IV. BIOTIC METRICS

A. Phytoplankton

1. US Northeast Continental Shelf Ecosystem, Chlorophyll-a

Time: 1977-1988

Spatial: US Northeast Shelf Ecosystem (Shelf wide)

Contributed by: J. Jossi and J.E. O'Reilly

Methodology and Data Source

These data were collected as part of the MARMAP Program. Six to twelve research vessel surveys/year undertook water column sampling of phyto-pigments in the euphotic zone (O'Reilly and Zetlin 1998).

Key Points and Major Observations

Fifty-seven thousand eighty-eight measurements were made during 78 oceanographic surveys from 1977 through 1988. Extensive horizontal, vertical, and seasonal distributions are portrayed. No time series per se has been constructed. Not much inter-annual change in chlorophyll *a* is observed.

B. Birds

We recognize that birds are an important part of this ecosystem, but few time series data are available for these species. Although there is some extant data, no one from the group provided data for this report. Certainly this is an important issue to consider for some species, and merits further examination in the future. In fact, basic questions such as "what are the trends in abundance of major species?" remain unanswered. How often do we need to sample to better answer these questions? What spatial extent and resolution do we need? What are the most cost effective methodologies?

C. Turtles

We also recognize that turtles are an important part of this ecosystem, but few time series data are available for these species. Although there is some extant data, no one from the group provided data for this report. See Palka et al. (In review) for some estimates of turtle abundance for selected years in the 1990s. Certainly this is an important issue to consider for some species, and merits further examination in the future.

D. Benthos

In general, few time series data are available for the benthos. Classic shelf-wide studies were conducted by Theroux and Wigley (1998). Other studies have covered smaller areas, and synoptic, shelf-wide information is generally lacking. However, a few components of the benthic community are surveyed regularly.

1. Georges Bank, Mid-Atlantic Bight Scallop Biomass, Landings, and Survey Indices

Time: 1962-1999 (Landings & Survey), 1980-2000 (Biomass)

Spatial: Georges Bank, Mid Atlantic Bight

Contributed by: Hart

Figures B.1-B.4

Methodology and Data Source

These data were collected from the NMFS sea scallop survey and landings database. Biomass was poststratified into open and closed areas. For further details see NEFSC (2001) and Murawski et al. (2000).

Key Points and Major Observations

Biomass was at low levels through 1994 due to increasingly severe overfishing. This resulted in highly variable landings well below optimal levels, driven primarily by sporadic recruitment events. After area closures (December 1994 in Georges Bank, April 1998 in Mid-Atlantic), there was a rapid buildup of biomass in the closed areas. The limited amount of fishing permitted in the closed areas in 1999-2000 does not appear to have substantially impacted the biomass there. Biomasses in open areas have increased recently due to effort reductions and good recruitment. Recent good recruitment on both Georges Bank and Mid-Atlantic may be related to the increased levels of spawning-stock biomass in the closed areas.

2. Sculpin abundance from fall bottom trawl survey

Time: 1963 - 1998

Spatial: Southern New England and Georges Bank

Contributed by: Link

Figure B.5

Methodology and Data Source

These data were collected as part of the NEFSC Habitat Research Program and standard bottom trawl survey. The stratified mean trawl catch per tow (Azarovitz 1981) was calculated for this species. See Link and Almeida (2002) for further details.

Key Points and Major Observations

Longhorn sculpin abundance peaked in the mid 1960s and then exhibited a relatively steady period for the first 15 years of the survey. This was followed by a period of lower abundance during the mid 1980s and an increasing trend in the 1990s. In most years sculpin abundance ranged from 10 to 20 fish per tow. The years with highest index of sculpin abundance were 1966 and 1998. Relative to the several preceding years, the index of sculpin abundance notably increased during 1966, 1987 and 1998.

3. Blue crab abundance

Time: July 1996 - October 2000 (spring, summer, and fall)

Spatial: Navesink River and Sandy Hook Bay in the mid-Atlantic region

Contributed by: Fabrizio

Figure B.6

Methodology and Data Source

These data were collected as part of the Behavioral Ecology Survey of Demersal Species in Navesink River. Three seasonal collections were made in the spring, summer, and fall beginning in the summer of 1996. Demersal species were collected by replicate tows of a 1-m beam and a 5- m otter trawl at 84 stations throughout the Navesink River and Sandy Hook Bay. Beginning in July 1998, only 24 stations were sampled throughout this system. All fish and decapod crustaceans were enumerated and environmental characteristics were measured. The data in the figure represent the mean number of blue crabs per m^2 across all stations in the Navesink River and Sandy Hook Bay (Meise and Stehlik In Review).

Key Points and Major Observations

Blue crab abundance increased in 1998-1999 in the Navesink River-Sandy Hook Bay estuarine system, but declined by 2000. These data are from a short time series with limited spatial coverage, but are important to the local estuarine dynamics.

E. Zooplankton

1. Central Gulf of Maine Calanus finmarchicus*, c.1-4, c.5-6 anomalies*

Time: 1961-1990

Spatial: Central Gulf of Maine

Contributed by: Jossi

Figure B.7 (a-b)

Methodology and Data Source

These data were collected as part of the MARMAP Ships of Opportunity Program (Benway et al. In Review; Jossi et al. In Review). Continuous Plankton Recorders were towed monthly by merchant vessels along a transect from Boston, MA to Cape Sable, NS. Zooplankton and larger phytoplankton were captured, identified and enumerated. Abundance values were gridded in time and space (distance along transect). Grids of long term medians, means and standard deviations; and single year conditions, anomalies, and standardized anomalies are produced. Grids were sliced through time at a distance representing the central Gulf of Maine in this portrayal. The portrayal also shows a smooth curve based on a 15 month running average

(Jossi and Goulet 1993; Pershing et al. 2001).

