B. ASSESSMENT OF NORTHEAST SKATE SPECIES COMPLEX

Report of the SAW Southern Demersal Working Group
(Members are listed at front of Report)

(EDITOR'S NOTE: In this skate assessment report, tables and figures are numbered according to Term of Reference, TOR. For example, Figure 3.1 would be the first figure for TOR 3.)

1.0 EXECUTIVE SUMMARY AND TERMS OF REFERENCE

TOR 1. Characterize the commercial and recreational catch including landings and discards.

The principal commercial fishing method in the directed skate fishery is otter trawling. Skates are frequently taken as bycatch during groundfish trawling and scallop dredge operations and discarded. Recreational and foreign landings are currently insignificant. There are few regulations governing the harvesting of skates in U.S. waters. Skates have been reported in New England fishery landings since the late 1800s. Reported commercial fishery landings, primarily from off Rhode Island, however, 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 primarily from the distant water fleet, but declined quickly during the 1970s, falling to 800 mt in 1981. Since that time, landings have increased, partially in response to increased demand for lobster bait, and more significantly, to the increased export market for skate wings. Landings are not reported by species, with over 99% of the landings reported as "unclassified skates." Wings were likely taken from large-bodied skates (winter, thorny and barndoor), with winter and thorny skate 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 increased to 12,900 mt in 1993 and then declined somewhat to 7,200 mt in 1995. Landings increased again and the 2004 reported commercial landings of 16,073 mt were the highest on record. Estimates of discards suggest they may be 2-4 times larger than the average landings. The commercial fishery discard mortality rates by species are unknown.

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. 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.

TOR 2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.

Fishing Mortality

(EDITOR'S NOTE: MODEL-BASED FISHING MORTALITY ESTIMATES WERE PROPOSED; BUT THEY WERE REJECTED BY THE REVIEW PANEL)

Total Biomass

NEFSC survey data were the primary source of information to index biomass of skate species. Indices of winter skate abundance and biomass from the NEFSC autumn surveys were stable, but below the time series mean, during the late 1960s and 1970s. 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. Indices of little skate abundance and biomass from the NEFSC spring 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. Indices of barndoor skate abundance and biomass from the NEFSC autumn surveys were at the highest values during early to late 1960s, and then declined to 0 fish per tow during the early 1980s. Since 1990, autumn survey indices have steadily increased, with the survey nearing the peak values found in the 1960s. NEFSC autumn survey indices for thorny skate have declined continuously over the last 40 years. NEFSC indices of thorny skate abundance have declined steadily since the late 1970s, reaching a historically low value in 2005 is less than10% of the peak observed in the 1970s. Indices of smooth skate abundance and biomass from the NEFSC autumn survey were at a peak during the late 1970s. NEFSC survey indices declined during the 1980s, before stabilizing during the early 1990s at about 25% of the values of the 1970s. NEFSC spring and autumn survey indices for clearnose skate increased from the mid-1980s through 2000 and have since declined to about average values. 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.

Spawning Stock Biomass:

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. 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. 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. The decline in thorny skate SSB indices is more pronounced than for the total biomass index. Smooth skate SSB indices are very variable, but exhibit a slight decline over the time series. Clearnose skate SSB has increased over the time period. Rosette skate SSB has been variable but has generally increased.

TOR 3. Either update or redefine biological reference points (BRPs; proxies for BMSY and FMSY), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs.

Existing Reference Points:

Biomass reference points (Figure B2) are based entirely on survey data because commercial catches are not available by species. For all species except barndoor, the B_{msy} proxy (B_{target}) is estimated as the 75th percentile of the appropriate survey series for that species (see Summary Status Table). For barndoor skate, the B_{msy} proxy is the average of the autumn survey biomass indices from a short period, 1963-1966. This period is used for barndoor skates because the survey captured few barndoor skates for a protracted period after these years. The stocks are declared to be overfished when the three-year moving average of the NMFS trawl survey index (mean weight per tow) is less than one half of the 75th percentile of mean weight per tow of the reference survey series for that species ($B_{threshold}$).

The overfishing definition is based on changes in survey biomass indices. In any year, if the three-year moving average of the survey biomass index for a skate species declines by more than a critical percentage from the previous year's moving average, then fishing mortality is assumed to be greater than F_{msy} and overfishing is assumed to be occurring for that skate species. The critical percentages for each species are given in the Summary Status Table (below).

Proposed Reference Points:

(EDITOR'S NOTE: NEW REFERENCE POINTS WERE PROPOSED; HOWEVER THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

TOR 4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).

Summary Status Table – Northeast Skate Species – Basis: **Existing Reference Points**

Species	Series	Btarget	Bthresh	Current	Status	Target Percent	Current	Status
Winter	GOM-MA Off Autumn 67-98	6.46	3.23	3.34	Not Overfished	-20	-22.9	Overfishing
Little	GOM-MA All Spring 82-99	6.54	3.27	4.59	Not Overfished	-20	-15.9	No Overfishing
Barndoor	GOM-SNE Off Autumn 63-66	1.62	0.81	0.96	Not Overfished	-30	9.8	No Overfishing
Thorny	GOM-SNE Off Autumn 63-98	4.41	2.20	0.56	Overfished	-20	-11.2	No Overfishing
Smooth	GOM-SNE Off Autumn 63-98	0.31	0.16	0.18	Not Overfished	-30	3.7	No Overfishing
Clearnose	MA All Autumn 75-98	0.56	0.28	0.63	Not Overfished	-30	-16.2	No Overfishing
Rosette	MA Offshore Autumn 67-98	0.029	0.015	0.049	Not Overfished	-60	9.7	No Overfishing

TOR 5. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC-reviewed assessments.

Completed. See Section 5.

TOR 6. Examine the NEFSC Food Habits Database to estimate diet composition and annual consumptive demand for seven species of skates for as many years as feasible.

Most skates are benthivorous in their feeding habits. A clear prominence on *Cancer* crabs, other crabs, amphipods, polychaetes and similar benthic macrofauna and megafauna was apparent in the diets of these skates. Some of the larger skates- barndoor, thorny, and winter- can be piscivorous, particularly with ontogeny. The vast majority of fish (or fish-like) prey for these skates were small pelagic fishes and squids.

Save winter and little skates, overall consumption by most skate stocks is a relatively small amount of biomass flow. Most total consumption by any particular species of skate was scaled singularly by the abundance of that species. The vast majority of consumptive removals by all skates except little and winter was < 20 MT per year.

As an aggregate group, skates consume a very small fraction of the total energy flow in the ecosystem. Skate consumptive removal is two to three orders of magnitude lower than biomass or production of skate prey. When abundance estimates are scaled by gear efficiency, it is possible that skates could consume a notable fraction of forage fish and squid biomass relative to what is removed by a fishery. Yet most of those forage fish stocks are at relatively high levels of abundance.

2.0 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 last 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.

Following SARC 30, an FMP was developed 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. The FMP prohibited possession of barndoor and thorny skate, as well as smooth skate from the Gulf of Maine. 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. Biomass reference points developed at SARC 30 were maintained, but new fishing mortality reference points were developed.

3.0 TOR 1. Characterize the commercial and recreational catch including landings and discards

3.1 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 B1.1, Figure B1.1). Landings then increased markedly, 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 2004 reported commercial landings of 16,073 mt were the highest on record (Table B1.1, Figure B1.1).

United States landings of skates are reported in all months (Table B1.2). 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 B1.3). 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 B1.4). 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 are generally not reported by species, with over 99% of the landings reported as Aunclassified skates@ until the FMP was implemented in September of 2003 (Table B1.5). 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 B1.6). For example, in 2004, barndoor were landed in Virginia which is too far south for barndoor skate.

