The Effects of Bottom Fishing on the Benthic Macrofauna and Demersal Fish Feeding Habits of Northern Georges Bank

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ABSTRACT

The impact of mobile bottom fishing gear on marine benthic habitat and demersal communities has been well documented for Georges Bank in the northwest Atlantic and elsewhere. However, few studies have examined the effects of bottom fishing on the feeding habits of benthivorous fishes within this shelf region. Here, we quantified the differences in the benthic macrofaunal and demersal fish communities between sites with disparate levels of disturbance from mobile bottom fishing gear for northern Georges Bank (*i.e.* the Habitat Area of Particular Concern (HAPC) of northern Closed Area II, and a contiguous Canadian region). The study compares a suite of benthic macrofaunal and fish diet indices across year and fishing disturbance level as fixed effects. Fishes selected for diet comparisons included winter skate (*Leucoraja ocellata*), little skate (*Leucoraja erinacea*), Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), winter flounder (*Pseudopleuronectes americanus*), and longhorn sculpin (*Myoxocephalus octodecemspinosus*).

Benthic macrofaunal abundance (n/L), biomass (g/L), and species richness were generally higher in the non-fished areas, whereas an evenness index was greatest in areas disturbed by bottom fishing. Within the HAPC region, the effect of fishing was less pronounced and additional factors were proposed. Nonetheless, marked differences in fish feeding habits were present and predator-prey dynamics were shown to be altered by a fishing disturbance effect. In several cases, prey that contributed to the diet dissimilarity between sites were taxa most sensitive to the impact of bottom fishing disturbance as shown in the benthic macrofaunal community, yet these results were variable on Georges Bank.

Hauling back 4-seam otter trawl.

Sorting Naturalists' dredge sample.

Stomach sampling winter flounder (*Pseudopleuronectes americanus*)

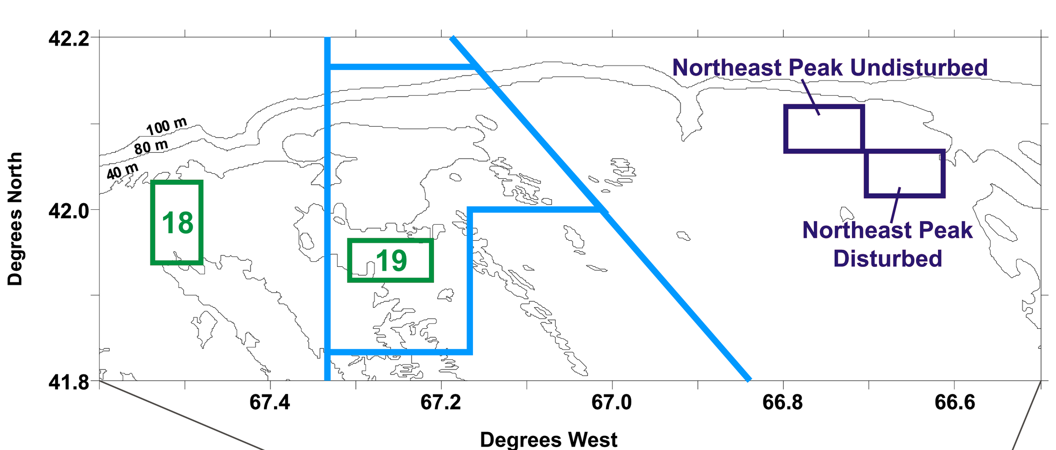
BACKGROUND

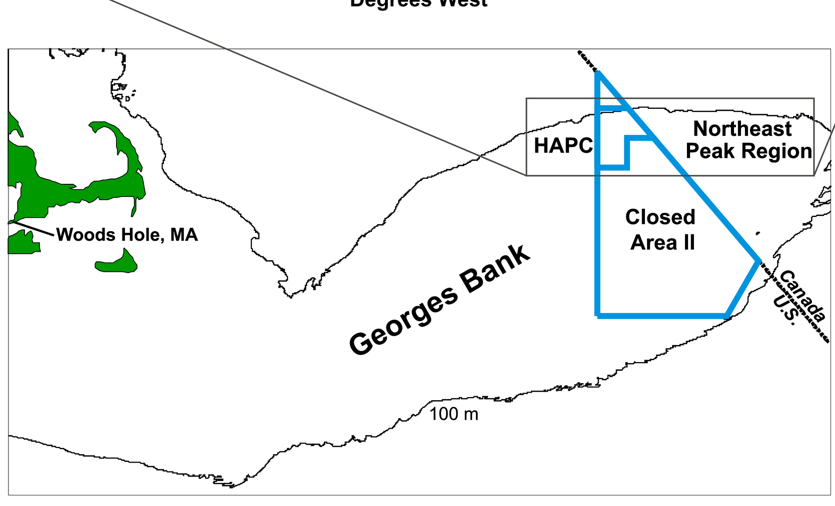
There has been much global concern over human disturbance of continental shelves and its effects on ecosystem function particularly for the benthos (Hermsen et al. 2003; Allen and Clark 2007). The use of mobile bottom fishing gear (*i.e.* scallop dredges and demersal fish trawls) is one method of anthropogenic disturbance that has received considerable attention due to the physical effects on the substratum and the ecological effects on benthic macrofaunal communities (*e.g.* Auster et al. 1996; Kaiser and Spencer 1996).

