Skate Species Complex: Examination of Potential Biological Reference Points for the Northeast Region

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Executive Summary

The seven species in the Northeast Region (Maine to Virginia) skate complex are: little skate (*Leucoraja erinacea*), winter skate (*L. ocellata*), barndoor skate (*Dipturus laevis)*, thorny skate (*Amblyraja radiata*), smooth skate (*Malacoraja senta*), clearnose skate (*Raja eglanteria*), and rosette skate (*L. garmani*). Landings have generally been increasing since 2000 and the 2007 reported commercial landings of 19,000 mt were the highest on record. Discard estimates from SAW/SARC 44 in 2006 were revised in this assessment based on Standardized Bycatch Reporting Methodology. Most differences were due to inclusion of more trips from the last few years (e.g., Special Access Programs, etc.).

The landings estimates were not disaggregated to skate species in previous assessments because identification of skates is uncertain in the Domestic Observer Program (NEFSC 2007). Alternative methods to estimate landings by species were developed, each of which has strengths and weaknesses. The Review Panel concluded that progress had been made and future efforts should be encouraged, but that the Panel had insufficient time to explore the alternative methods in detail. Therefore, these approaches will be used in future modeling efforts, and will serve as an indication of the uncertainty in the catch of skates. Discards were also disaggregated to skate species using one method.

Survey indices by species were updated through 2007/2008 and aggregate indices were developed by area. These were used along with the catch data in An Index Method (AIM). Attempts to use this model were unsuccessful. Another model, SEINE (Survival Estimation in Non-Equilibrium Situations Model), was attempted to estimate fishing mortality. While the model estimated fishing mortality, it did so over a very long time period, but was not useful for producing annual estimates.

SPR-based reference points for three skate species, barndoor, winter, and thorny, were derived from life-history parameters and fitted Beverton-Holt stock recruit relationships. Future assessments might determine stock status by comparing these depletion levels either with depletion in the surveys or from a stock assessment model that incorporates information about maturity. These results were not accepted for reference points at this time.

Until new models are constructed using the new catch by species information, the existing overfishing definitions, updated through 2007/2008 will remain the best available. For barndoor skate, the current (i.e., non-updated) definition will be retained. Stock status with respect to the updated estimates is described. For skates in general, no new measurable stock status definitions were identified.

Terms of Reference

The following Terms of Reference were provided to the Data Poor Stocks Working Group for peer review in December 2008:

a. Recommend biological reference points (BRPs) and measurable BRP and maximum sustainable yield (MSY) proxies for the following data poor stocks: Black sea bass; Deep-sea red crab; Scup; Skates; Atlantic wolffish.

b. Provide advice about scientific uncertainty and risk for Scientific and Statistical Committees (SSCs) to consider when they develop fishing level recommendations for these stocks.

c. Consider developing BRPs for species groups for situations where the catch or landings can not be identified to species. Work on this objective will depend on, and needs to be consistent

with, final guidance on implementing the Reauthorized Magnuson-Stevens Act, whenever that guidance becomes available.
d. Comment on what can be done to improve the information, proxies or assessments for each species.

Introduction

The seven species in the Northeast Region (Maine to Virginia) skate complex are distributed along the coast of the northeast United States from near the tide line to depths exceeding 700 m (383 fathoms). The species are: little skate (*Leucoraja erinacea*), winter skate (*L. ocellata*), barndoor skate (*Dipturus laevis)*, thorny skate (*Amblyraja radiata*), smooth skate (*Malacoraja senta*), clearnose skate (*Raja eglanteria*), and rosette skate (*L. garmani*).

In the Northeast region, the center of distribution for the little and winter skates is Georges Bank and Southern New England. The barndoor skate is most common in the Gulf of Maine, on Georges Bank, and in Southern New England. The thorny and smooth skates are commonly found in the Gulf of Maine. The clearnose and rosette skates have a more southern distribution, and are found primarily in Southern New England and the Chesapeake Bight. Skates are not known to undertake large-scale migrations, but they do move seasonally in response to changes in water temperature, moving offshore in summer and early autumn and returning inshore during winter and spring. Members of the skate family lay eggs that are enclosed in a hard, leathery case commonly called a mermaid's purse. Incubation time is 6 to 12 months, with the young having the adult form at the time of hatching (Bigelow and Schroeder 1953).

The first stock assessment for the skate complex was conducted in 1999 at SARC/SAW 30 (NEFSC 2000). At that time there was no Fishery Management Plan (FMP) in place. The National Marine Fisheries Service had been petitioned to list barndoor skate as endangered based on a paper published by Casey and Myers (1998) and was also asked to assess the other species in the complex. SARC 30 found no cause to list barndoor as endangered but recommended that the species remain on the candidate species list as well as to put thorny skate on the candidate species list. Biomass reference points were developed for all seven species and four were listed as overfished. Fishing mortality reference points were developed for winter and little skate and overfishing was occurring for winter skate.

An FMP was developed following SARC 30 by the New England Fishery Management Council (NEFMC) when they were informed of the overfished status of thorny and barndoor (winter and smooth biomass increased in the 1999 autumn survey and were no longer considered overfished). The FMP was implemented in September of 2003 with a primary requirement for mandatory reporting of skate landings by species by both dealers and vessels. Possession prohibitions of barndoor and thorny skate as well as smooth skate in the Gulf of Maine were also provisions of the FMP. A trip limit of 10,000 lbs was implemented for winter skate with a Letter of Authorization for the bait fishery (little skate) to exceed the trip limit. The biomass reference points developed at SARC 30 were maintained, but new fishing mortality reference points were developed.