3.2 Commercial Fishery Discards

Discard estimates from SAW/SARC 30 were revised in this assessment. The previous method, which employed primary species groups to bin the discard data, was found to be a biased estimator (NEFSC 2006). Instead, the ratio-estimator used in this assessment is based on the methodology described in Rago et al. (2005). 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, season, and geographic region. Each of these attributes is an observable property and easily defined within existing data bases. Moreover, it is not dependent on ambiguous properties such as "target species" or imprecise self-reported attributes such as area fished.

The discard ratio for spiny dogfish 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 dogfish 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 stratum is the product of the estimate discard ratio R and the total landings for the fishery in stratum h, i.e., $D_h = R_h K_h$.

Annual estimated discards by fishery for 1989-2005 are summarized in Table B1.7. Total discards in 1990 were estimated to be about 80,000 mt. Most of this came from the otter trawl fishery. However, in the first two years, there were no estimates of discards from the scallop dredge fishery, which represent a significant portion in later years. The peak in the estimates was in 1992 at almost 90,000 mt, almost half came from the scallop dredge fishery. Estimates have since declined except for 2002 which was inflated by one blue crab pot trip which is probably not representative of that fishery. Estimates in recent years are still higher than reported landings but are much lower than the estimates from the early 1990s. This is likely due to reduced effort in the multispecies groundfish fishery as well as the scallop dredge fishery. Sampling of the three main gear types (otter trawl, sink gill net, and scallop dredge) has improved in recent years (Tables B1.8-B1.10).

The discard estimates were not dis-aggregated to skate species because species identification is uncertain in the Domestic Observer Program. Catches of skates by species were mapped to determine if the data were potentially useful. Winter and little skate distributions look reasonable (Figures B1.2-B1.3). Barndoor distribution from the observer data shows fairly substantial amounts off Virginia and North Carolina (Figure B1.4). These are unlikely to be correctly identified. The distributions of thorny and smooth are also curious showing catches in the Mid-Atlantic (Figures B1.5-B1.6). The reverse is true for clearnose and rosette (Figures B1.7-B1.8). These two species have a southern distribution and the maps show considerable amounts of fish found in the Gulf of Maine. The length compositions of kept and discarded fish also show that there are identification problems (Figures B1.8-B1.15). In particular, the length frequency for kept little skate has fish that are 60 to 80 cm which is a larger size than this species can attain. The same thing occurs for smooth and rosette showing larger sizes than is possible.

3.3 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 times 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.

4.0 TOR 2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years.

4.1 Research survey data – Total Stock Biomass

Indices of relative abundance from NEFSC bottom trawl surveys form the basis for most of the conclusions about status of the seven species in the skate 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 (Figure B2.1). A spring survey was started in 1968 with stations <= 27 m added in 1975 (Figures B2.2-2.4). 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, but then increased 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 B2.5A). 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 B2.5B,C). The biomass of large sized skates steadily declined from the mid-1980s to the mid-1990s and has since been stable (Figure B2.5B). 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 B2.5C).

Indices of relative abundance for some of the species have also been developed from MADMF and CTDEP research surveys.

The previous SARC computed variance estimates for the survey indices assuming a normal error distribution. A recommendation was made to explore alternate error distributions since this assumption may not hold at very low stock sizes and results in confidence intervals which are below zero. Another alternative to assuming any error distribution is to use bootstrap methods. The bootstrap methodology of Smith (1997) was implemented using the Splus software written by Stephen Smith (DFO, Halifax). In order to bootstrap the NEFSC survey data, some strata had to be combined to ensure that at least two tows were made in each stratum during each year (Table B2.1). The second figure in each species section shows the stratified mean without combining strata, the mean combining strata and the bootstrapped mean.

Winter skate

NEFSC spring and autumn bottom trawl surveys indicate that winter skate are most abundant in the Georges Bank (GBK) and Southern New England (SNE) offshore strata regions, with few fish caught in the Gulf of Maine (GOM), or Mid-Atlantic (MA) regions (NEFSC 2000; Figure B2.6). In the NEFSC spring survey offshore strata (1968-2006), 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 (1963-2005), 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 B2.2-B2.3).

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 (1992-2006) 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 B2.4). 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 (Figure B2.7). The NEFSC scallop dredge survey also catches winter skates mostly on Georges Bank (Figures B2.8-B2.9). The scallop survey also does not sample in the Gulf of Maine and on the very shallowest portions of Georges Bank.

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 B2.10). Winter skate indices increased to the time series mean by 1980, and then reached a peak during the mid 1980s. Winter skate 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 (Figures B2.10). The combining of strata did not have much impact on the stratified mean (Figures B2.11-B2.14).

The minimum length of winter skate caught in NEFSC surveys is 15 cm (6 in), and the largest individual caught was 116 cm (46 in) total length, during the 1985 spring survey on Georges Bank (Tables B2.2-B2.4). The median length of the survey catch has ranged from 28 cm in the 2003 winter survey to 79 cm in the 1978 spring survey and the 1985 autumn survey. The median length of the survey catch generally declined from 1979 to the mid-1990s in both the spring and autumn surveys, increased through 2002, and then declined slightly to currently remain about 45-52 cm (18-20 inches)(Figure B2.15). Length frequency distributions from the NEFSC spring and autumn surveys show several modes, most often at 40, 60, and 80 cm (Figures B2.16-B2.20). The spring survey length distributions show large modes at about 40 cm during the mid-1980s through the mid 1990s, suggesting strong recruitment during that period.

Truncation of the length distributions is evident in the NEFSC spring and autumn series since 1990.

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.4. Given that the strata on Georges Bank were not sampled in some years, the set for bootstrapping was limited to Southern New England to the Mid-Atlantic (Table B2.1). This created more of a difference between the original mean, with usually a lower index when Georges Bank was included in the original (Figure B2.21-B2.22). The indices of both abundance and biomass fluctuated without trend through the series.

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some winter skate (Figures B2.23-B2.24) while the original was the entire scallop survey strata set. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance was high in the mid-1980s, declined through the 1990s, increased through 2000 and then declined.

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 1978-2006. 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 2006 (Figure B2.25). 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 1984-2006 (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 B2.26).

Little skate

NEFSC bottom trawl surveys indicate that little skate are abundant in the inshore and offshore strata in all regions of the northeast US coast, but are most abundant on Georges Bank and in Southern New England (NEFSC 2000, Figure B2.27). In the NEFSC spring surveys (1976-2006), the annual total catch of little skate has ranged from 3,512 fish in 1986 to 16,406 fish in 1999 (Table 2.5). In the NEFSC autumn surveys (1975-2005), the annual total catch of little skate has ranged from 1,124 fish in 1993 to 6,523 fish in 2003 (Table 2.6). 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 B2.5-B2.6).

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 (1992-2006) 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 B2.7). 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 (Figure B2.28). The NEFSC scallop dredge survey also catches little skates in all areas of sampling (Figures B2.29-B2.30). 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 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 B2.31). Autumn survey indices have been relatively stable over the duration of the time series, with a slight increase in recent years (Figure B2.31). The application of the NEFSC gear conversion factors to spring survey indices decreased the indices in 1981 and earlier years by 75 percent. The combining of strata had slightly more impact for little skate than for winter skate, since many of the inshore strata were combined (Figures B2.32-B2.35).

The minimum length of little skate caught in NEFSC surveys is 6 cm (3 in), and the largest individual caught was 62 cm (24 in) total length, during the 1978 autumn survey on Georges Bank. The median length of the survey catch has ranged from 31 cm in the 1979 and 1987 spring surveys to 44 cm, most recently in the 2005 autumn survey. The median length of the survey catch has been generally stable over the duration of the spring and autumn surveys and is currently about 42 cm in the spring and 43 cm in the autumn (17 inches)(Figure B2.36). Length frequency distributions from the NEFSC spring and autumn surveys show several modes, most often at 10, 20, 30, and 45 cm, which may represent ages 0, 1, 2, and 3 and older little skate (Figures B2.37-B2.40).