Key Points and Major Observations

A biphase pattern has been found in in this, and several other of the dominant zooplankton taxa of the Gulf of Maine during the 1961-1990 period (Jossi and Goulet, 1993), and also an uptrend for the adult stages of *Calanus finmarchicus*. Also, the adult stages of this taxon have exhibited a positive (with lag) correlation with the winter North Atlantic Oscillation (Pershing,et al. 2001).

2. Anomalies of major zooplankton during spring

Time: 1977 - 1996, Spring (15 Feb- 15 May)

Spatial: Georges Bank

Contributed by: Jossi

Figure B.8

Methodology and Data Source

These data were collected as part of the MARMAP Surveys (Benway et al. In Review; Jossi et al. In Review). Zooplankton and larger phytoplankton were captured, identified and enumerated. Abundance values were gridded in time and space (distance along transect). Single year conditions, anomalies, and standardized anomalies are produced.

Key Points and Major Observations

The community composition has changed notably over time. Yet there are no apparent trends in total zooplankton abundance and no major departures from zero even though predator biomass has changed greatly during the time period.

3. Time and space conditions of* Centropagus typicus *across the continental shelf

Time: 1976 - 1990, averaged

Spatial: transect from New York to Bermuda

Contributed by: Jossi

Figure B.9

Methodology and Data Source

These data were collected as part of the MARMAP Ships of Opportunity Program (Benway et al. In Review; Jossi et al. In Review). Continuous Plankton Recorders were towed monthly by merchant vessels along a transect from New York to Bermuda. Zooplankton and larger phytoplankton were captured, identified and enumerated. Abundance values were gridded in time and space (distance along transect). Grids of long term medians, means and standard deviations; and single year conditions, anomalies, and standardized anomalies are produced.

Key Points and Major Observations

An impressive color figure captures seasonal and local spatial dynamics well, although this is not a time series per se.

4.* Calanus *abundance by day of year over time

Time: 1961 - 1998

Spatial: transect from Boston, Mass. to Cape Sable

Contributed by: Jossi

Figure B.10

Methodology and Data Source

These data were collected as part of the MARMAP Ships of Opportunity Program (Benway et al. In Review; Jossi et al. In Review). Continuous Plankton Recorders were towed monthly by merchant vessels along a transect from Boston, MA to Cape Sable, NS. Zooplankton and larger phytoplankton were captured, identified and enumerated. Abundance values were gridded in time and space (distance along transect). Grids of long term medians, means and standard deviations; and single year conditions, anomalies, and standardized anomalies are produced. Grids were sliced through time at a distance representing the central Gulf of Maine in this portrayal. The portrayal also shows a smooth curve based on a 15 month running average (Jossi and Goulet 1993; Pershing et al. 2001).

Key Points and Major Observations

During the mid 1980s, *Calanus finmarchicus* shows up later and leaves earlier. In the early1990s there is an even earlier appearance of this species. Can these timing changes be related to the changing oceanographic conditions over this time period?

5: The overall zooplankton biomass and abundance trends of two dominant copepods:

Calanus finmarchicus *and* Centropages typicus

Time: 1977 - 2000

Spatial: Georges Bank and Gulf of Maine

Contributed by: Kane

Figures B.11 and B.12

Methodology and Data Source

These data were collected as part of the MARMAP Surveys (Benway et al. In Review; Jossi et al. In Review). Zooplankton samples were collected at approximately bimonthly intervals throughout the region with a 0.333-mm mesh net fitted on one side of a 61-cm bongo frame. Biomass was measured by displacement volume and individual species were sorted and counted from sub samples. Data in the figures represent ranked departures from the time series monthly means with a fourth order polynomial fit to the data. See Kane (1993), Sherman et al. (1998), and Kane (1999) for further details.

Key Points and Major Observations

Zooplankton trends in both regions were similar. Biomass was usually high in the late seventies, low throughout most of the eighties, and highly variable during the 1990s. The biomass trend line on Georges Bank during the 1990s is higher because of high values recorded in 1989 and 1990, years where budget constraints prevented sampling in the GOM. *Calanus finmarchicus* abundance was high in the late seventies and highly variable during the past two decades with no persistent long-term trend. *Centropages typicus* density was high from 1978-82, low throughout the remainder of the 1980s, and above average during the past decade.

6. Total Zooplankton Biomass

Time: 1977-2000

Spatial: Shelf wide

Contributed by: Kane

Figure B.13

Methodology and Data Source

These data were collected as part of the MARMAP Surveys (Benway et al. In Review; Jossi et al. In Review). Zooplankton samples were collected at approximately bimonthly intervals throughout the region with a 0.333-mm mesh net fitted on one side of a 61-cm bongo frame. Biomass was measured by displacement volume and individual species were sorted and counted from sub samples. Data in the figures represent ranked departures from the time series monthly means with a fourth order polynomial fit to the data. See Kane (1993), Sherman et al. (1998), and Kane (1999) for further details.

Key Points and Major Observations

Biomass was generally higher in the late 1970s, with no persistant long term trend during the past two decades. There was a lot of variability in the data. Patterns are similar in each of the four main subregions.

