The Presence of Gelatinous Zooplankton in the Diets of Fishes of the Northeast U.S. Continental Shelf: Trends in Shelf-wide Feeding and Consumptive Removals

Brian E. Smith* and Jason S. Link

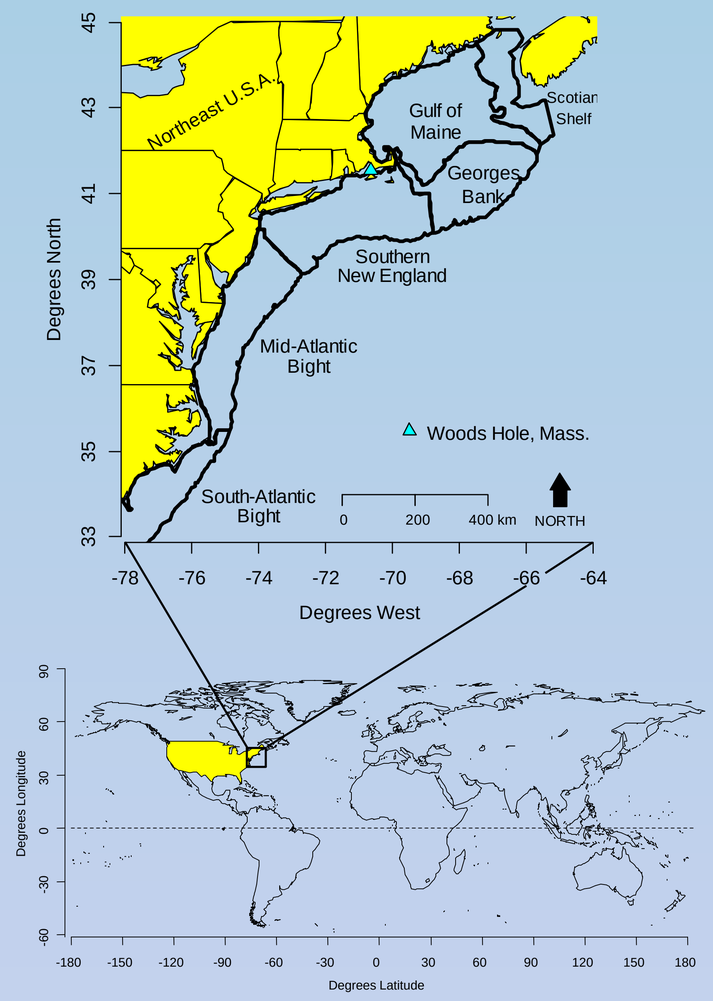
National Marine Fisheries Service, Northeast Fisheries Science Center,
Woods Hole, Massachusetts, USA, *Email: Brian.Smith@noaa.gov*

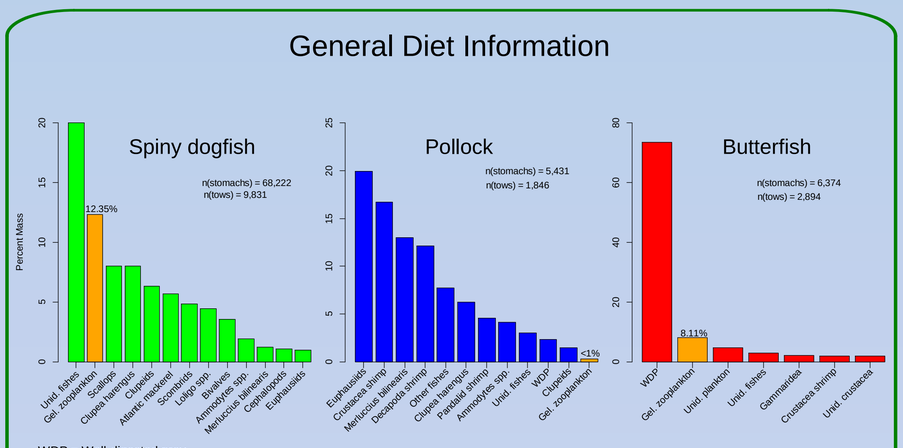
INTRODUCTION

There has been global concern over episodic increases of gelatinous zooplankton (GZ) abundance in marine environments and these dynamics have been attributed to various drivers (e.g. climate change, overfishing, eutrophication; see Brodeur et al. 2008; Richardson et at. 2009; Brotz et al. 2012). Evidence of GZ as fish prey on the Northeast U.S. continental shelf (figure right) has been shown (Link & Ford 2006; Smith & Link 2010), but at the population-level, GZ consumption and its connection with GZ in the environment remain largely unexamined. Here we define GZ as scyphozoans, siphonophores, ctenophores, and salps.

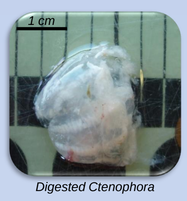
The objectives of this study were to examine the presence of GZ in the diets of commercially-important fishes of the shelf, quantify the annual shelf-wide consumptive removal of GZ by fishes, and relate annual trends of baseline GZ abundance in the environment with trends in GZ consumption across the shelf. The hypothesis was that environmental trends in GZ would be reflected in fish diets.