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.7. Given that the strata on Georges Bank were not sampled in some years, the set for bootstrapping was limited to Southern New England to the Mid-Atlantic (Table B2.1). This created more of a difference between the original mean, with usually a higher index when Georges Bank was included in the original (Figure B2.41-B2.42). The indices of both abundance and biomass declined through 2000, increased for a few years and subsequently declined..

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some little skate (Figures B2.43-B2.44) while the original was the entire scallop survey strata set. There are only differences in the early part of the time series when more strata were sampled. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance indices increased to a peak in 2000 and have subsequently declined.

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 1978-2006 (Figure B2.45). 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 1984-2006 (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 over the 1984-2006 time series followed by a decline (Figure B2.46).

Barndoor skate

NEFSC bottom trawl surveys (Figure B2.47) indicate that barndoor skate are most abundant in the Gulf of Maine, Georges Bank, and Southern New England offshore strata regions, with very few fish caught in inshore (< 27 meters depth) or Mid-Atlantic regions. Bigelow and Schroeder (1953), however, noted that historically barndoor skate were found in inshore waters to the tide-line, and in depths as great as 400 meters off Nantucket. In the NEFSC spring surveys (1968-2006), the annual total catch of barndoor skate has ranged from 0 fish (several years during the 1970s and 1980s) to 196 fish in 2006 (Table B2.8). In the NEFSC autumn surveys (1963-2005), 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 B2.9). 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 (Tables B2.8-B2.9).

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 (1992-2006) 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 1999 (Table B2.10). 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 (Figure B2.48). The NEFSC scallop dredge survey also catches barndoor skates primarily on Georges Bank (Figure B2.48). 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 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 B2.49). The combining of strata did not have much impact on the stratified mean (Figures B2.50-B2.53).

The minimum length of barndoor skate caught in NEFSC surveys is 20 cm (8 inches), and the largest individual caught was 136 cm (54 in) total length, during the 1963 autumn survey in the Gulf of Maine. The median length of the survey catch has ranged from 20 cm in the 1985 spring survey to 119 cm in the 1972 spring survey. The median length of the survey catch has been stable in recent years in both the spring and autumn surveys, and is currently 70-75 cm (28-30 in; Figure B2.54). Length frequency distributions from the NEFSC spring and autumn surveys illustrate the decline in abundance of barndoor skate to survey catches of zero during the 1980s (Figures B2.55-B2.59). Recent catches have included individuals as large as those recorded during the peak abundance of the 1960s, and the large number of fish between 40 and 80 cm evident during the 1960s is now apparent in recent surveys.

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.10. Given that the strata on Georges Bank were not sampled in some years, the set for bootstrapping was limited to Southern New England to the Mid-Atlantic (Table B2.1). This created more of a difference between the original mean, with usually a lower index when Georges Bank was included in the original (Figure B2.60-B2.61). The indices of both abundance and biomass have increased substantially from 1993 to 2006. The NEFSC winter survey length frequency distributions for indicate a significant increase in the abundance of barndoor skate at lengths less than 80 cm (Figure B2.62).

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some barndoor skate (Figures B2.63-B2.64) while the original was the entire scallop survey strata set. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance indices increased consistently while the biomass indices have been more variable.

Thorny skate

NEFSC bottom trawl surveys indicate that thorny skate are most abundant in the Gulf of Maine and Georges Bank offshore strata regions, with very few fish caught in inshore (< 27 meters depth), Southern New England, or Mid-Atlantic regions (Figure B2.65). In the NEFSC spring surveys (1968-2006), the annual total catch of thorny skate has ranged from 29 fish in 2006 to 574 fish in 1973 (Table 2.11). In the NEFSC autumn surveys (1963-2005), the annual total catch of thorny skate has ranged from 35 fish in 2005 to 874 fish in 1978 (Table 2.12). Calculated on a per tow basis, these spring and autumn survey catches equate to maximum stratified mean number per tow indices for the GOM-SNE offshore strata of about 2 to 3 fish, or about 6.0 kg, per tow during the early 1970s (Tables B2.11-2.12).

The NEFSC scallop dredge survey also catches thorny skates primarily on the edges of Georges Bank (Figure B2.66). 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. A summer shrimp survey is conducted in the Gulf of Maine which also catches thorny skate (Figure B2.66). Indices from this survey have not been updated.

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 and1.8 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 in 2005 and 2006 that are less than10% of the peak observed in the 1970s (Figure B2.67). The combining of strata did not have much impact on the stratified mean (Figures B2.68-B2.71).

The minimum length of thorny skate caught in NEFSC surveys is about 10 cm (4 inches), and the largest individual caught was 111 cm (44 inches) total length, most recently during the 1977 spring survey on Georges Bank (Tables B2.11-B2.12). The median length of the survey catch has ranged from 23 cm in the 2003 autumn survey to 63 cm in the 1971 autumn survey. The median length of the survey catch has trended downward through most of the survey time series, but has been stable in recent years in autumn surveys, and is currently 40-50 cm (16-20 inches; Figure B2.72). Length frequency distributions from the NEFSC spring and autumn surveys show a pattern of decline in abundance of larger individuals consistent with an increase in total mortality over the survey time series (Figures B2.73-B2.77).

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some thorny skate (Figures B2.78-B2.79) while the original was the entire scallop survey strata set. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance indices declined from a peak in 1986 while the biomass indices declined since 2001.

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 1978-2006. 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 B2.80).

Smooth skate

NEFSC bottom trawl surveys indicate that smooth skate are most abundant in the Gulf of Maine and Georges Bank offshore strata regions, with very few fish caught in inshore (< 27 meters depth), Southern New England, or Mid-Atlantic regions (Figure B2.81). In the NEFSC spring surveys (1968-2006), the annual total catch of smooth skate has ranged from 12 fish in 1996 to 179 fish in 1973 (Table B2.13). In the NEFSC autumn surveys (1963-2005), the annual total catch of smooth skate has ranged from 10 fish in 1976 to 130 fish in 1978 (Table B2.14). 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 B2.13-B2.14).

The NEFSC scallop dredge survey also catches smooth skates primarily on the edges of Georges Bank (Figure B2.82). 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. A summer shrimp survey is conducted in the Gulf of Maine which also catches smooth skate (Figure B2.82). Indices from this survey have not been updated.

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 B2.83). 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 combining of strata did not have much impact on the stratified mean (Figures B2.84-B2.87).

The minimum length of smooth skate caught in NEFSC surveys is about 8 cm (3 inches), and the largest individual caught was 73 cm (29 inches) total length, during the 2000 autumn survey on Georges Bank (Tables B2.13-B2.14). The median length of the survey catch has ranged from 26 cm in the 1993 autumn survey to 53 cm in the 1971 autumn survey. The median length of the survey catch in the GOM-SNE offshore region shows no trend over the full survey time series, and is currently at about 40 cm (16 in) (Figure B2.88). Length frequency distributions from the NEFSC spring and autumn surveys in the GOM offshore region show modes at 30 and 50 cm (Figures B2.89-B2.93). The relatively high abundances evident in the 1969-1983 spring surveys at the larger mode may represent the accumulated abundance at several older ages. Truncation of the larger mode is evident in the spring distributions during the 1980s and most of the 1990s. The 1999 spring survey length frequency distribution indicated strong recruitment in the region.

The difference between the original mean and the combined strata mean in the scallop survey was due to the bootstrapped mean consisting of only strata which caught some smooth skate (Figures B2.94-B2.95) while the original was the entire scallop survey strata set. There are no biomass estimates from 1985 through 2000 since no weights were taken at sea and the survey in 1999 was completed on a commercial scalloper and therefore the data are not comparable. Abundance indices were low at the beginning of the time series and have since increased.