The last stock assessment for the skate complex was conducted in 2006 at SARC/SAW 44 (NEFSC 2007). Several methods were attempted to develop fishing mortality estimates and biological reference points. These included the Gedamke-Hoenig length-based mortality estimator, length-based yield-per-recruit, spawner-per-recruit, and a length-tuned model. None of these methods were accepted, although some had promise. SARC 44 did not change the biological reference points.

Commercial Fishery Landings

Skates have been reported in New England fishery landings since the late 1800s. However, commercial fishery landings, primarily from off Rhode Island, never exceeded several hundred metric tons until the advent of distant-water fleets and the industrial fishery during the 1950s and 1960s. Skate landings reached 9,500 mt in 1969, but declined quickly during the 1970s, falling to 800 mt in 1981 (Table 1, Figure 1). Landings then increased substantially; partially in response to increased demand for lobster bait, and more significantly, to the increased export market for skate wings. Landings increased to 12,900 mt in 1993 and then declined somewhat to 7,200 mt in 1995. Landings increased again and the 2007 reported commercial landings of 19,000 mt were the highest on record (Table 1, Figure 1).

United States landings of skates are reported in all months (Table 2). There is a relatively even distribution of landings across months, but the summer months do show a slightly higher percentage, probably due to the increased demand for lobster bait during those months.

Skate landings are primarily from Massachusetts and Rhode Island (mainly New Bedford and Point Judith) with 85-95% of the landings occurring in those two states (Table 3). Landings from other states did occur back through time and the table somewhat reflects better reporting as more states reported in the NMFS database. Also, the difference in total landings between Table B1.1 and B1.3 is likely the result of landings from the industrial fishery not included in the Weighout database. These landings were sampled during the 1960s and 1970s for species composition and prorated. Skates accounted for about 10% of those landings.

Otter trawls are the primary gear used to land skates in the United States, with some landings coming from sink gill nets (Table 4). In the last couple of years, landings from longline gear have increased slightly in importance. The increase in other gear reflects the new reporting system implemented in 2004.

Landings historically were taken from the Georges Bank and Southern New England during the early 1960s as the industrial fishery operated mainly out of Point Judith and the distant-water fleet fished mainly on Georges Bank (Table 5). Landings from Mid-Atlantic increased through the early 2000s while landings from Georges Bank in 2007 were the highest on record.

Landings are generally not reported by species, with over 99% of the landings reported as "unclassified skates" until the FMP was implemented in September of 2003 (Table 6). Wings are most likely taken from winter and thorny skates, the two species currently known to be used for human consumption. Bait landings are presumed to be primarily from little skate, based on areas fished and known species distribution patterns. Landings of barndoor and thorny skate are being reported by the dealers even though there is a possession prohibition for those two species. There are also wings reported for rosette, little and smooth which are known to be too small for wings. The distribution of skate landings by state and species also shows that some species are landed in areas that they do not occur (Table 7). For example, in 2004, barndoor were landed in Virginia which is too far south for barndoor skate.

Commercial Fishery Discards

Discard estimates from SAW/SARC 44 were revised in this assessment. The ratio-estimator used in this assessment is based on the methodology described in Rago et al. (2005)

and updated in Wigley et al 2007. It relies on a d/k ratio where the kept component is defined as the total landings of all species within a "fishery". A fishery is defined as a homogeneous group of vessels with respect to gear type (longline, otter trawl, shrimp trawl, sink gill net, and scallop dredge), quarter (months 1-4, 5-6, 7-8, 9-12), and area fished (GOM, GB, SNE, MA). Mesh size was not used to split out otter trawl trips or sink gill net trips. All trips were included if they occurred within this stratification regardless of whether or not they caught skates.

The discard ratio for skates in stratum h is the sum of discard weight over all trips divided by sum of kept weights over all trips:

$$\hat{R}_h = \frac{\sum_{i=1}^{n_h} d_{ih}}{\sum_{i=1}^{n_h} k_{ih}} \qquad (1)$$

where d_{ih} is the discards for skates within trip i in stratum h and k_{ih} is the kept component of the catch for all species. R_h is the discard rate in stratum h. The stratum weighted discard to kept ratio is obtained by weighted sum of discard ratios over all strata:

$$\hat{R} = \sum_{h=1}^{H} \left(\frac{N_h}{\sum_{h=1}^{H} N_h} \right) \hat{R}_h \qquad (2)$$

The total discard within a strata is simply the product of the estimate discard ratio R and the total landings for the fishery defined as stratum h, i.e., $D_h=R_hK_h$.

Missing cells were inputed using averages of existing cells. If information existed in the same area fished, the annual average discard ratio was applied in the missing cells. If the information was missing in the area fished, but available in the region (i.e. SNE and MA or GOM and GBK), then the annual average for that region was applied. There were some cases for the longline fishery in which the entire year was averaged for all areas or for a span of 12 years (1993-2004). The details of the imputation are given in Appendix 1.