Northeast U.S. Continental Shelf





- The three fishes examined are generalist feeders, eating a variety of fishes, crustaceans, and gelatinous zooplankton (GZ).
- The importance of GZ as prey is most notable for spiny dogfish.



Digested Ctenophora

FRV Bigelow

METHODS

Data Collection

Fish diet sampling occurred during seasonal bottom trawl surveys of the Northeast Fisheries Science Center (NEFSC) located in Woods Hole, Massachusetts from 1977-2010 (Smith & Link 2010). The top-3 gelatinous zooplankton (GZ) predators included spiny dogfish (*Squalus acanthias*), pollock (*Pollachius virens*), and butterfish (*Peprilus triacanthus*); comprising 95% of the total occurrences of GZ in fish stomachs.

Baseline GZ abundance was collected during NEFSC Ecosystem Monitoring surveys from 1977-2010. Values are expressed as an annual average of monthly anomalies (time series mean subtracted from each data point then divided by the time series standard deviation; data source: NEFSC 2012).

Consumption Rates

Per capita consumption of GZ (C_{it}) was estimated with the gastric evacuation rate method (Eggers 1977; Elliott & Persson 1978) as

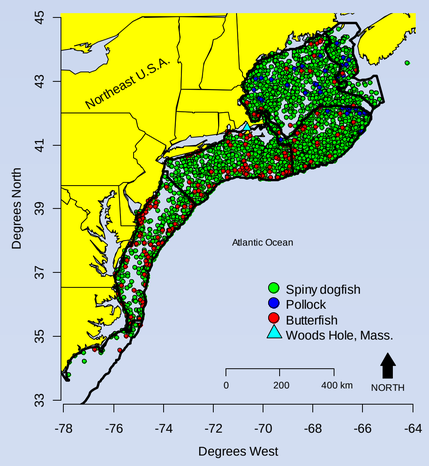
$$C_{it} = 24 \cdot E_{it} \cdot \overline{S_{it}}, \qquad E_{it} = \alpha e^{\beta T},$$

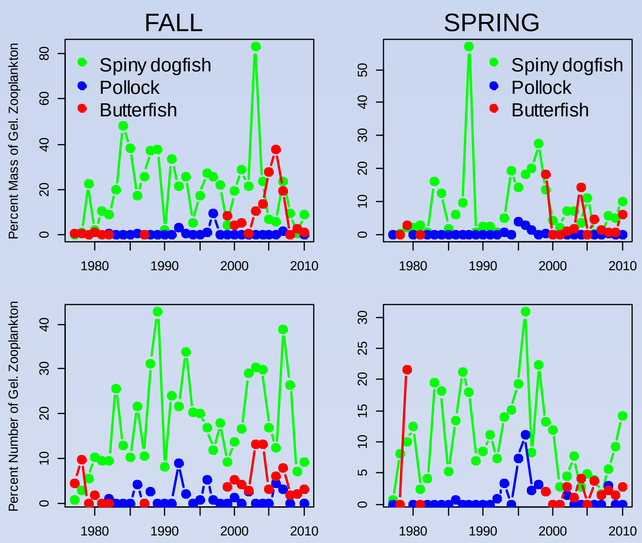
where 24 is the number of hours in a day, estimates of mean stomach contents (S_{it}), and E_{it} is the evacuation rate. Temperature (T) is the average bottom temperature from NEFSC bottom trawl surveys associated with the presence of each predator per fall and spring season. The parameters α and β were assumed to be 0.002 and 0.115 respectively for spiny dogfish, and 0.004 and 0.115 respectively for pollock and butterfish (Tsou & Collie 2001a, b).

Per capita consumption estimates were scaled for each predator and season (half-year; 182.5 days), multiplied by the proportion of GZ in the diet by mass per season, and summed for each year. Final estimates were scaled by the annual stock abundance taken from recent assessments (spiny dogfish and pollock) or based on swept area biomass (butterfish). Total GZ consumption was summed across all predators and reported as thousands of metric tons (MT) per year.