Clearnose skate

NEFSC bottom trawl surveys indicate that clearnose skate are most abundant in the Mid-Atlantic offshore and inshore strata regions, with very few fish caught in Southern New England and no fish caught in other survey regions (Figure B2.96). In the NEFSC spring surveys (1976-2006), the annual total catch of clearnose skate has ranged from 9 fish in 1979 to 136 fish in 1993 (Table B2.15). In the NEFSC autumn surveys (1975-2005), the annual total catch of clearnose skate has ranged from 19 fish in 1983 to 221 fish in 2001 (Table B2.16). 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 B2.15-B2.16).

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 (1992-2006) 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 B2.17). 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 (Figure B2.97).

NEFSC spring and autumn survey indices for clearnose skate have been increased from the mid-1980s through 2000 and have since declined to about average values (Figure B2.98). The combining of strata had more impact for clearnose skate than for other species, since many of the inshore strata were combined and the most southern strata were combined into one stratum (Figures B2.99-B2.102).

The minimum length of clearnose skate caught in NEFSC surveys is about 10 cm (4 inches), and the largest individual caught was 93 cm (33 in) total length, during the 1992 and 2000 winter surveys in the Mid-Atlantic Bight region (Tables B2.15-B2.17). The median length of the survey catch has ranged from 41 cm in the 1980 spring survey to 67 cm in the 1995 spring survey. The median length of the spring survey catch has increased over the time series, from about 50 cm during the late 1970s to at about 60 cm in recent years (24 inches; Figure B2.103). The median length of the autumn survey catch has been stable over the time series, and is also at about 60 cm. Length frequency distributions from the NEFSC spring and autumn surveys show a consistent mode at 60-70 cm that may represent the accumulated abundance of several older ages (Figures B2.104-B2.107).

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.17. Given that the strata on Georges Bank were not sampled in some years, the set for bootstrapping was limited to a few Southern New England strata and the Mid-Atlantic (Table B2.1). This created more of a difference between the original mean, with usually a lower index when Georges Bank was included in the original (Figure B2.108-B2.109). The indices of both abundance and biomass have generally fluctuated without trend.

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 1984-1998 (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 (Figure B2.110).

Rosette skate

NEFSC bottom trawl surveys indicate that rosette skate are most abundant in the Mid-Atlantic offshore strata region, with very few fish caught in Southern New England and Georges Bank and no fish caught in the Gulf of Maine or inshore (Figure B2.111). In the NEFSC spring surveys (1968-2006), the annual total catch of rosette skate has ranged from 0 fish, in 1970 and1984, to 70 fish in 1977 (Table B2.18). 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 B2.19). 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 B2.18-B2.19).

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 (1992-2006) 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 B2.20). 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 (Figure B2.112).

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 B2.113). The combining of strata had more impact for rosette skate than for other species, since the deep offshore strata were combined with the next deepest stratum and the most southern strata were combined into one stratum (Figures B2.114-B2.117).

The minimum length of rosette skate caught in NEFSC surveys is about 7 cm (3 inches), and the largest individual caught was 57 cm (22 inches) total length, during the 1971 spring survey in the Mid-Atlantic Bight region (Tables B2.18-B2.20). The median length of the survey catch has ranged from 18 cm in the 1985 spring survey to 57 cm in the 1971 spring survey, during which only 1 rosette skate was caught. The median length of the survey catch has been stable over the spring and autumn time series at about 36-37 cm (14 inches; Figure B2.118). Length frequency distributions from the NEFSC spring and autumn surveys show a consistent mode at 30-40 cm (Figures B2.119-B2.123).

The strata set used for bootstrapping the winter survey differed from the standard consistent strata set used for the information in Table 2.17. Given that the strata on Georges Bank were not sampled in some years and the deepwater strata which are important for rosette skate were not sampled until 1998, the set for bootstrapping was limited to a few Southern New England strata and the Mid-Atlantic from 1998 on (Table B2.1). This created more of a difference between the original mean, with usually a lower index when Georges Bank was included in the original (Figure B2.124-B2.125). The indices of both abundance and biomass increased through 2002 and have subsequently declined.

4.2 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 2.21). 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. As it is generally the longest running series, the autumn survey was used for all species except little skate. For little skate, the spring series from 1982 on was used; this date was chosen 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 B2.22; Figure B2.126). 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 B2.22; Figure B2.126). 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 B2.22; Figure B2.126). The decline in thorny skate SSB indices is more pronounced than for the total biomass index (Table B2.22; Figure B2.126). Smooth skate SSB indices are very variable, but exhibit a slight decline over the time series (Table B2.22; Figure B2.126). Clearnose skate SSB has increased over the time period (Table B2.22; Figure B2.126). Rosette skate SSB has been variable but has generally increased (Table B2.22; Figure B2.126).

4.3 Fishing mortality estimates

The length-based mortality estimators of Beverton and Holt (1956) and Hoenig (1987) were considered for the estimation of fishing mortality rates for winter, little, barndoor, thorny, and clearnose skates from NEFSC spring and autumn length frequency distributions. Only these five species were analyzed since age and growth information is available for these species and unavailable for rosette and smooth (Table 2.21).

(EDITOR'S NOTE: MODEL-BASED FISHING MORTALITY ESTIMATES WERE PROPOSED; THEY ARE NOT SHOWN BECAUSE THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

4.3.1 Mortality from Mean Length Gedamke and Hoenig (2006) Method

Gedamke and Hoenig (2006) developed a method to estimate mortality from mean length data in nonequilibrium situations. 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.

(EDITOR'S NOTE: FISHING MORTALITY ESTIMATES WERE PROPOSED; THEY ARE NOT SHOWN BECAUSE THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

4.3.2 Thorny Skate Length Tuned Model (LTM)

Introduction

A forward projecting length tuned model (LTM) was modified to fit only survey abundance indices and survey size information for the estimation of fishing mortality rates. Results from this analysis were compared to the Hoenig length based estimates to help determine the influences of assuming equilibrium conditions. The LTM model does not assume equilibrium conditions since fishing mortality estimates in year n will influence the population size structure in year n+1. However the initial population in year one of the model is calculated assuming equilibrium conditions.

Herein we used a simple forward projecting age-based model tuned with age-3 recruitment (estimated from fish in the survey that were between 35 and 45 cm), survey numbers of 40+ cm fish and length frequency of the 40+ cm fish. The Length Tuned Model was developed in the AD model builder framework. The model estimates fishing mortality and relative recruitment changes each year, fishing mortality to produce the initial population length frequency (F_{start}), and Qs for each survey index. Initial population abundance was fixed since no catch information can be used to scale the model in terms of abundance.

(EDITOR'S NOTE: RESULTS FROM THIS MODEL ARE NOT SHOWN BECAUSE THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

5.0 TOR 3. Either update or redefine biological reference points (BRPs; proxies for BMSY and FMSY), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs.

5.1 Current Reference Points

The existing biomass reference points were developed at SARC 30 (NEFSC 2000) with B_{msy}Proxy formulated as the 75th percentile of the given time series of each species, except barndoor (Table B3.1) 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.

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.

5.2 Alternative Reference Points

(EDITOR'S NOTE: ALTERNATIVE REFERENCE POINTS WERE PRESENTED; THEY ARE NOT SHOWN BECAUSE THEY WERE NOT ACCEPTED BY THE REVIEW PANEL)

6.0 TOR 4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3).

6.1 Current Reference Points

For winter skate, the 2003-2005 NEFSC autumn survey biomass index average of 3.34 kg/tow is below the biomass target of 6.46 kg/tow but above the threshold reference point of 3.23 kg/tow (Figure B4.1). Winter skate is not overfished. The 2003-2005 average of 3.34 kg/tow was more than 20% below the 2002-2004 average of 4.34 kg/tow (Table B4.1), therefore overfishing is occurring for winter skate.