To hindcast the discard estimates back to 1964, a three-year average (the earliest three years of data) of the discards of skates/landings of all species was used. The sensitivity of this estimate was examined using a five-year average and a time-series average (Figure 2). The trends in the total estimates are similar, with the time-series average giving the lowest estimate and the three-year average the highest estimates. Using the three estimates in any future modeling efforts will give some idea of the uncertainty in the data.

Estimated discards by fishery, region and half year for 1964-2007 are summarized in Tables 8-10. The new estimated discards are different than those estimated in SARC/SAW 44 (Figure 3). There are two main reasons for these differences. First, missing cells were imputed in the new method. This should lead to higher values in general. Second, the data for any Special Access Programs for 2005 -2007 were included in the new estimates. These trips showed a higher discard ratio than those outside the closed areas. These should be placed in a separate stratum, however, there is no easy way to determine if a trip in the dealer database was fishing in an SAP. The coefficients of variation for the otter trawl are generally reasonable, while the scallop dredge estimates are highly variable (Table 11). Alternative stratification schemes were examined to determine if this had any impact on the magnitude of the discard estimates (Appendix 2). When all trips were included the estimates were all fairly similar.

The estimates from 1992-2007 were hind-cast using the first three years of the time series to compare actual estimates and hind-cast estimates (Figure 4). For years when the regulations were similar (mid-1990s), the hind-cast estimates were comparable to the actual estimates. In more recent years, management has changed and the estimates are not and probably should not be comparable.

Recreational Fishery Catch

Aggregate recreational landings of the seven species in the skate complex are relatively insignificant when compared to the commercial landings, never exceeding 300 mt during the 1981-1998 time series of Marine Recreational Fishery Statistics Survey (MRFSS) estimates. Little and clearnose skates are the most frequently landed species of the complex. For little skate, total landings varied between <1000 and 56,000 fish, equivalent to <1 to 15 mt, during 1981-1998. For clearnose skate, total landings varied between 2,000 and 145,000 fish, equivalent to 2 to 232 mt, during 1981-1998. The number of skates reported as released alive averages an order of magnitude higher than the reported landed number. Party/charter boats have historically been undersampled compared to the private/rental boat sector that accounts for most of the recreational catch, and may have a different discard rate. The recreational fishery release mortality rate of skates is unknown, but is likely comparable to that for flounders and other demersal species, which generally ranges from 10-15%. Assuming a 10-15% release mortality rate would suggest that recreational fishery discard mortality is of about the same magnitude as the recreational landings. Data from 1999 through 2005 were similar in magnitude.

Landings by Species Estimation

The landings estimates were not dis-aggregated to skate species in previous assessments because identification of skates is uncertain in the Domestic Observer Program (NEFSC 2007). Alternative methods to estimate landings by species were developed, each of which has both strengths and weaknesses. Therefore, both sets of estimates were chosen to be used in any future modeling efforts as an indication of the uncertainty in the catch of skates.

The first method used the observer lengths of the kept component of the catch directly. In order to split the data into the bait (whole) and wing components of the fishery, a length cutoff of 60 cm was used, since there is no direct way of determining the disposition of the landings until recently. This seemed justified, since the maximum size in the bait fishery was instituted to also be close to the minimum accepted length for the wing fishery. Examination of the samples by the two main gear types also showed two groups of fish with a trough at about 60 cm (Figure 5). The data were apportioned into two regions, Gulf of Maine to Georges Bank (GOMGBK – Divisions 51 and 52), and Southern New England to Mid-Atlantic (SNEMA – Divisions 53 and Subarea 6). The number of fish measured in these regions was barely sufficient (Table 12) so no further areal division was attempted. Pooling over years within a region was still required to get an adequate number of fish (Figure 6). An average skate length-weight equation was applied to the samples and used to estimate the landings numbers at length for each market category (Figure 7).

Length compositions for each species for the two regions (GOMGBK – Offshore strata 13-30, 36-40, and Inshore strata 56-66; SNEMA – Offshore strata 1-12, 61-76, and Inshore strata 1-55) were estimated. The species length-weight equations were then applied to determine weight-at-length by species. The proportions at length by species for both number and weight were applied to the commercial landings-at-length to estimate landings-at-length by species. The lengths had to be grouped into 5 cm intervals to avoid zero cells in the survey and all fish greater than 112 cm were set to be barndoor skate.

For the second method, a selectivity ogive was estimated for observed hauls in each skate fishery compared to the applicable surveys during 2004-2007. The data were fit using a three parameter logistic curve via Millar's (1992) SELECT model. Results of these logistic model fits are given in Table 13 and in Figures 8-11. In most cases where the parameters could be estimated, the L50s for winter and little skates were similar to the overall fit for all skate species (with a notable exception of little skates observed in the retained fraction of gillnet catches). Also the ogives by region were very similar to one another within each fishery and gear type. As a result, pooled selectivity ogives for each gear and skate fishery were used to determine the exploitable species composition at size in each survey stratum. In the following table, the L50s for the newly estimated ogives are compared with the PDT's assumed knife edge selectivity ogive.