F. Fish and Squids

For the majority of these organisms, we refer the reader to NEFSC (1998a, 1998b, 1998c, 2000a, 2000b, 2000c, 2001). These documents contain individual species stock assessments and annual reports on the status of the major or commerically valuable species.

1. Relative abundance of northeast species groups (groundfish, pelagics, elasmobranchs, others) from combined fall and spring bottom trawl surveys

Time: 1963 - 1999

Spatial: Shelf wide

Contributed by: NEFSC

Figure B.14 (a-d)

Methodology and Data Source

These data were collected as part of the NEFSC Bottom Trawl Survey (Azarovitz 1981; NEFC 1988). Species were aggregated as principal groundfish, other groundfish, principal pelagics, and elasmobranchs. A stratified mean biomass per tow was calculated and smoothed over the time series.

Key Points and Major Observations

The abundance of principal groundfish declined through the mid 1970s, increased slightly in the late 1970s and early 1980s, and declined thereafter, remaining at low levels through the 1990s. The abundance of pelagic fishes declined in the 1970s and increased substantially and continuously thereafter. Elasmobranch abundance increased from the 1960s through the 1990s, then declined moderately in the late 1990s. The abundance of other groundfish has fluctuated without trend. These observations suggest a shift in community structure and food web dominance.

2. Principal groundfish biomass for Georges Bank from autumn bottom trawl survey

Time: 1963 - 1999

Spatial: Georges Bank

Contributed by: Brodziak

Figure B.15

Methodology and Data Source

The principal groundfish index is the sum of indices of 12 principal (exploited) groundfish on Georges Bank. These species include Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), redfish (*Sebastes fasciatus*), silver hake (*Merluccius bilinearis*), red hake (*Urophyscis chuss*), pollock (*Pollachius virens*), yellowtail flounder (*Limanda ferruginea*), summer flounder (*Paralichthys dentatus*), American plaice (*Hippoglossoides platessoides*), witch flounder (*Glyptocephalus cynoglosses*), winter flounder (*Pseudopleuronectes americanus*), and windowpane flounder (*Scophthalmus aquosus*). The individual indices are stratified mean weight per tow during autumn, calculated with survey gear adjustment factors applied where appropriate using NEFSC offshore survey strata 9-23 and 25. See Brodziak and Link (In press) and Azarovitz (1981) for further details.

Key Points and Major Observations

A large decline in principal groundfish occurred during 1960s and early 1970s. A moderate increase occurred during the late-1970s and early 1980s. Principal groundfish abundance declined through the 1990s, although recently there has been a moderate increase.

3. Elasmobranch biomass for Georges Bank from autumn bottom trawl survey

Time: 1968 - 2000

Spatial: Georges Bank

Contributed by: Brodziak

Figure B.16

Methodology and Data Source

The elasmobranch index is the sum of indices of 6 primary elasmobranchs on Georges Bank. These species include spiny dogfish (*Squalus acanthius*), barndoor skate (*Raja laevis*), thorny skate (*Raja radiata*), smooth skate (*Raja senta*), winter skate (*Raja ocellata*), and little skate (*Raja erinacea*). The individual indices are stratified mean weight per tow during spring, calculated with survey gear adjustment factors applied where appropriate using NEFSC offshore survey strata 9-23 and 25. See Brodziak and Link (In press) and Azarovitz (1981) for further details.

Key Points and Major Observations

Elasmobranch biomass was low in the 1970s. Elasmobranch biomass increased to high values in the 1980s and early1990s. Elasmobranch biomass has decreased in the late1990s.

4. Principal pelagics biomass estimates from recent assessments

Time: 1967 - 1994

Spatial: entire range of population in the northwest Atlantic (shelf wide)

Contributed by: Brodziak

Figure B.17

Methodology and Data Source

These data were derived from the NEFSC assessments of pelagics species. Age-structured assessments using sequential population analysis tuned to NEFSC survey abundance-at-age indices were used. See Brodziak and Link (In press) and NEFSC (1998a) for further details.

Key Points and Major Observations

The principal pelagics (Altantic herring *Clupea harengus* and Atlantic mackerel *Scomber scombrus*) are migratory resources that were heavily fished by distant water fleets in the 1960s-1970s. Abundance of principal pelagics was high (or moderate) in the early-1970s and declined to record lows in the 1970s and early-1980s. Abundance was high and increasing in the late-1980s through the 1990s.

5. Cephalapod biomass for Georges Bank from fall bottom trawl survey

Time: 1967 - 1999

Spatial: Georges Bank

Contributed by: Brodziak

Figure B.18

Methodology and Data Source

The cephalopod biomass index is the sum of indices of two principal (exploited) cephalopods, long-finned squid (*Loligo pealeii*) and northern short-finned squid (*Illex illecebrosus*), along with other squid and octopuses on Georges Bank. The individual indices are stratified mean weight per tow during autumn, calculated with survey gear adjustment factors applied where appropriate using NEFSC offshore survey strata 9-23 and 25. See Brodziak and Link (In press) and Azarovitz (1981) for further details.

Key Points and Major Observations

Cephalopods are short-lived (lifespan< 1 year) and are common prey for many species. Distribution of the two primary squids on Georges Bank depends on seasonal changes in water temperatures. Cephalopod abundance increased during the late-1960s to late-1970s, declined to the mid-1980s, and increased in the late-1980s. Abundance declined during the early 1990s and has increased moderately since 1996.