For little skate, the 2004-2006 NEFSC spring survey biomass index average of 4.59 kg/tow is below the biomass target of 6.54 kg/tow but above the threshold reference point of 3.27 kg/tow (Figure B4.1). Little skate is not overfished. The 2004-2006 average of 4.56 kg/tow was less than 20% below the 2003-2005 average of 5.65 kg/tow (Table B4.1), therefore overfishing is not occurring for little skate.

For barndoor skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.96 kg/tow is below the biomass target of 1.62 kg/tow but above the threshold reference points of 0.81 kg/tow(Figure B4.1). Barndoor skate is not overfished. The 2003-2005 average of 0.96 kg/tow was above the 2002-2004 average of 0.88 kg/tow (Table B4.1), therefore overfishing is not occurring for barndoor skate.

For thorny skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.56 kg/tow is below the biomass target and threshold reference points of 4.41 kg/tow and 2.20 kg/tow (Figure B4.1). Thorny skate is overfished. The 2003-2005 average of 0.56 kg/tow was less than 20% below the 2002-2004 average of 0.63 kg/tow (Table B4.1), therefore overfishing is not occurring for thorny skate.

For smooth skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.18 kg/tow is below the biomass target of 0.31 kg/tow but above the threshold reference point of 0.16 kg/tow(Figure B4.1) . Smooth skate is not overfished. The 2003-2005 average of 0.18 kg/tow was above the 2002-2004 average of 0.17 kg/tow (Table B4.1), therefore overfishing is not occurring for smooth skate.

For clearnose skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.63 kg/tow is above the biomass target and threshold reference points of 0.56 kg/tow and 0.28 kg/tow (Figure B4.1). Clearnose skate is not overfished. The 2003-2005 average of 0.63 kg/tow was less than 30% below the 2002-2004 average of 0.75 kg/tow (Table B4.1), therefore overfishing is not occurring for clearnose skate.

For rosette skate, the 2003-2005 NEFSC autumn survey biomass index average of 0.049 kg/tow is above the biomass target and threshold reference points of 0.029 kg/tow and 0.015 kg/tow (Figure B4.1) . Rosette skate is not overfished. The 2003-2005 average of 0.049 kg/tow was above the 2002-2004 average of 0.045 kg/tow (Table B4.1), therefore overfishing is not occurring for rosette skate.

7.0 TOR 5. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC-reviewed assessments.

1) The commercial fishery statistics sampling programs should be adapted to report skates landings by species.

Since the implementation of the Skate Complex FMP, there is a requirement to report landings of skates by species. However, training is needed to improve the accuracy of the reporting.

2) Commercial fishery size composition data should be collected by species.

Observers are collecting landings and discarded size composition by species. However, more training is needed to improve the accuracy of the data.

3) Sea sampling of directed skate landings and skate bycatch should be increased, and the identification of the species composition of the skate catch improved.

Observer coverage was increased in 2004 and 2005 primarily for the multi-species groundfish fisheries which have a large bycatch of skates. Observer coverage of scallop fisheries has improved as well. More training is needed to improve the accuracy of the species identification.

4) Age and growth studies, for all seven species in the complex, are needed.

Studies have been conducted for five of the seven species (Frisk 2004,Gedamke 2006, Gedamke et al. 2005, Gelschleiter 1998, Sulikowski et al. 2005) and samples have been collected by NEFSC for the other two species.

5) Maturity and 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.

Maturity studies estimating L_{50} have been conducted for barndoor (Gedamke 2005), winter and little (Frisk 2004), and thorny (Sulikowski et al. 2006). Sosebee (2005) estimated size at first maturity for all seven species.

6) 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.

Not completed.

7) 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.

Not completed.

8) Explore possible stock-recruit relationships by examination of NEFSC survey data. A simultaneous examination of the species in the complex may prove a useful first step.

Stock-recruit relationships have been examined for five of the species in the complex. The second method is not appropriate for skates.

9) Investigate trophic interactions between skate species in the complex, and between skates and other groundfish.

Considerable progress has been made.

10) Further consideration of the validity of NEFSC trawl survey catchability conversion factors for skate species is needed (diel, gear, vessel).

Not completed.

11) Investigate the influence of annual changes in water temperature or other environmental factors on shifts in the range and distribution of the species in the skate complex. Establish the bathymetric distribution of the species in the complex off the U.S. Northeast coast.

Work has been done on winter skate to explore the changes in abundance between the Scotian Shelf and Georges Bank (Frisk et al, in review).

12) Investigate the SEAMAP survey data for clearnose and rosette skate.

Not completed.

13) Investigate historical NEFSC survey data from the Albatross III cruises during 1948-1962 when they become readily accessible, as they may provide valuable historical context for long term trends in skate biomass.

Not completed.

14) Recalculate the error distributions of the survey indices using alternative distributions.

Instead of assuming an error distribution, confidence intervals were derived using the bootstrap methods of Smith (1997).

8.0 TOR 6. Examine the NEFSC Food Habits Database to estimate diet composition and annual consumptive demand for seven species of skates for as many years as feasible.

8.1 Introduction

Skate food habits were evaluated for all seven species in the skate complex. The total amount of food eaten and the type of food eaten were the primary food habits data examined. From these basic food habits data, diet composition, per capita consumption, total consumption, and the amount of prey removed by skates were calculated. Contrasts to total energy flows in the ecosystem and fishery removals of commercially targeted skate prey were conducted to fully address the Term of Reference.

8.2 Methods

Each skate was analyzed separately; emphasizing at least two if not three size classes as appropriate (Table B6.1). These size classes correspond to notable changes in diet and life history and also minimized low data density (i.e., number of stomachs sampled) for each size class. Each skate was analyzed for a particular bottom trawl survey strata set germane for each case (Table B6.1). For all the estimates, small winter skates (< 30 cm) were grouped with immature little skates. Estimates were analyzed on an annualized basis for each species, save instances were data density of stomach samples was too low. In those cases data were evaluated across 5-year time blocks. Although the food habits data collections started quantitatively in 1973, not all species of skates were sampled during the full extent of this sampling program. For more details on the food habits sampling protocols and approaches, see Link and Almeida (2000). Where data are available, they are used except in the case of little skate (see above for discussion on why those estimates begin in 1982). This sampling program was a part of the NEFSC bottom trawl survey program; for background and context, further details of the survey program can be found in Azarovitz (1981) and NEFC (1988).

Basic Food Habits

To estimate mean stomach contents (S_i), each skate had the total amount of food eaten (as observed from food habits sampling) calculated for each size class, temporal and spatial scheme. The denominator in the mean stomach contents (i.e., the number of stomachs sampled) was inclusive of empty stomachs. These means were weighted by the number of tows in a temporal and spatial scheme as part of a two-stage cluster design. Further particulars of these estimators can be found in Link and Almeida (2000). Units for this estimate are in g.

To estimate diet composition (D_{ij}), the amount of each prey item was summed across all skate stomachs. These estimates were then divided by the total amount of food eaten in a size class, temporal and spatial scheme, totaling 100%. These estimates are proportions and were only presented for those major prey comprising >85% of the total for each size class, temporal and spatial scheme. Further particulars of these estimators can be found in Link and Almeida (2000).