Fishery	**L50 for selectivity ogive applied to survey weight per tow data**	**PDT assumed knife edge selectivity**
Trawl wing	66.9 cm	> 40 cm
Trawl whole/bait	44.4 cm and < 59 cm	< 59 cm
Gillnet	54.9 cm	> 65 cm

Average proportional weight per tow by three digit statistical area was re-estimated by determining an average stratum weight per tow and then computing an area-weighted average for the sampled strata within each three digit statistical area. While this approach does not readily allow estimation of variance (like a domain estimator), the averages computed in this way satisfy the conditions of the stratified random survey design. These average proportions of survey catch by skate species were then applied to the VTR data by gear type, fishery (product form), and trimester (corresponding to the spring, fall, and winter surveys).

Comparison of the two methods generally shows higher amounts of winter, clearnose, and rosette skate in method one (length composition) compared to the second method (selectivity ogive) and lower amounts of little, smooth, and thorny skate (Tables 14-15; Figures 12-14). Barndoor skate are generally comparable. The length composition method uses the annual length data when possible, but may be ignoring some sub-regional differences due to the low sample sizes. The selectivity ogive method, on the other hand, uses the sub-regional data while assuming that the length composition of the survey, once the skates are fully selected, reflects the length composition of the fishery. The two methods give a range of values and will both be used in any future modeling efforts.

Discards by Species Estimation

The discard estimates were not dis-aggregated to skate species in previous assessments because identification of skates is uncertain in the Domestic Observer Program (NEFSC 2007).

The observer lengths of the discarded component of the catch were used by gear type. The data were apportioned into two regions, Gulf of Maine to Georges Bank (GOMGBK – Divisions 51 and 52), and Southern New England to Mid-Atlantic (SNEMA – Divisions 53 and Subarea 6). The number of fish measured in these regions was barely sufficient (Table 16) so no further areal division was attempted. Pooling over years, sometimes over the entire time series, within a region was still required to get an adequate number of fish (Figure 15). For longline gear, all samples were used for both regions. An average skate length-weight equation was applied to the samples and used to estimate the discard numbers at length by gear category (Figure 16).

Length compositions for each species for the two regions (GOMGBK – Offshore strata 13-30, 36-40, and Inshore strata 56-66; SNEMA – Offshore strata 1-12, 61-76, and Inshore strata 1-55) were estimated. The species length-weight equations were then applied to determine weight-at-length by species. The proportions at length by species for both number and weight were applied to the commercial landings-at-length to estimate landings-at-length by species. The lengths had to be grouped into 5 cm intervals to avoid zero cells in the survey and all fish greater than 112 cm were set to be barndoor skate. The estimates by gear type and species are given in Table 17.

Research Survey Data- Total Stock Biomass

Indices of relative abundance have been developed from NEFSC bottom trawl surveys for the seven species in the skate complex, and these form the basis for most of the conclusions about the status of the complex. The NEFSC trawl survey has been conducted in the autumn from the Gulf of Maine to Southern New England since 1963 (Azarovitz 1981) and the Mid-Atlantic was added in 1967. A spring survey was started in 1968 with stations <= 27 m added in 1975. All statistically significant NEFSC gear, door, and vessel conversion factors were applied to little, winter, and smooth skate indices when applicable (Sissenwine and Bowman, 1978; NEFC 1991). Juvenile little and winter skates are not readily distinguished in the field. The numbers of juveniles were split between the two species based on the abundance of the adults in the same tow.

For the aggregate skate complex, the spring survey index of biomass was relatively constant from 1968 to 1980, then increased significantly to peak levels in the mid to late 1980s. The index of skate complex biomass then declined steadily until 1994, but increased until 2000 and has since decreased (Figure 17). If the species in the complex are divided into large (barndoor, winter, and thorny) and small sized skates (little, clearnose, rosette, and smooth), it is evident that the large increase in skate biomass in the mid to late 1980s was dominated by winter and little skate (Figure 17). The biomass of large sized skates steadily declined from the mid-1980s to the mid-1990s and has since been stable. The increase in aggregate skate biomass from the mid-1990s to 2000 was due to an increase in little skate and the subsequent decline is also due to little skate (Figure 17).

Indices were also derived for the aggregate skate complex by region. The index of skate biomass in the Gulf of Maine (Offshore strata 26-30, 36-40) was steady through the mid-1970s, started to decline and is currently among the lowest on record (Figure 18). The index for the Georges Bank region (Offshore strata 13-25) was relatively low at the start of the time series, increased to high levels in the 1980s and has since declined to low levels (Figure 18). For the Southern New England region (Offshore strata 1-12), the index either increased over time (the spring survey) or was stable (the fall survey) (Figure 19). The index for the Mid-Atlantic (Offshore strata 61-76) region has increased over time (Figure 19).

Indices of relative abundance for some of the species have also been developed from MADMF and CTDEP research surveys. Data are also available from the Maine-New Hampshire inshore survey, the ASMFC shrimp trawl survey, the monkfish survey, and the VIMS trawl survey but have not been developed into indices at this time.

The bootstrap methodology of Smith (1997) was continued from the previous SARC and also applied to the MADMF survey but the complete results are not shown. The data are shown to demonstrate what may be available for future modeling work.