6. Frequency of occurrence of parasitic nematodes in all predators

Time: 1973 - 1998 in five year blocks

Spatial: Shelf wide

Contributed by: Link

Figure B.19

Methodology and Data Source

These data were derived from the NEFSC Food Habits Database. Live nematodes observed in examined stomachs were noted. See Link and Almeida (2000) for further details.

Key Points and Major Observations

There was a methodological shift between 1980 and 1981, so the apparent trend may be misleading. Otherwise nematode occurrence may provide an index of density dependent health in fish.

7. Winter flounder collected by beam and otter trawls

Time: July 1996 - October 2000 (spring, summer, and fall)

Spatial: Navesink River and Sandy Hook Bay in the mid-Atlantic region

Contributed by: Fabrizio

Figure B.20

Methodology and Data Source

These data were collected in the Behavioral Ecology Survey of Demersal Species. Three seasonal collections were made in the spring, summer, and fall beginning in the summer of 1996. Demersal species were collected by replicate tows of a 1-m beam and a 5- m otter trawl at 84 stations throughout the Navesink River and Sandy Hook Bay. Beginning in July 1998, only 24 stations were sampled throughout this system. All fish and decapod crustaceans were enumerated and environmental characteristics were measured. The data in the figure represent the mean number of winter flounder per m^2 across all stations in the Navesink River and Sandy Hook Bay. See Stehlik and Meise (2000) and Stoner et al. (2001) for further details.

Key Points and Major Observations

Beam trawls captured newly settled winter flounder, and generally not older stages. As indicated by the beam trawl samples, young-of-the-year winter flounder abundance was high in the spring of 1999. These data are from a short time series with limited spatial coverage, but are important to the local estuarine dynamics.

8. Haddock and cod % maturity for ages 1 and 2

Time: 1963 - 1997 in five year blocks (haddock) and 1978 - 1997 in four year blocks (cod)

Spatial: Georges Bank

Contributed by: NEFSC SARCs

Figure B.21

Methodology and Data Source

These data are from the NEFSC Age Database (SVBIO) collected as part of the bottom trawl survey. The particular analyses for these species can be found in NEFSC (1998b, 1998c, 2000a, 2000b, 2000c, 2001).

Key Points and Major Observations

Haddock seem to show an increase in early maturity over time. How do changes in maturity reflect ecosystem level effects?

9. Cod survival ratio anomaly

Time: 1978 - 1998

Spatial: Georges Bank

Contributed by: Brodziak

Figure B.22

Methodology and Data Source

The cod survival ratio anomaly measures the difference between the observed value of cod recruitment per unit of spawning biomass (survival ratio index) and its predicted value from a fitted Beverton-Holt stock-recruitment curve. Higher anomaly values are associated with more favorable recruitment conditions. See Brodziak and Link (In press) for further details.

Key Points and Major Observations

The Georges Bank cod survival ratio anomaly has no apparent trend during 1978-1998, although anomaly values were negative in the late 1980s-early 1990s and have been more positive since 1995. Georges Bank cod recruitment has been low in recent years and this data suggests that this is not primarily due to adverse environmental conditions. Survival ratio anomaly measures deviation of recruits per spawner from a spawner recruit relationship.

10. Haddock survival ratio anomaly

Time: 1931 - 1998

Spatial: Georges Bank

Contributed by: Brodziak

Figure B.23

Methodology and Data Source

The haddock survival ratio anomaly measures the difference between the observed value of haddock recruitment per unit of spawning biomass (survival ratio index) and its predicted value from a fitted Beverton-Holt stock-recruitment curve. Lower anomaly values are associated with less favorable recruitment conditions. See Brodziak and Link (In press) for further details.

Key Points and Major Observations

Georges Bank haddock survival ratio anomalies appear to be higher during the 1930s-early 1960s than during the late1960s-1990. The two largest anomalies correspond to the 1963 and 1975 year classes which were very large based on assessment results (i.e., the two "super year classes" are apparent). Survival ratio anomaly measures deviation of recruits per spawner from a spawner recruit relationship.

11. Yellowtail flounder survival ratio anomaly

Time: 1973 - 1997

Spatial: Georges Bank

Contributed by: Brodziak

Figure B.24

Methodology and Data Source

The yellowtail survival ratio anomaly measures the difference between the observed value of yellowtail flounder recruitment per unit of spawning biomass (survival ratio index) and its predicted value from a fitted Beverton-Holt stock-recruitment curve. See Brodziak and Link (In press) for further details.

Key Points and Major Observations

There appears to be an increasing trend in the survival ratio anomaly since the mid-1980s. Since area II was closed on Georges Bank in 1994, the survival ratio anomalies have been relatively high. Survival ratio anomalies for Georges Bank yellowtail flounder appear to be more variable than for cod or haddock. Survival ratio anomaly measures deviation of recruits per spawner from a spawner recruit relationship.

G. Mammals

1. Several marine mammal trends

Time: Various years in the 1980s, 90s

Spatial: Shelf wide

Contributed by: Palka, Smith

Table 4.1

Methodology and Data Sources

Abundance of harbor seals were estimated as the total count of hauled out animals that were estimated from aerial photos of animals hauled out during the pupping season on the New England coast (Gilbert and Guldager 1998). This abundance is considered a minimum estimate because it was not corrected for animals in the water or outside the survey area.