Consumption Rates

To estimate per capita consumption, the gastric evacuation rate method was used (Eggers 1977, Elliott and Persson 1978). There are several approaches used for estimating consumption, but this approach was chosen as it was not overly simplistic (as compared to % body weight; Bajkov 1935) or overly complex (as compared to highly parameterized bioenergetics models; Kitchell et al. 1977). There has been extensive use of these models (Durbin et al. 1983, Ursin et al. 1985, Pennington 1985, Overholtz et al. 1991, 1999, 2000, Tsou & Collie 2001a, 2001b, Link & Garrison 2002, Link et al. 2002, 2006, Overholtz & Link 2007). Units are in g year^{-1}.

Using the evacuation rate model to calculate consumption requires two variables and two parameters. The per capita consumption rate, C_i is calculated as:

$$C_i = 24 \cdot E_i \cdot \overline{S_i}^{\gamma}$$

where 24 is the number of hours in a day and the evacuation rate E_i is:

$$E_i = \alpha e^{\beta T} \quad ;$$

and is formulated such that estimates of mean stomach contents (S_i) and ambient temperature (T; here used as bottom temperature from the NEFSC bottom trawl surveys (Taylor and Bascunan 2000; Taylor et al. 2005) are the only data required. The parameters α and β are set as values chosen from the literature (Tsou and Collie 2001a, 2001b, Overholtz et al. 1999, 2000). The parameter γ is a shape function is almost always set to 1 (Gerking 1994).

To evaluate the performance of the evacuation rate method for calculating consumption, a simple sensitivity analysis was executed. The first phase of the sensitivity analysis fixed the two parameters and two variables, varying them one at a time. These varied across both the normal range from the data or literature and across proximal orders of magnitude to the normative range. The second phase varied all two pairs of values simultaneously, presented as surface plots to denote areas of rapid change and areas of relative stability (flat surfaces).

Scaling Consumption

After per capita consumption rates were estimated for each skate in a size class, temporal and spatial scheme, those estimates were scaled up to an annual and stock wide basis, C:

$$C = 365 \cdot C_i \cdot N_i$$

where N_i is the swept area estimate of abundance for each skate in each size class, temporal and spatial scheme and 365 is the number of days in a year.

This total consumption was partitioned for the major prey items of each skate by multiplying it by the diet composition of each prey (D_{ij}) to provide an estimate of prey removals by each skate. Both the total consumption and the amount of prey removed by each skate are presented as metric tons year^{-1}.

To evaluate the consumptive demands of a skate stock and the predatory removals of a skate stock in a broader ecosystem context, two contrasts were executed. First, comparisons of total consumption by each skate and by all skates combined were compared to the amount of energy flows for the entire ecosystem. These total energy flows were calculated in a recent energy budget (Link et al. 2006). Skate consumption is presented as a percentage of total energy flows in the ecosystem.

Second, the total amount of commercially targeted prey eaten by skates was treated as a removal and summed across all skates. These estimates were then compared to concurrently estimated fishery landings to provide an evaluation of potential competition between skates and fisheries on some of their major prey.

One concern of this approach is that the abundance estimates used to scale per capita skate consumption up to total population level consumption were not corrected for catchability or gear efficiency of the bottom trawl survey. To evaluate the potential effect of this factor, efficiencies of 100, 50, 25 and 10% were applied to estimates of total prey removal by all skates.

8.3 Results

Sensitivity analysis

The fixed values for all parameters were mean stomachs, S_i = 10, mean bottom temperature, T = 10, scaling coefficient α = 0.02, and exponent coefficient β = 0.111. The parameters are consistent with literature values for other elasmobranchs (Tsou and Collie 2001a, 2001b).

Examining the sensitivity to mean stomach contents demonstrates a clear linear relationship to per capita consumption across the full range of observed skate stomachs (Figure B6.1a). This is obvious the one factor that most highly data driven and represents an intuitive relationship- the more food measured that a skate eats, the higher the annual per capita consumption. The range of food consumed can be anywhere from 50 g to 60 kg, consistent with observed food habits for this species complex.

Examining the sensitivity to mean bottom temperature demonstrates a curvilinear relationship with per capita consumption (Figure B6.1b). The upper tail of the range (i.e., > 15^{o}C) represents an increase up to 10-20 kg consumed per year. However, the per capita consumption in the range of typical temperatures encountered by skates are on the order of 4-6 kg per year.

Examining the sensitivity to changes in α similarly demonstrates a curvilinear relationship with per capita consumption (Figure B6.2a), albeit with α presented on a logarithmic scale. This relationship is much more convex than with temperature, with consumption values where α ~ 0.1 approaching 30 kg per year. However, within the range of α typically reported from the literature (α = 0.01 to 0.05) results in a consumption on the order of 5-10 kg per year.

Examining the sensitivity to changes in β also demonstrates a curvilinear relationship with per capita consumption (Figure. B6.2b). At the upper tail of the analysis with > 0.2 results in a consumption estimate of 15-20 kg per year. However, within the range of β typically reported from the literature (β = 0.1 to 0.12) results in a consumption on the order of 5-7 kg per year.

The most sensitive factor, when within normal range, is mean stomach contents of these skates.

Examining some salient pairs, one sees that categorically when looking at the upper end of mean stomach contents versus β, α or T (Figures B6.3-B6.5) there is a clear spike at the upper range of any of those three factors with stomach contents. These peaks can result in per capita consumption estimates of over 300 kg per year. However, when one looks at the typical range of β, α or T the surfaces are much flatter and more stable, even at the upper range of S_i. A similar pattern emerges when comparing β and α (Figure B6.6). Yet even this maximum-maximum range is on the order of 120 kg per capita consumption per year, much less than when including S_i. This surface is also much flatter than the other ones that include S_i.

To put the sensitivity analysis in perspective, when both parameters were within the normal range, the change to per capita consumption was < half to one order of magnitude. The temperature variable across the maximum possible range only changes the per capita consumption by < an order of magnitude. Most observed temperature ranges are << quarter of an order of magnitude.

An order of magnitude change in the amount of food eaten results in an order of magnitude change in per capita consumption. Variance about any particular species of skate has a CV of ~50%. Thus, within any given species for each size class, temporal and spatial scheme, the variability of S_i is likely to only influence per capita consumption by half an order of magnitude or less.

Estimates of abundance, and changes in estimates thereof, are likely going to dominate the scaling of total consumption by a broader range of magnitudes than the parameters and variables requisite for an evacuation method of estimating consumption.

Winter Skate

The mean stomach contents for winter skate show a relatively stable amount of food eaten for both size classes (Figure B6.7a). Small winter skates (< 30 cm) were grouped with immature little skates. In instances with large error bars, there is an appearance of a major increase in food eaten during the early 1980s, yet this may be due to limited sample sizes during that period. Except the early 1980s, the number of empty stomachs has remained similar across the time period, averaging ~ 20% and ~25% for the medium and large size classes respectively (Figure B6.7b).

The mean length of skates sampled for stomach contents was consistent over time, averaging approximately 45 cm and 80 cm for medium and large size classes respectively (Figure B6.8a). There is a relationship between the size of skates and the amount of food eaten by skates, despite the wide variability in a few years (Figure B6.8b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 10^{o}C (Figure B6.9a).

The per capita consumption of this skate (Figure B6.9b) generally tracks the amount of food eaten (Figure B6.7a). Values average approximately 2 kg per year for the medium size class and between 9 kg per year for the large size class.

Total minimal estimates of swept area abundance (Figure B6.10a) are generally comparable to estimates noted above. There was generally no trend for all three size classes over the entire time period except the large size. The large winter skates class exhibited a peak in the 1980s followed by a notable decline in the 1990s, with some recovery now apparent in more recent years. This is one of the more abundant skate species.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.10b). Both size classes show a peak in the 1980s, consistent with the observed peak in the abundance of the larger size class (Figure B6.10a). Estimates here for total consumptive demand by this skate range between 20,000 and 180,000 MT per year.