Winter skate

In the NEFSC spring survey offshore strata (1968-2008), the annual total catch of winter skate has ranged from 160 fish in 1976 to 1,891 fish in 1985. In the NEFSC autumn survey offshore strata (1963-2007), the annual total catch of winter skate has ranged from 115 fish in 1975 to 1,187 fish in 1984. Calculated on a per tow basis, these spring survey catches equate to maximum stratified mean number per tow indices for the GOM-MA offshore strata of about 7.9 fish, or 16.4 kg, per tow during 1985; autumn maximum catches equate to indices of 3.7 fish, or 13.3 kg, per tow in 1984 (Tables 18-19).

The catchability of winter skate in the NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series, especially for smaller winter skates. NEFSC winter survey (1992-2007) annual catches of winter skate have ranged from 841 fish in 1993 to 4,055 fish in 1996, equating to a maximum stratified mean catch per tow of 43.5 fish, or 25.2 kg, per tow in 1996 (Table 20). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine and has been discontinued.

Indices of winter skate abundance and biomass from the NEFSC spring and autumn surveys were stable, but below the time series mean, during the late 1960s and 1970s (Figure 20). Winter skate indices increased to the time series mean by 1980, and then reached a peak during the mid 1980s. Winter skates indices began to decline in the late 1980s. Current NEFSC indices of winter skate abundance are below the time series mean, at about the same value as during the early 1970s. Current NEFSC indices of winter skate biomass are about 20% of the peak observed during the mid 1980s (Figure 20).

The NEFSC scallop dredge survey, as with the winter survey also catches winter skates mostly on Georges Bank and also does not sample in the Gulf of Maine and on the very shallowest portions of Georges Bank. However, the trends in abundance are similar to the trends in the spring and autumn surveys (Figure 21).

Indices of abundance for winter skate are available from the Massachusetts Division of Marine Fisheries (MADMF) spring and autumn research trawl surveys in the inshore waters of Massachusetts for the years 1978-2008. MADMF biomass indices of winter skate were moderate to high from 1981 through 1987. Thereafter, both spring and autumn indices declined to time series lows in 1989-1991. The spring index rebounded to moderate levels during 1992-1996 before dropping again to low values in the late 1990s and remaining low through 2008 (Figure 22). The autumn index is more erratic, but generally shows the same pattern.

Indices of abundance for winter skate are available from the Connecticut Department of Environmental Protection (CTDEP) spring and autumn finfish trawl surveys in Long Island Sound for the years 1984-2008 (1992 and later only for biomass). Annual CTDEP survey catches have ranged from 0 to 115 skates. CTDEP survey indices suggest that after increasing to a time series high from 1984 through 1989, winter skate in Long Island Sound has declined slightly (Figure 23).

Little skate

In the NEFSC spring surveys (1976-2008), the annual total catch of little skate has ranged from 2,271 fish in 2006 to 16,406 fish in 1999 (Table 21). In the NEFSC autumn surveys (1975-2007), the annual total catch of little skate has ranged from 1,124 fish in 1993 to 6,523 fish in 2003 (Table 22). Calculated on a per tow basis, these spring survey catches equate to maximum stratified mean number per tow indices for the GOM-MA inshore and offshore strata of about 28 fish, or 10 kg, per tow during 1999; autumn maximum catches equate to indices of 18 fish, or 7.7 kg, per tow in 2003 (Tables 21-22).

The catchability of little skate in the NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series. NEFSC winter survey (1992-2007) annual catches of little skate have ranged from 8,870 fish in 2003 to 18,418 fish in 1992, equating to a maximum stratified mean catch per tow of 170 fish, or 66 kg, per tow in 1992 (Table 23). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine and has been discontinued.

Indices of little skate abundance and biomass from the NEFSC spring and autumn surveys were stable, but below the time series mean, during the 1970s. Little skate spring survey indices began to increase in 1982, reached a peak in 1999, and declined thereafter (Figure 24). Autumn survey indices have been relatively stable over the duration of the time series, with a slight increase in recent years (Figure 24). The application of the NEFSC gear conversion factors to spring survey indices decreased the indices in 1981 and earlier years by 75 percent. This may account for some of the mis-match between the spring and autumn surveys.

The NEFSC scallop dredge survey, as with the winter survey also catches little skates in all areas and also does not sample in the Gulf of Maine, on the very shallowest portions of Georges Bank, and parts of Southern New England. However, the trends in abundance are similar to the spring and autumn surveys with the indices showing little trend over the time series (Figure 25).

Indices of abundance for little skate are available from the Massachusetts Division of Marine Fisheries (MADMF) spring and autumn research trawl surveys in the inshore waters of Massachusetts for the years 1978-2008 (Figure 26). MADMF biomass indices of little skate declined through the 1980's to time series lows in 1989 (autumn) and 1991 (spring). Biomass indices quickly rose to high levels in the early 1990's, and have since fluctuated without trend.

Indices of abundance for little skate are available from the Connecticut Department of Environmental Protection (CTDEP) spring and autumn finfish trawl surveys in Long Island Sound for the years 1984-2008 (1992 and later only for biomass). Little skate are the most abundant species in the skate complex in Long Island Sound, with annual CTDEP survey catches ranging from 142 to 837 skates. CTDEP survey indices suggest an increase in abundance of little skate in Long Island Sound through 1996 followed by a decline (Figure 27).