Spatial and Temporal Trends in Gelatinous Zooplankton Predation

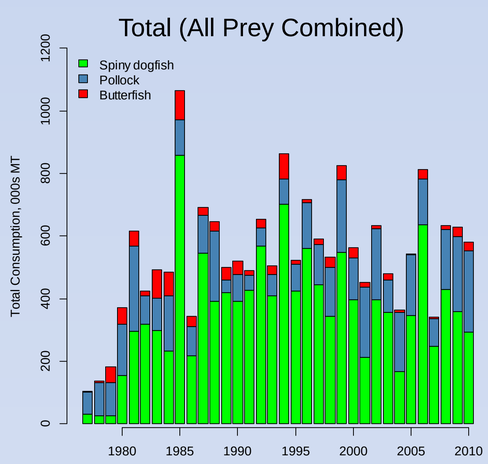
Presence of GZ in Fish Stomachs

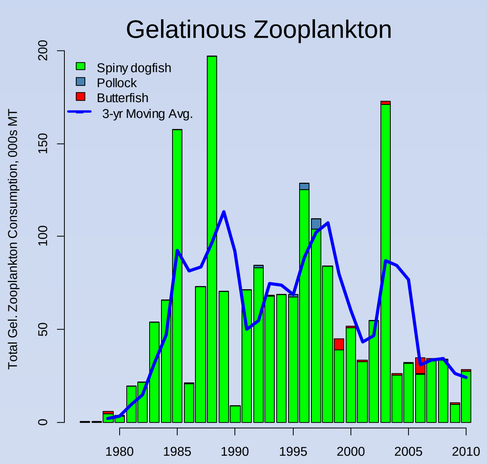




- Gelatinous zooplankton (GZ) predation is widespread across the shelf given fish predator distributions.
- Diet indices of percent mass and percent number of GZ suggest pulses of predation by predator and season.

Scaled Consumption

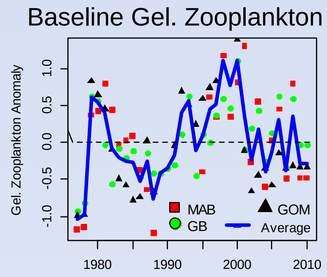




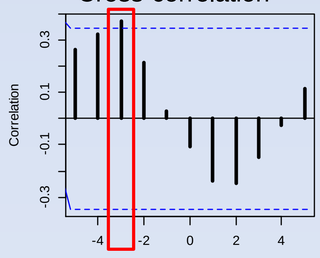
- Total consumption of all prey for these predators was approximately 500,000 MT per year across the shelf.
- Total gelatinous zooplankton (GZ) consumption ranged from approximately 10,000-200,000 MT per year with spiny dogfish being the primary GZ feeder.
- 3-year moving average of GZ consumption generally followed a decadal period with peaks in the mid-late-1980s and 1990s, and early 2000s.

Time Series Correlations

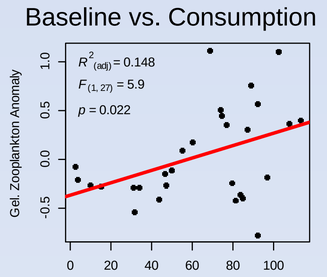
Baseline Gel. Zooplankton



Cross-correlation



Baseline vs. Consumption



MAB = Mid-Atlantic Bight and Southern New England
GB = Georges Bank; GOM = Gulf of Maine

- Average baseline gelatinous zooplankton (GZ) abundance for the shelf exhibits 10-12 year periods.
- Cross-correlations between baseline GZ and smoothed GZ consumption suggest similar trends in both series with 3-year lag in GZ consumption (blue dotted line denotes $p < 0.05$); relationship is positive.
- Lag in GZ consumption possibly due to differences in sampling efficiency between samplers.

CONCLUSIONS

- Episodic increases in gelatinous zooplankton (GZ) consumption by fishes was associated with increases of GZ in the environment.
- Given the various challenges of sampling GZ in the environment directly and as fish prey (e.g. spatial/temporal variation, fragility/digestibility), pulses of GZ appear to provide surges of food for commercially- and ecologically-important fishes of the Northeast U.S. continental shelf.
- Understanding the bioenergetic tradeoffs of consuming greater amounts of GZ with lower energy density compared to other prey (e.g. fishes and crustaceans) remains a critical question.

REFERENCES

Brodeur et al. (2008). Rise and fall of jellyfish in the eastern Bering Sea in relation to climate regime shifts. *Progress in Oceanography* 77:103-111.

Brotz et al. (2012). Increasing jellyfish populations: trends in Large Marine Ecosystems. *Hydrobiologia* 690:3-20.

Eggers, DM. (1977). Factors in interpreting data obtained by diel sampling of fish stomachs. *Journal of the Fisheries Research Board of Canada* 34:290-294.

Elliot & Persson (1978). The estimation of daily rates of food consumption. *Journal of Animal Ecology* 47:977-999.

Link & Ford (2006). Widespread and persistent increase of Ctenophora in the continental shelf ecosystem off NE USA. *Marine Ecology Progress Series* 320:153-159.

NEFSC 2012. Ecosystem status report for the Northeast Shelf Large Marine Ecosystem – 2011. *US Dept. Commerce. NEFSC Reference Document,12-07*, 32 p.

Richardson et al. (2009). The jellyfish joyride: causes, consequences, and management responses to a more gelatinous future. *Trends in Ecology and Evolution* 24:312-322.

Smith & Link (2010). The trophic dynamics of 50 finfish and 2 squid species of the Northeast US continental shelf. *US Dept. of Commerce. NOAA Technical Memorandum NMFS-NE-216*, 640 p.

Tsou & Collie (2001a). Estimating predation mortality in the Georges Bank fish community. *Canadian Journal of Fisheries and Aquatic Sciences* 58:908-922.

Tsou & Collie (2001b). Predation-mediated recruitment in the Georges Bank fish community. *ICES Journal of Marine Science* 58:994-1001.