Data for all other species were collected during sighting line transect surveys conducted by planes (1982, 1995, 1998, and 1999) and/or ships (1991-1999). Shipboard data were collected using the two independent sighting team procedure and were analyzed using the product integral or modified direct duplicate methods (Palka 1995). These estimates were corrected for *g(0)*, the probability of detecting a group on the track line and, if applicable, also for school size-bias. Standard aerial sighting procedures with two bubble windows and one belly window observer were used during the aerial surveys. An estimate of *g(0)* was not made for the aerial portion of the surveys, except for harbor porpoises from surveys conducted after 1990. For a brief overview of all survey results, see CETAP (1982), Smith et al. (1993), Palka (1996), Palka (2000), Waring et al. (2000), Mullin (In review) and Palka et al. (In review).

Key Points and Major Observations

These surveys were conducted in different areas within the US and Canadian Northwest Atlantic Ocean, thus, it is not possible to directly compare the reported numbers. Most of these estimates are negatively biased due to not accounting for dive times, ship reaction, and animals outside of the surveyed area. These biases vary by species. Estimates from1998/1999 are generally the largest, and the best recent estimates, because the surveys covered waters from

Florida to the Gulf of St. Lawrence, the largest portion of the animal's habitat that was ever covered.

H. Aggregate

1. Total biomass from both fall and spring bottom trawl surveys

Time: 1963 - 2000

Spatial: Shelf wide

Contributed by: Link

Figure B.25 (a-b)

Methodology and Data Source

These data were collected as part of the NEFSC Bottom Trawl Survey (Azarovitz 1981; NEFC 1988). Biomass of all net-caught organisms was aggregated irrespective of species, and a stratified mean biomass per tow was calculated over the time series. Both a mean per tow and minimum swept area estimate of total biomass were calculated.

Key Points and Major Observations

There is no apparent trend in total biomass from the mid 1960s to 2000s. The may reflect an overall system carrying capacity. The implication is that if we want to simulataneously rebuild/restore all major groups, then other components of the ecosystem will have to decline. Can fluctuations in total biomass be linked to the physical environment? This raises the question of examining standing stock vs productivity (changes in trophic transfer) of the different component species. The bottom trawl is not highly selective for pelagics, jellyfish, plankton, etc., and no corrections for selectivity were made. The jump in biomass during the late 1960s could be due to adding the spring survey in 1968.

2. Mean length of all species collected in fall and spring bottom trawl

Time: 1963 - 2000

Spatial: Georges Bank

Contributed by: Link

Figure B.26

Methodology and Data Source

These data were collected as part of the NEFSC Bottom Trawl Survey (Azarovitz 1981; NEFC 1988). Organisms were aggregated irrespective of species, and a stratified mean length for each year was calculated over the time series.

Key Points and Major Observations

Lengths were lower through the mid 1970s, and longer in the late 1970s through early 1990s. Lengths were again shorter in the mid to late 1990s. Does this infer regime shifts, or could it just be the effect of dogfish and skates? The peak length corresponds to the period when herring and other pelagics were low in abundance.

3. Abundance of various guilds in fall and spring bottom trawl surveys

Time: 1963 - 2000

Spatial: Shelf wide

Contributed by: Link

Figure B.27 (a-l)

Methodology and Data Source

These data were collected as part of the NEFSC Bottom Trawl Survey (Azarovitz 1981; NEFC 1988). Species were aggregated into appropriate guilds (Garrison and Link 2000), and a stratified mean biomass per tow was calculated and smoothed over the time series. Both a mean per tow and minimum swept area estimate of total biomass were calculated.

Key Points and Major Observations

These results are similar to other graphs of grouped biomass. Do these better convey information better than groupings by taxonomy? Guilds may be an useful approach, and certainly provide a slightly different picture of fish community dynamics than the taxonomic groupings.

I. Community Indices

1. Gulf of Maine total species diversity from bottom trawl survey

Time: 1963 - 2000

Spatial: Gulf of Maine

Contributed by: Brodziak

Figure B.28

Methodology and Data Source

Total species diversity was indexed by the average number of species per haul during the autumn bottom trawl survey in Gulf of Maine offshore strata. See Brodziak and Link (In press) for related details, and Ludwig and Reynolds (1988) for a further discussion of diversity.

Key Points and Major Observations

This diversity index has an increasing trend since late 1980s. The most recent index value is the highest in time series. This measure may have been impacted by decisions regarding recording of species during trawl survey cruises.

2. Gulf of Maine abundant species diversity from bottom trawl survey

Time: 1963 - 2000

Spatial: Gulf of Maine

Contributed by: Brodziak

Figure B.29

Methodology and Data Source

Abundant species diversity was indexed by the average number of abundant species (N1) per haul during the autumn bottom trawl survey in Gulf of Maine offshore strata. N1 was computed as the $N1=e^H$, where H was Shannon's diversity index evaluated in terms of the biomass proportion within a trawl sample. See Brodziak and Link (In press) for related details, and Ludwig and Reynolds (1988) for a further discussion of diversity.

Key Points and Major Observations

This diversity index peaked in the early 1980s. This index provides a measure of species dominance.

3. Gulf of Maine species evenness from bottom trawl survey

Time: 1963 - 2000

Spatial: Gulf of Maine

Contributed by: Brodziak

Figure B.30

Methodology and Data Source

This is Hill's modified evenness index (see for example, Ludwig and Reynolds 1988). Species evenness was indexed by the average of the ratio (N2-1)/(N1-1) during the autumn bottom trawl survey in Gulf of Maine offshore strata. N2 was computed as the inverse of Simpson's diversity index, evaluated in terms of the biomass proportion within a trawl sample. See Brodziak and Link (In press) for related details, and Ludwig and Reynolds (1988) for a further discussion of diversity.