Barndoor skate

In the NEFSC spring surveys (1968-2008), the annual total catch of barndoor skate has ranged from 0 fish (several years during the 1970s and 1980s) to 325 fish in 2007 (Table 24). In the NEFSC autumn surveys (1963-2007), the annual total catch of barndoor skate has ranged from 0 fish (several years in the 1970s and 1980s) to 120 fish in 1963 (Table 25). Calculated on a per tow basis, the autumn survey catches equate to maximum stratified mean number per tow indices for the GOM-SNE offshore strata of about 0.8 fish, or 2.6 kg, per tow in 1963 while the spring maximum is 1.5 fish, or 6.8 kg, per tow in 2007 (Tables 24-25). The spring survey index was driven mainly by one large tow (277 fish; >1500 kg).

The catchability of barndoor skate in the NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series and may be particularly higher for smaller skates as in winter skates. NEFSC winter survey (1992-2007) annual catches of barndoor skate have ranged from 0 fish in 1992 to 355 in 2006, equating to a maximum stratified mean catch per tow of 3.2 fish, or 3.0 kg, per tow in 2006 (Table 26). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine and has been discontinued.

Indices of barndoor skate abundance and biomass from the NEFSC spring and autumn surveys were at their highest values during early to late 1960s, and then declined to 0 fish per tow during the early 1980s. Since 1990, both spring and autumn survey indices have steadily increased, with the spring survey at the highest value and the autumn survey nearing the peak values found in the 1960s (Figure 28).

The NEFSC scallop dredge survey, as with the winter survey also catches winter skates mostly on Georges Bank and also does not sample in the Gulf of Maine, on the very shallowest portions of Georges Bank, and parts of Southern New England. However, the trends in abundance are similar to the trends in the spring and autumn surveys showing a large increase since 1992 while the biomass is much noisier (Figure 29).

Thorny skate

In the NEFSC spring surveys (1968-2008), the annual total catch of thorny skate has ranged from 29 fish in 2006 to 574 fish in 1973 (Table 27). In the NEFSC autumn surveys (1963-2007), the annual total catch of thorny skate has ranged from 36 fish in 2005 to 874 fish in 1978 (Table 28). Calculated on a per tow basis, these spring and autumn survey catches equate to maximum stratified mean number per tow indices for the GOMSNE offshore strata of about 2 to 3 fish, or about 6.0 kg, per tow during the early 1970s (Tables 27-28).

NEFSC spring and autumn survey indices for thorny skate have declined continuously over the last 40 years. Indices of thorny skate abundance and biomass from the NEFSC spring and autumn surveys were at a peak during the early 1970s, reaching 2.9 fish per tow (5.3 kg per tow) in the spring survey and 1.8 fish per tow (5.9 kg per tow) in the autumn survey. Kulka and Mowbray (1998) indicated a similar period of high abundance for thorny skate in Canadian waters. NEFSC indices of thorny skate abundance have declined steadily since the late 1970s, reaching historically low values by 2005-2007 that are less than 10% of the peak observed in the 1970s (Figure 30).

The NEFSC scallop dredge survey also catches thorny skates primarily on the edges of Georges Bank and a sharp decline followed by no trend (Figure 31). The scallop survey also does not sample in the Gulf of Maine, on the very shallowest portions of Georges Bank and parts of Southern New England.

Indices of abundance for thorny skate are available from the Massachusetts Division of Marine Fisheries (MADMF) spring and autumn research trawl surveys in the inshore waters of Massachusetts for the years 1978-2008. MADMF indices of thorny skate biomass have been variable over the time series, but there is a decreasing trend evident in both the spring and autumn time series. The spring index has stabilized around the median of 0.2 kg/tow throughout the 2000's, while the autumn index has been below the median of 0.6 kg/tow since 1994 except for 2001 and 2002 (Figure 32).

Smooth skate

In the NEFSC spring surveys (1968-2008), the annual total catch of smooth skate has ranged from 12 fish in 1996 to 179 fish in 1973 (Table 29). In the NEFSC autumn surveys (1963-2007), the annual total catch of smooth skate has ranged from 10 fish in 1976 to 130 fish in 1978 (Table 30). Calculated on a per tow basis, these spring and autumn survey catches equate to maximum stratified mean number per tow indices for the GOM-MA offshore strata of 0.6 to 1.6 fish, or about 0.6 to 0.9 kg, per tow during the 1970s (Tables 29-30).

Indices of smooth skate abundance and biomass from the NEFSC surveys were at a peak during the early 1970s for the spring series and the late 1970s for the autumn series (Figure 33). NEFSC survey indices declined during the 1980s, before stabilizing during the early 1990s at about 25% of the autumn and 50% of the spring survey index values of the 1970s.

The NEFSC scallop dredge survey also catches smooth skates primarily on the edges of Georges Bank and the indices have slightly increased (Figure 34). The scallop survey also does not sample in the Gulf of Maine, on the very shallowest portions of Georges Bank and parts of Southern New England.

Clearnose skate

In the NEFSC spring surveys (1976-2008), the annual total catch of clearnose skate has ranged from 9 fish in 1979 to 136 fish in 1993 (Table 31). In the NEFSC autumn surveys (1975-2007), the annual total catch of clearnose skate has ranged from 19 fish in 1983 to 221 fish in 2001 (Table 32). Calculated on a per tow basis, these spring and autumn survey catches equate to maximum stratified mean number per tow indices for the Mid-Atlantic offshore and inshore strata set of 1.2-1.6 fish, or about 0.8-0.9 kg, per tow during the mid 1990s and 2000s (Tables 31-32).

