	Change
GB	9 (CL-1 FW13)	384	22623	4866	-78%	0	490		0	471	
GB	10+11 (CL-1)	287	88326	19569	-78%	0	1475		0	1250	
GB	14 (CL-2 FW13)	994	80734	17596	-78%	0	4590		0	3870	
GB	15 (CL-2 N)	662	19945	4372	-78%	0	980		0	966	
GB	12 (NLS FW13)	123	47203	10635	-77%	0	345		0	298	
GB	13 (NLS)	704	13407	2819	-79%	0	521		0	597	
GB	*CLOSED*	*3354*	*43744*	*9551*	*-78%*	*0*	*8410*		*0*	*7451*	
GB	8	138	921	2136	132%	63	77	22%	177	102	-42%
GB	7	710	1365	4766	249%	650	888	37%	1465	853	-42%
GB	6	587	1227	3643	197%	441	561	27%	1055	577	-45%
GB	5	1196	818	1479	81%	424	465	10%	1299	775	-40%
GB	4	481	1073	2566	139%	276	324	17%	711	382	-46%
GB	3	255	1534	5793	278%	278	388	40%	599	357	-40%
GB	2	404	3448	33908	883%	1475	3595	144%	2959	3026	2%
GB	1	115	1137	4216	271%	80	127	58%	195	129	-34%
GB	*OPEN*	*3886*	*1345*	*6297*	*368%*	*3690*	*6424*	*74%*	*8462*	*6201*	*-27%*
GB	**TOTAL**	**7240**	**20989**	**7806**	**-63%**	**3690**	**14834**	**302%**	**8462**	**13653**	**61%**
MA	9	1182	817	2161	164%	408	479	17%	1325	676	-49%
MA	8	2677	1077	3581	232%	1462	1798	23%	4019	1956	-51%
MA	7	1431	1463	6833	367%	1315	1833	39%	3140	1697	-46%
MA	6	746	1754	9589	447%	913	1341	47%	2073	1195	-42%
MA	5	1036	1725	9424	446%	1227	1831	49%	2769	1634	-41%
MA	4	530	1149	8393	631%	484	834	72%	1611	753	-53%
MA	3	457	1145	8476	640%	418	726	73%	1412	654	-54%
MA	2	173	1418	13186	830%	207	428	106%	657	373	-43%
MA	1	130	1235	10633	761%	130	259	99%	439	229	-48%
MA	*TOTAL*	*8363*	*1265*	*6076*	*380%*	*6569*	*9529*	*45%*	*17451*	*9166*	*-47%*
ALL	***TOTAL***	***15603***				***10260***	***24363***	***137%***	***25913***	***22818***	***-12%***

	Unsurveyed areas Mean Landings (MT)
Gulf of Maine[1]	472
S. New England[2]	64

[1] High percentage in state waters within three miles of shore
[2] West of NLS area