Key Points and Major Observations

Species evenness has a decreasing trend since the early 1980s. Current evenness values are the lowest in the time series. The decreasing trend in evenness may be due to the abundance of large skates in some areas of the Gulf of Maine.

4. Georges Bank total species diversity from bottom trawl survey

Time: 1963 - 2000

Spatial: Georges Bank

Contributed by: Brodziak

Figure B.31

Methodology and Data Source

Total species diversity was indexed by the average number of species per haul during the autumn bottom trawl survey in Georges Bank strata. See Brodziak and Link (In press) for related details, and Ludwig and Reynolds (1988) for a further discussion of diversity.

Key Points and Major Observations

This diversity index appears to trend up and down throughout the observed time series. Total species diversity on Georges Bank has trended upward since the early 1990s after declining to a time series low during the 1980s. This measure may have been impacted by decisions regarding recording of species during trawl survey cruises.

5. Georges Bank abundant species diversity from bottom trawl surveys

Time: 1963 - 2000

Spatial: Georges Bank

Contributed by: Brodziak

Figure B.32

Methodology and Data Source

Abundant species diversity was indexed by the average number of abundant species (N1) per haul during the autumn bottom trawl survey in Georges Bank strata. N1 was computed as the $N1=e^H$, where H was Shannon's diversity index evaluated in terms of the biomass proportion within a trawl sample. See Brodziak and Link (In press) for related details, and Ludwig and Reynolds (1988) for a further discussion of diversity.

Key Points and Major Observations

This species dominance index was higher during the 1960s-1970s than during the 1980s. In recent years, abundant species diversity has exhibited an increasing trend. This metric is a measure of dominance.

6. Georges Bank species evenness from bottom trawl surveys

Time: 1963 - 2000

Spatial: Georges Bank

Contributed by: Brodziak

Figure B.33

Methodology and Data Source

This is Hill's modified evenness index (see for example, Ludwig and Reynolds 1988). Species evenness was indexed by the average of the ratio (N2-1)/(N1-1) during the autumn bottom trawl survey in Georges Bank strata. N2 was computed as the inverse of Simpson's diversity index, evaluated in terms of the biomass proportion within a trawl sample. See Brodziak and Link (In press) for related details, and Ludwig and Reynolds (1988) for a further discussion of diversity.

Key Points and Major Observations

Species evenness on Georges Bank peaked in the early 1970s. This index steadily decreased during 1975-1990 and has only increased a small amount in recent years.

7. Mid-Atlantic Bight total species diversity from bottom trawl surveys

Time: 1963 - 2000

Spatial: Mid-Atlantic Bight

Contributed by: Brodziak

Figure B.34

Methodology and Data Source

Total species diversity was indexed by the average number of species per haul during the autumn bottom trawl survey in Mid-Atlantic Bight offshore strata. See Brodziak and Link (In press) for related details, and Ludwig and Reynolds (1988) for a further discussion of diversity.

Key Points and Major Observations

This diversity index has no apparent trend.

8. Mid-Atlantic Bight Abundant species diversity from bottom trawl surveys

Time: 1963 - 2000

Spatial: Mid-Atlantic Bight

Contributed by: Brodziak

Figure B.35

Methodology and Data Source

Abundant species diversity was indexed by the average number of abundant species (N1) per haul during the autumn bottom trawl survey in Gulf of Maine offshore strata. N1 was computed as the $N1=e^{H}$, where H was Shannon's diversity index evaluated in terms of the biomass proportion within a trawl sample. See Brodziak and Link (In press) for related details, and Ludwig and Reynolds (1988) for a further discussion of diversity.

Key Points and Major Observations

This measure of species dominance has no apparent trend.

9. Mid-Atlantic Bight Species evenness from bottom trawl survey

Time: 1963 - 2000

Spatial: Mid-Atlantic Bight

Contributed by: Brodziak

Figure B.36

Methodology and Data Source

This is Hill's modified evenness index (see for example, Ludwig and Reynolds 1988). Species evenness was indexed by the average of the ratio (N2-1)/(N1-1) during the autumn bottom trawl survey in Gulf of Maine offshore strata. N2 was computed as the inverse of Simpson's diversity index, evaluated in terms of the biomass proportion within a trawl sample. See Brodziak and Link (In press) for related details, and Ludwig and Reynolds (1988) for a further discussion of diversity.

Key Points and Major Observations

Species evenness has had no apparent trend in the Mid-Atlantic Bight.

J. Food Web Indices

1. Silver hake linkage density

Time: 1973 - 1998

Spatial: Shelf wide

Contributed by: Link

Figure B.37

Methodology and Data Source

These data are derived from the NEFSC Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling.

Key Points and Major Observations

This metric measures number of species eating and being eaten by silver hake. Silver hake is a "canary" population because a large amount of energy passes through this species, i.e., it eats many species and many species eat it. The same is true for red hake (not shown). The number of prey species consumed by silver hake declined in the mid 1980s, but has increased through the mid 1990s. Do these changes reflect an overall change in number of species in ecosystem?

2. Total consumption by 12 piscivores

Time: 1977 - 1997

Spatial: primarily Georges Bank

Contributed by: Overholtz

Figure B.38

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For specifics on the consumption estimation, see Overholtz et al. (2000).