The catchability of clearnose skate in the NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series. NEFSC winter survey (1992-2007) annual catches of clearnose skate have ranged from 343 fish in 1999 to 3,086 fish in 1996, equating to a maximum stratified mean catch per tow of 12 fish or 15 kg per tow in 1996 (Table 33). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine, and has been discontinued.

NEFSC spring and autumn survey indices for clearnose skate increased from the mid-1980s through 2000, declined to about average values, and increased slightly in the last few years (Figure 35).

Indices of abundance for clearnose skate are available from the Connecticut Department of Environmental Protection (CTDEP) spring and autumn finfish trawl surveys in Long Island Sound for the years 1984-2008 (1992 and later only for biomass). The CTDEP survey had caught very few clearnose skate, with annual catches ranging from 0 to 20 skates through 1998, but the indices have increased in Long Island Sound over the times series with 100 caught in 2005 (Figure 36).

Rosette skate

In the NEFSC spring surveys (1968-2008), the annual total catch of rosette skate has ranged from 0 fish, in 1970 and1984, to 70 fish in 1977 (Table 34). In the NEFSC autumn surveys (1967-2005), the annual total catch of rosette skate has ranged from 1 fish, most recently in 1982, to 46 fish in 1999 (Table 35). Calculated on a per tow basis, these spring survey catches equate to maximum stratified mean number per tow indices for the Mid-Atlantic offshore strata set of about 0.6 fish, or about 0.1 kg, per tow during 1977 (Tables 34-35).

The catchability of rosette skate in the NEFSC winter bottom trawl survey (which substitutes a chain sweep with small cookies for the large rollers used in the spring and autumn surveys, to better target flatfish) is significantly higher than in the spring and autumn series. NEFSC winter survey (1992-2007) annual catches of rosette skate have ranged from 143 fish in 1993 to 1029 fish in 2003, equating to a maximum stratified mean catch per tow of 2.8 fish or 0.7 kg per tow in 2003 (Table 36). The winter survey is focused in the Southern New England and Mid-Atlantic offshore regions, with a limited number of samples on Georges Bank, and no sampling in the Gulf of Maine and has since been discontinued.

Indices of rosette skate abundance and biomass from the NEFSC surveys were at a peak during 1975-1980, before declining through 1986. NEFSC survey indices for rosette skate increased from 1986 through 2001, declined slightly and recent indices are near the peak values of the late 1970s (Figure 37).

Research Survey Data- Spawning Stock Biomass

Maturity information was available in some form for all species to split the survey length information into mature and immature animals (Table 37). The series chosen for each species was the same as chosen for reference points at SARC30. There is a protracted spawning as females likely lay eggs year round so there is no need to pick a season based on spawning time. The autumn survey was used for all species except little as it is generally the longest. For little skate, the spring series from 1982 on was used to avoid gear conversion issues.

Winter skate SSB generally follows the pattern of the autumn total biomass index with very low values in the 1970s followed by the large expansion of the size composition in the 1980s (Table 38; Figure 38). The index of SSB declined in the mid- to late 1990s, increased slightly, and is currently at low values. Little skate SSB has been fairly stable through the time series with slightly higher values from 1999-2004 than in the 1980s and early 1990s (Table 38; Figure 38). The pattern in barndoor skate SSB indices is much the same as that of total biomass with high values in the early 1960s, followed by very low to nonexistent values in the 1970s and 1980s, and then a consistent increase in the 1990s and 2000s (Table 38; Figure 38). The decline in thorny skate SSB indices is more pronounced than for the total biomass index (Table 38; Figure 38). Smooth skate SSB indices are very variable, but exhibit a slight decline over the time series (Table 38; Figure 38). Clearnose skate SSB has increased over the time period (Table 38; Figure 38). Rosette skate SSB has been variable but has generally increased (Table 38; Figure 38).

Fishing Mortality Estimates

Gedamke and Hoenig (2006) developed a method to estimate mortality from mean length data in nonequilibrium situations, now called Survival Estimation in Non-Equilibrium Situations Model (SEINE, available at http://nft.nefsc.noaa.gov/). It is an extension of the Beverton-Holt length-based mortality estimator that assumes constant recruitment throughout the time series and mortality at fixed levels for certain periods within the time series. The approach allows for the transitory changes in mean length to be modeled as a function of mortality rate changes. After an increase in mortality, mean length will gradually decrease due to larger animals being less prevalent in the population. After a decrease in mortality, mean length will increase slowly due to growth of the fish in the population. The rates of change in both cases depend on the von Bertalanffy growth parameters and the magnitude of change in the mortality rates. Since the method requires only a series of mean length above a user defined minimum size and the von Bertalanffy growth parameters, it can be applied in many data poor situations. Gedamke and Hoenig (2006) demonstrated the utility of this approach using both simulated data and an application to data for goosefish caught in the NEFSC fall groundfish survey.

Most of the information for the six species suggests that there is one break-point in the time series. This is not useful in monitoring the species on an annual basis. Further modeling efforts are required to estimate fishing mortality.