The diet composition of winter skate is reflective of the generally benthivorous diet of all skates and the piscivorous nature of particularly larger skates (Table B6.2). Major prey of this skate are primarily forage fishes (herrings, hakes) or benthic megafauna (crabs, shrimp). The category other fish refers to those species that are not primarily commercially targeted. The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of winter skate proportionally to each prey item, forage fish, squids, and benthic macrofauna are clearly the major amount of prey removed by this skate (Figures B6.11-B6.12). Up to 80,000 MT of a particular prey item can be removed by this skate in any given year.

Little Skate

The mean stomach contents for Little Skate show an increasing amount of food eaten in the 1980s for the both size classes, followed by a more stable amount during the past 20 years (Figure B6.13a). The number of empty stomachs has remained mostly similar across the time period, averaging ~10% for both size classes (Figure B6.13b). Recall that small winter skates (< 30 cm) are grouped in with the immature little skates.

The mean length of skates sampled for stomach contents was consistent over time, averaging approximately 20 cm and 45 cm for immature and mature size classes (Figure B6.14a). There is a clear relationship between the size of skates and the amount of food eaten by skates (Figure B6.14b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 11^{o}C (Figure B6.15a).

The per capita consumption of this skate (Figure B6.15b) generally tracks the amount of food eaten (Figure B6.13a). Values average approximately 500 g per year for immatures and 2.5 kg per year for matures.

Total minimal estimates of swept area abundance (Figure B6.16a) are generally comparable to estimates noted above. There were some fluctuations during the later 1990s and early 2000s, but these were centered about, and returned to, the long term average abundance. This was the most abundant skate species in the ecosystem.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.16b). Both size classes exhibit a reasonably stable amount of food eaten, but the total consumption is dominated by the mature size class (Figure B6.16a). Estimates here for total consumptive demand by this skate range between 100,000 and 350,000 MT per year.

The diet composition of little skate is reflective of the generally benthivorous nature of all skates (Table B6.3). Most of the major prey of this skate are comprised of benthic macrofauna (polychaetes, amphipods) or benthic megafauna (crabs, bivalves).

When allocating total consumption of little skate proportionally to each prey item, benthic invertebrates are clearly the major amount of prey removed by this skate (Figure B6.17). Up to 100,000 MT of a particular prey item can be removed by this skate in any given year.

Barndoor Skate

The mean stomach contents for barndoor skate show a relatively stable amount of food eaten for the immature size class (Figure B6.18a). In the larger size class there are instances with large error bars, giving an appearance of a major decline in food eaten circa 2002 to 2003. Yet this may be due to limited sample sizes during 2002. The number of empty stomachs has remained similar across the time period, averaging ~25% for both size classes (Figure B6.18b).

The mean length of skates sampled for stomach contents was consistent over time, averaging slightly less than 60 cm and slightly over 100 cm for immature and mature size classes respectively (Figure B6.19a). There is a clear relationship between the size of skates and the amount of food eaten by skates, despite the wide variability in a few years (Figure B6.19b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 9^{o}C, declining slightly in more recent years (Figure B6.20a).

The per capita consumption of this skate (Figure B6.20b) generally tracks the amount of food eaten (Figure B6.18a). Values typically range approximately 5 kg per year for immatures and between 10 to 20 kg per year for matures.

Total minimal estimates of swept area abundance (Figure B6.21a) are generally comparable to estimates noted above. There was a generally increasing trend for both size classes over time, although numbers are still relatively low.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.21b). Both size classes show a peak in 2002, consistent with the observed peak in mean stomach contents (Figure B6.18.a). Estimates here for total consumptive demand by this skate range between 4,000 and 16,000 MT per year.

The diet composition of barndoor skate is reflective of the generally benthivorous nature of all skates and the piscivorous nature of particularly larger skates (Table B.6.4). Most of the major prey of this skate are comprised of forage fishes (herrings, hakes) or benthic megafauna (crabs, shrimp). The category other fish refers to those species that are not primarily commercially targeted. The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of barndoor skate proportionally to each prey item, herrings, Pandalid shrimps, and *Cancer* crabs are clearly the major amount of prey removed by this skate (Figure B6.22). Up to 8,000 MT of a particular prey item can be removed by this skate in any given year.

Thorny Skate

The mean stomach contents for thorny Skate show a relatively stable amount of food eaten for two of the three size classes, with medium skates exhibiting a slight increase (Figure B6.23a). Aside from the 1976 to 1980 time period (five year block), the number of empty stomachs has remained similar across the time period, averaging ~15 to 20% for all size classes (Figure B6.23b).

The mean length of skates sampled for stomach contents was consistent over time for all three size classes, averaging approximately 20 cm, 45 cm, and slightly less than 80 cm for the small, medium and large size classes respectively (Figure B6.24a). There is a clear relationship between the size of skates and the amount of food eaten by skates (Figure B6.24b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 9^{o}C, declining slightly in more recent years (Figure B6.25a).

The per capita consumption of this skate (Figure B6.25b) generally tracks the amount of food eaten (Figure B6.23a). Values average approximately 500 g per year for the small size class,1.5 kg per year for the medium size class, and 12 kg per year for the large size class.

Total minimal estimates of swept area abundance (Figure B6.26a) are generally comparable to estimates noted above. There was a clear declining trend for all size classes over time, although numbers are still relatively low.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.26b). All three size classes show a peak in the early 1980s, consistent with the observed peak in mean stomach contents (Figure B6.23a). Estimates here for total consumptive demand by this skate range between 10,000 and 40,000 MT per year.

The diet composition of thorny skate is reflective of the generally benthivorous nature of all skates and the piscivorous nature of particularly larger skates (Table B6.5). Most of the major prey of this skate are comprised of forage fishes (herrings, hakes) or benthic megafauna (crabs, euphasiids). The category other fish refers to those species that are not primarily commercially targeted. The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of thorny skate proportionally to each prey item, herrings, squids, polychaetes, silver hake and other fish are the major amount of prey removed by this skate (Figures B6.27-B6.28). Up to 8,000 MT of a particular prey item can be removed by this skate in any given year.

Smooth Skate

The mean stomach contents for Smooth Skate show a relatively stable amount of food eaten for both size classes (Figure B6.29a). The number of empty stomachs has remained stationary across the time period, albeit with a wide range of variability (particularly for immatures), averaging ~15 to 20% for both size classes (Figure B6.29b). There were no empties for one part of the time series.

The mean length of skates sampled for stomach contents was consistent over time, averaging around 20-25 cm and 50 cm for immature and mature size classes respectively (Figure B6.30a). There is a clear relationship between the size of skates and the amount of food eaten by skates (Figure B6.30b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 7 and 10^{o}C (Figure B6.31a).

The per capita consumption of this skate (Figure B6.31b) generally tracks the amount of food eaten (Figure B6.29a). Values typically range between 0.5 to 1 kg per year for immatures and 2 to 3 kg per year for matures. Because these stomachs were calculated in five year time blocks, these estimates reflect that periodicity.

Total minimal estimates of swept area abundance (Figure B6.32a) are generally comparable to estimates noted above. There was a lot of variability and the abundance of both size classes varied without trend.

Total consumption when scaled to the population level generally tracks abundance and amount of food consumed more than any other contributing factors (Figure B6.32b). Both size classes are highly variable, with the majority of the consumption for this population occurring in the mature size class.. Estimates for total consumptive demand by this skate range between 1,000 and 5,000 MT per year.

The diet composition of smooth skate is reflective of the generally benthivorous nature of all skates (Table B6.6). Most of the major prey of this skate are comprised of common benthic megafauna (pandalids, euphausiids).

When allocating total consumption of smooth skate proportionally to each prey item, pandalid shrimp and euphausiids are clearly the major amount of prey removed by this skate (Figure B6.33). Up to 2,000 MT of a particular prey item can be removed by this skate in any given year, but values are typically on the order of 500 to 1,000 MT.