Key Points and Major Observations

Total consumption (all prey) by 12 predatory fish (pollock, goosefish, cod-2 stocks, spiny dogfish, white hake, weakfish, winter skate, summer flounder, bluefish, red hake, spotted hake, and silver hake) averaged 1.5 million mt and ranged between 1.3 and 2.9 million mt during 1977-1997. Consumption peaked in the early 1980s and declined steadily through 1997. This trend is consistent with the large biomass of elasmobranchs and groundfish that were present during the 1980s and a subsequent large decline in spiny dogfish, cod, white hake, and bluefish, due to fishing, during the later period. Total annual consumption by individual predators was lowest by goosefish and summer flounder and highest by silver hake, and spiny dogfish. Consumption estimates for individual predator species spanned nearly three orders of magnitude and was heavily influenced by predator abundance. As an example, spiny dogfish consumed an average of 619,000 mt, bluefish, 108,000 mt, and goosefish, 14,000 mt during 1977-1997.

3. Total fish consumption by six piscivores on Georges Bank

Time: 1977 - 1998 in three year blocks

Spatial: Georges Bank

Contributed by: Link

Figure B.39

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For specifics on the consumption estimation, see Link and Garrison (2002a).

Key Points and Major Observations

There was a peak in the early 1980s due to an abundance of extra large cod. Consumption by silver hake and cod dominated 1977 and 1980 values; consumption by dogfish dominated the rest of the time series. The total consumption was relatively consistent aside from the one peak.

4. Consumption of prey species by 12 piscivores

Time: 1977 - 1997

Spatial: Shelf wide

Contributed by: Overholtz

Figure B.40 (a-f)

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For specifics on the consumption estimation, see Overholtz et al. (2000).

Key Points and Major Observations

Consumption of pelagic fishes and squids by the 12 predators varied greatly during 1977-1997 and was particularly large in some years on herring and sandlance. Predation on sand lance reached high levels in the late 1970s and early 1980s, coincident with the large biomass of this species present at the time and major declines in Atlantic mackerel and herring. As the Atlantic mackerel stock began to recover, predation on mackerel increased, reaching 89,000 mt in 1988.

This was followed by an increase in herring consumption to over 200,000 mt during 1992 and 1993, declining to about 100,000 mt in 1997. Consumption of short-finned and long-finned squid averaged 24,000 and 46,000 mt during 1977-1997, but remained relatively constant over this period. Predation on butterfish was more variable than the other species, but with the exception of a few years , was relatively low. The recent decline in consumption of these species is directly related to declines in the biomass of key predators such as spiny dogfish, cod, white hake, and bluefish. Earlier studies (Bowman and Michaels 1984) suggest that these prey, especially sand lance, herring and mackerel, were important in the diets of these key predatory fish prior to 1977.

5. Snapshot of food web for three years in three different decades

Time: 1977, 1987, and 1997

Spatial: Shelf wide

Contributed by: Link

Figures B.41, B.42, and B.43

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For specifics on the consumption estimation, see Overholtz et al. (2000) and Link and Garrison (2002a).

Key Points and Major Observations

The size of the circle is proportional to the size of population; the thickness of an arrow shows how much of the population is consumed by predator. During1977, squid and sand lance were the major prey and this was a relatively simple food web. During 1987 and 1997, this was a much more complex food web, with the major groundfish populations lower in abundance and the importance of pelagics as prey more notable.

6. Fish consumption and % fish in diet of cod

Time: 1978 - 1997

Spatial: Shelf wide

Contributed by: Link

Figure B.44

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For specifics on the consumption estimation, see Overholtz et al. (2000) and Link and Garrison (2002a).

Key Points and Major Observations

There was a peak in the early 1980s for both how much fish comprised the diet of cod and how much fish biomass was consumed by cod. Lower values in the 1990s likely reflect the smaller size structure of the cod population.

7. Fish consumption by cod at age

Time: 1978 - 1997

Spatial: Shelf wide

Contributed by: Link

Figure B.45

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For specifics on the consumption estimation, see Overholtz et al. (2000) and Link and Garrison (2002a).

Key Points and Major Observations

There is an overall decline in the amount of total fish consumed by cod seen here and in Figure B.44. The amount of fish eaten by cod at different ages varied over time. Through the 1980s and into the 1990s, the relative and absolute amount of fish eaten by age 7+ cod declined. In early to mid 1990s older fish (ages 7+) were a smaller component of the population and contributed a relatively smaller proportion of the amount of fish consumed relative to age 3-5 cod.

8. Cod % diet composition of major fish prey

Time: 1973 - 1997

Spatial: Shelf wide

Contributed by: Link

Figure B.46

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For further details see Link and Garrison (2002b).

Key Points and Major Observations

This demonstrates the transfer of energy from pelagic to benthic environment. It also seems to show prey switching based upon prey availability.

9. Spiny dogfish % diet composition of major fish prey

Time: 1973 - 1997

Spatial: Shelf wide

Contributed by: Link

Figure B.47

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling.

Key Points and Major Observations

The dogfish diet seems to track prey availability. The diet of dogfish is comprised mainly by pelagic prey.

10. Number of predators for sand lance, herring, hermit crab, ophiuroids, mysids, and red hake

Time: 1973 - 1998

Spatial: Shelf wide

Contributed by: Link

Figure 48 (a-f)

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling.

Key Points and Major Observations

This metric is a measure of food web linkage density. There are some notable changes over time, particularly an increase in red hake and herring predators in more recent years.

11. Silver hake % cannibalism

Time: 1973 - 1998

Spatial: Shelf wide

Contributed by: Link

Figure B.49

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. These data represent what fraction of silver hake diet consists of silver hake.