Biological Reference Points

Current Reference Points

The existing biomass reference points were developed at SARC 30 (NEFSC 2000) and maintained at SARC 44 (NEFSC 2007) with B_{MSY} Proxy formulated as the 75th percentile of the given time series of each species, except barndoor (Table 39) and half that value for $B_{threshold}$. It was assumed that all species had at some time passed through B_{MSY} at some point in the time series. For barndoor skate, the mean of the first four years of the autumn survey were used instead, given that biomass had been extremely low during most of the time series. To reduce the variability in the survey estimates, a three-year moving average of the survey indices was proposed to evaluate stock status for all species (Table 40).

The fishing mortality reference points developed at SARC 30 were not accepted by the NEFMC and a different method for evaluating fishing mortality was developed by the Plan Development Team (PDT). The thresholds for fishing mortality are based on annual percentage declines of the three-year average of the NEFSC trawl survey time series chosen for the biomass reference points. The percentages are specified for each species individually based on historical variation within the survey. The thresholds also include what is termed a precautionary “backstop” that indicates that overfishing is occurring if the trawl survey mean weight per tow declines for three consecutive years. The main part of the definition is that overfishing is occurring when the three-year moving average of the given survey biomass index declines by more than the average CV of the time series. The resulting overfishing status determinations are shown in Table 41.

Extension of time series

One alternative biomass reference point is to use the 75th percentile of the series, but to add the nine years of survey data since the last SARC (Table 42). This gives slightly lower estimates of B_{target} for winter, thorny, and smooth, a much lower estimate for barndoor, and higher estimates for little, clearnose, and rosette.

An Index Method (AIM)

An Index Method (AIM, available at http://nft.nefsc.noaa.gov/) was attempted for all seven species using both spring and autumn surveys. For this method, the replacement ratios, defined as the biomass index in the current year divided by the average biomass indices from the previous 5 years was calculated. Autumn and spring survey biomass indices and total landings and total catch were used to compute the relative exploitation rates, defined as the catch in the current year divided by the 3 year average survey biomass index for the current year and the previous and following years. These relative exploitation rates (or relative F) may be considered a proxy for F. The relationship between replacement ratios and relative F was evaluated by a linear regression of the Log_e replacement ratio on Log_e relative F. None of the relationships were significant and some were actually positive. This method was also attempted for the aggregate skate landings/catch for the four regions. These model runs were also unsuccessful.

SPR- Based Reference Points

SPR-based reference points for three skate species, barndoor, winter, and thorny, were derived from life-history parameters and fitted Beverton-Holt stock recruit relationships (Appendix 3). Estimated overfishing reference points for these three species are $F_{25\%}$, $F_{37\%}$, and $F_{46\%}$, respectively. Future assessments could estimate comparable F's from mean length models (SEINE, e.g.), or from age-specific assessment models provided discards and landings could be disaggregated to species level. Estimates of overfished reference points are also SPR based, and are defined in terms of depletion, i.e. the proportion of spawners relative to unexploited levels. For barndoor, winter, and thorny skates, the depletion reference points are 0.20, 0.27, and 0.32, respectively. Future assessments could determine stock status by comparing these depletion levels either with depletion in the surveys or from a stock assessment model that incorporates information about maturity. There are several important caveats for the methods used in this working paper, namely, that a fixed value of M was assumed for all ages, that the errors in variables problem was ignored in fitting the stock recruit relationship (*status quo*), and that no fishing is assumed to occur prior to the age of recruitment. The sensitivity to the assumed M value is addressed by exploring alternative values. If any fishing were to occur prior to the age of recruitment, then the estimated slope at the origin (*a* in the Beverton-Holt function) would be biased low, leading to an SPR reference point having a positive bias.

Reference Point Recommendation

In general for skates, no new measurable alternative BRPs were identified or recommended. Until new models are constructed using the new catch by species information, the existing overfishing definitions, using information updated through 2007/2008 (except for barndoor skate), will remain in place (Table 43; Figure 39). For barndoor skate, the reference point estimates will not be updated through 2007/2008 because barndoor skate survey indices were extremely low during most of the time series and have been increasing recently (Table 40).

Under the current definition, a stock of skates is designated as overfished when the three year moving average of the NEFSC survey index is less than $B_{THRESHOLD}$. For each of the skate stocks, estimates of the three year moving average survey index are provided in Table 40.

Overfished status determinations can be made by comparing the survey index estimates (Table 40) to the recommended biomass-based reference points (Table 43).

The overfishing status determinations are shown in Table 41 (See additional description in the earlier section labeled "Current Reference Points".

Research Recommendations

1) Given the new information on catch by species, efforts should be made to use a more complex model such as Stock Synthesis.
2) The identification of the species composition of the skate catch should be improved.
3) Age and growth studies, for all seven species in the complex, should be continued.
4) Fecundity studies, for all seven species in the complex, are needed. Use of life history models requires these data, and may prove useful in establishing biological reference points for the skate species.
5) Estimates of commercial and recreational fishery discard mortality rates, for different fishing gears and coastal regions and/or bottom types, for all seven species in the complex, are needed.
6) Studies of the stock structure of the species in the skate complex are needed to identify unit stocks. Stock identification studies, especially for barndoor, thorny, winter, and little skate, are needed.

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