Clearnose Skate

The mean stomach contents for Clearnose Skate show a relatively stable amount of food eaten for the immature size class (Figure B6.34a). The same is true for the larger size class. In the larger size class there may be a slightly increasing trend in the amount of food eaten. In the instance with large error bars there is an appearance of a major change in the amount of food eaten. Again this may be due to limited sample sizes during that 2005. The number of empty stomachs has remained stationary across the time period, albeit with a wide range of variability (particularly for immatures), averaging ~25 to 30% for both size classes (Figure B6.34b).

The mean length of skates sampled for stomach contents was consistent over time, averaging around 45-50 cm and 60-65 cm for immature and mature size classes respectively (Figure B6.35a). There is a clear relationship between the size of skates and the amount of food eaten by skates, despite the wide variability in one year (Figure B6.35b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 9 and 13^{o}C (Figure B6.36a).

The per capita consumption of this skate (Figure B6.36b) generally tracks the amount of food eaten (Figure B6.34a). Values typically range approximately 1 to 2 kg per year for immatures and 5 kg per year for matures. Because these stomachs were calculated in five year time blocks, these estimates are similar in that periodicity.

Total minimal estimates of swept area abundance (Figure B6.37a) are generally comparable to estimates noted above. There was a generally increasing trend for both size classes over time, although numbers are still relatively low.

Total consumption when scaled to the population level generally tracks abundance and amount of food consumed more than any other contributing factors (Figure B6.37b). Both size classes show a peak in 2002, consistent with the observed peak in abundance and mean stomach contents during that five year period (Figures B6.37a and B6.34a). Estimates here for total consumptive demand by this skate range between 2,000 and 18,000 MT per year.

The diet composition of clearnose skate is reflective of the generally benthivorous nature of all skates (Table B6.7). Most of the major prey of this skate are comprised of common benthic megafauna (crabs, misc. crustaceans). The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of clearnose skate proportionally to each prey item, other crabs, *Cancer* crabs, squids are clearly the major amount of prey removed by this skate (Figure B6.38). Up to 8,000-10,000 MT of a particular prey item can be removed by this skate in any given year, but values are typically on the order of 2,000 to 4,000 MT.

Rosette Skate

The mean stomach contents for Rosette Skate show a relatively stable amount of food eaten for both the immature and mature size classes (Figure B6.39a). The number of empty stomachs was again around 30%, but increased slightly in more recent years (Figure B6.39b).

The mean length of skates sampled for stomach contents was consistent over time, averaging approximately 22 cm and 38 cm for immature and mature size classes respectively (Figure B6.40a). There is a clear relationship between the size of skates and the amount of food eaten by skates (Figure B6.40b).

The temperature for these strata (and the environment which this skate was experiencing) ranged between 9 and 12^{o}C (Figure B6.41a).

The per capita consumption of this skate (Figure B6.41b) generally tracks the amount of food eaten (Figure B6.39a). Values average approximately 200 g per year for immatures and 800g per year for matures.

Total minimal estimates of swept area abundance (Figure B6.42a) are generally comparable to estimates noted above. There was a peak in 2001 for matures and 2002 for immatures. No major trend for both size classes was evident.

Total consumption when scaled to the population level generally tracks abundance more than any other contributing factor (Figure B6.42b). The mature size classes shows a peak in 2001 and the immatures show a peak in 2002, consistent with the observed abundances (Figure B6.42a). Estimates here for total consumptive demand by this skate range between 50 and 500 MT per year.

The diet composition of rosette skate is reflective of the generally benthivorous nature of all skates (Table B6.8). Most of the major prey of this skate are comprised of some form of benthic macrofauna (amphipods, polychaetes) or megafauna (crabs, shrimp). The category other crabs refers to those crabs that are not in the genus *Cancer* or Paguroidean family.

When allocating total consumption of rosette skate proportionally to each prey item, benthic macrofauna are clearly the major prey removed by this skate. Pandalid shrimps, squids, and *Cancer* crabs are also removed by this skate but in lesser amounts (Figure B6.43). Up to 70 MT of a particular prey item can be removed by this skate in any given year, but more typically 10-30 MT.

All Skates relative to the ecosystem and fisheries on major prey

The total amount of skate consumption across all skates has averaged around 230,000 MT over the past 25-30 years (Figure B6.44). This represents a relatively small amount of the total energy flow in the ecosystem. There is 3.9×10^9 MT of total throughput through the ecosystem (Link et al. 2006) and skate consumption represents less than 0.006% of that total energy flow in the system. The total removal of most major skate prey relative to their standing stock biomass (B) or annual production (P) is small (Table B.6.9). Estimates of B and P tend to be at least two to three orders of magnitude greater than C by all skates for any particular prey item.

Those prey which are commercially important species and which are also important skate prey can be removed by skates at a rate comparable to their fisheries (Figure B.6.44; Table B.6.10). In the minimum swept area scenario, most skate prey are on the order of one quarter or less of what is landed for those prey, with the exception of red hake. When decreasing gear efficiencies are incorporated, the relative removal by skate consumption compared with fishery removals becomes much higher. With gear efficiencies of 50%, about half of fishery removals are removed by skate consumption for the two squids and silver hake, with over double removed by skates relative to the fishery for red hake. The pattern continues with increasingly less efficient assumptions, with squids and silver hake removed by skates up to twice of what is removed by the fishery at the lowest assumed value (10%), while red hake is up to 10 times what is removed by the fishery. The only exception is herrings, which although have a large amount of biomass removed by skates, remain a relatively small amount of removals compared to those fishery removals.

Finally, it is worth noting that some of the potential species interactions of interest- e.g. skates eating yellowtail flounder, winter flounder, sea scallops, etc.- were not of sufficient magnitude to analyze. In fact, each of the species just mentioned as examples only comprised a very small (<<0.1% of the diet) for only one or two skate species.

8.4 Summary

Most skates are benthivorous in their feeding habits. A clear prominence on *Cancer* crabs, other crabs, amphipods, polychaetes and similar benthic macrofauna and megafauna was apparent in the diets of these skates. Some of the larger skates- barndoor, thorny, and winter- can be piscivorous, particularly with ontogeny. The vast majority of fish (or fish-like) prey for these skates were small pelagic fishes and squids.

Save winter and little skates, overall consumption by most skate stocks is a relatively small amount of biomass flow. Most total consumption by any particular species of skate was scaled singularly by the abundance of that species. The vast majority of consumptive removals by all skates except little and winter was < 20 MT per year.

As an aggregate group, skates consume a very small fraction of the total energy flow in the ecosystem. Skate consumptive removal is two to three orders of magnitude lower than biomass or production of skate prey. When abundance estimates are scaled by gear efficiency, it is possible that skates could consume a notable fraction of forage fish and squid biomass relative to what is removed by a fishery. Yet most of those forage fish stocks are at relatively high levels of abundance.

9.0 SOURCES OF UNCERTAINTY FOR ASSESSMENT

1) The species composition and size structure of landings are generally unknown.

2) The true level of discards and the discard mortality rate are unknown.

3) A lack of information on the stock structure of the species in the skate complex has increased the uncertainty of conclusions about historical trends in abundance, and recommendations of appropriate biological reference points.

4) Life history data are from localized areas for barndoor, thorny, and clearnose and incomplete or totally lacking for two other species.

5) Mortality estimates based on equilibrium assumptions which are only partially met for these stocks. A preferable approach for future assessments would be an age-based method for determining mortality rates and estimates of longevity. This will require several years of future adequate length and age sampling, both from the commercial and research survey catches.

6) The proposed SFA biomass reference points are based on selected time periods of survey indices, but it is unknown how these relate to true estimates of B_{MSY}.

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