See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling.

Key Points and Major Observations

When other prey are not available, silver hake are cannabilistic. This phenomena has a consistently high occurrence, with in an increasing trend in the mid 1990s. How this impacts population dynamics is unclear.

12. Silver hake and red hake number of prey items

Time: 1973 - 1998 (with 4 year moving averages overlaid)

Spatial: Shelf wide

Contributed by: Link

Figure B.50

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling.

Key Points and Major Observations

There was a decrease in the number of prey consumed by silver hake in mid 1980s, with an increasing number of prey throughout the 1990s. The number of prey of red hake has increased continuously until the mid 1990s. The two hakes show similar patterns and also exhibit similar diets.

13. Herring consumption to landings ratio

Time: 1977 - 1997

Spatial: Shelf wide

Contributed by: Overholtz

Figure B.51

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For specifics on the consumption and landings information, see Overholtz et al. (2000).

Key Points and Major Observations

Consumption of Atlantic herring was below 50,000 mt from 1977-1987 and then increased in the 1990s to over 200,000 mt in some years. Landings for this species averaged 82,000 mt during 1977-1997. As herring increased in the 1990s, consumption to landings ratios increased dramatically in the early 1990s and then declined. If predator fish biomass is allowed to recover we would expect consumption of this species to increase and greatly exceed landings in the future.

14. Mackerel consumption to landings ratio

Time: 1977 - 1997

Spatial: Shelf wide

Contributed by: Overholtz

Figure B.52

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For specifics on the consumption and landings information, see Overholtz et al. (2000).

Key Points and Major Observations

Consumption and landings of Atlantic mackerel by 12 predatory fish were fairly similar during 1977-1997 and both were well below established reference points for this species (MSY 326,000 mt). Consumption to landings ratios for this species were relatively constant during 1977-1997. This suggests that a recovery in predator biomass may not cause any large increases in consumption on this species, with the exception perhaps of a large recruiting year-class. Several factors such as fast swimming speed and enhanced growth rates, allowing for a larger body size, probably make Atlantic mackerel less available or suitable to this suite of 12 predators.

15.* Loligo *consumption to landings ratio

Time: 1977 - 1997

Spatial: Shelf wide

Contributed by: Overholtz

Figure B.53

Methodology and Data Source

These data are derived from both the NEFSC Bottom Trawl Survey Data and the Food Habits Database. See Link and Almeida (2000) for further details on the food habits sampling and Azarovitz (1981) for the bottom trawl survey sampling. For specifics on the consumption and landings information, see Overholtz et al. (2000).

Key Points and Major Observations

Consumption of long-finned squid exceeded landings and MSY (24,000 mt) in all years except 1993 and 1994. Consumption to landings ratios for this species were relatively high throughout the 1977-1997 period, averaging 2.36 and ranging from 0.58-4.88. This suggests that any increase in predator biomass will translate into an immediate increase in consumption of this species by predatory fish. Consumption will probably always be in excess of sustainable landings for this species.

K. System Level Indices

We recognize that there are also several system level indices that one could estimate to ascertain the status of this ecosystem. For example, what are the values for emergy, exergy, free energy, information content, energy flows, system level consumption, metabolism, and production, total production, total biomass, and flux rates across time? Similarly, how strong is the resilience, persistence, resistance, or stability of the system? Not much is known in general or in a time series sense for these measure, but these emergent metrics could be estimated in future efforts.

L. Summary of Biotic Metrics

We examined biotic metrics ranging from single species to ecosystem level.

The early to mid 1980s seem to have a consistent "blip" in many of the graphs. The cause of these peaks or troughs are currently unknown. Some potential hypotheses include a change in the "environmental condition" (not specified), removal of the foreign fishing fleets in 1976 and changes in management during the late 1970s and early 1980s, predatory release due to changes in overall selectivity, changes in the trophic linkages, alteration of habitat, or some combination thereof.

Total biomass (as measured by the trawl survey time series) has been remarkably consistent from the late 1960s to present given the large changes observed in biomass of individual species.

Changes in the abundance and diversity of commercially important species and associated bycatch species should be interpreted in light of changing management measures over time. In particular, the implementation of the closed areas since 1995 may influence these trends.

Are systematic (taxonomic) or trophic (functional) groupings more important for providing information? Would plotting fishing pressure on graphs of fish biomass improve our understanding? Similarly, would a similar plot against environmental variables improve our understanding? These and a suite of related questions merit examination in the future.

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Table 4.1. Abundance estimates of marine mammals and protected species in U.S. waters of the northwest Atlantic.

	Year						
Species	1982	1991	1992	1995	1997	1998	1999
Common dolphin	4201			6743		30768	
Riss's dolphin	11834			5050		29110	
Atl. Spotted dolphin	2441			4772		36439	
Pantropical spotted dolphin				4772		13117	
Bottlenose dolphin	12069			13440		30633	
Striped dolphin	16320			30935		61546	
White-sided dolphin	38016		20400	27157			51640
Harbor porpoise	18934	37500	67500	74000			89700
Pilot whale	8839			8111		14524	
Beaked whales	939			1516		3196	
Humpback whale							816
Sperm whale	1301			2695		4702	
Fin/Sei whale	6075			2229			2814
Minke whale	4945		2650	3810			2998
Loggerhead turtles	7702			4644		6010	
Leatherback turtles	361			3136		1175	
Kemps Ridley turtle				0		2260	
Harbor seal					30990		