Despite extensive efforts to quantify the first-order effects of chronic bottom fishing on benthic macrofaunal communities, few studies worldwide have examined the second-order effects such as altered predator-prey dynamics by concurrently sampling the available prey, predator, and diet fields (de Juan et al. 2007; Fanelli et al. 2009), and even less for Georges Bank (Link et al. 2005). Nonetheless, similar hypotheses relative to fish feeding and benthic disturbance have been considered (*e.g.* Badalamenti et al. 2008).

The objectives of this study were to quantify the differences between benthic macrofaunal communities and select demersal fishes of northern Georges Bank subjected to contrasting levels of bottom fishing pressure. Demersal fish feeding habits of these areas disturbed and undisturbed by mobile bottom fishing gear were examined to explore the alteration of predator-prey dynamics for this northwest Atlantic region.

Sampling Areas on Georges Bank





METHODS

Data Collection

The sampling for this project occurred August 22-September 2, 2005, August 22-September 1, 2006, July 2-13, 2007, and August 13-26, 2008 within two major regions of northern Georges Bank: Northeast Peak region (Canadian waters), and the Habitat Area of Particular Concern (HAPC) of Closed Area II (figure left).

Site selection for the Northeast Peak region and the HAPC (disturbed versus undisturbed) was determined to compare areas with contrasting levels of bottom fishing disturbance while considering benthic macrofaunal community variability due to substrate type and depth. Ultimately, site designations were generally based upon a continuation of work by Collie et al. (1997; 2005).

At each site, one station was selected for sampling benthic macrofauna, and two to three replicates were sampled with a 1-meter wide Naturalists' dredge with a 6.4 mm liner. Organisms were manually sorted from the substrate and later identified to the lowest taxon feasible, weighed (wet; ±1 mg), and enumerated in the laboratory. Taxa not quantitatively sampled by the dredge (*e.g.* colonial ascidians, caprellids, and other amphipods) were removed prior to analysis.

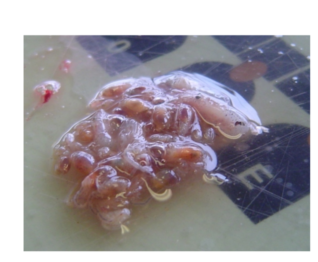
Concurrent with the benthic macrofaunal sampling at each site, stomach samples from the six species: winter skate (*Leucoraja ocellata*), little skate (*Leucoraja erinacea*), Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), winter flounder (*Pseudopleuronectes americanus*), and longhorn sculpin (*Myoxocephalus octodecemspinosus*) were collected with a #36 Yankee (2005-2007) or 4-seam (2008) otter trawl. Stomachs were examined at sea volumetrically or processed in the laboratory. In each case, stomach contents were identified to the lowest taxon feasible and wet masses (±0.01 g) were obtained.

Data Analysis (Indices and Statistical Tests Performed)

Benthic Macrofauna: Numerical abundance (n/L) and biomass (g/L; standardized per unit volume of substrate sampled) for the total amount (species combined), the 10 most abundant species, species richness (S), and evenness ($e^{H'}/S$; base 2 logarithm). Two-way ANOVAs (universal α= 0.05) with sampling year (YR) and fishing disturbance level (disturbed versus undisturbed; DIST) as fixed effects (displayed in RESULTS).

Demersal Fish Diet: Data pooled across sampling years per species-site combination (*e.g.* winter flounder at Site 18) to test fishing disturbance effect. Two-sample Kolmogorov-Smirnov test used to compare species length distributions across sites within each region to eliminate bias associated with ontogenetic diet shifts. Cumulative trophic diversity curves (Shannon-Wiener diversity) used to ensure adequate stomach samples sizes per sampling site; order of stomachs randomized 100 times.

Total stomach content index (g; standardized by predator mass (g)); Kruskal-Wallis nonparametric test. Diet composition (prey as proportion of individual total stomach content); Bray-Curtis similarity index (universal), one-way ANOSIM (9,999 permutations), and SIMPER routine (PRIMER) provided when significant diet dissimilarities were detected. Rank correlations (Spearman's *rho*) between fish diet and benthic macrofauna similarity matrices per species-site pair (*e.g.* Sites 18 and 19) were based on biomass data as proportions and significance tested via 9,999 permutations.



RESULTS: Rank Correlations

Northeast Peak:

Species	Northeast Peak *rho*	Probability
Atlantic cod	0.301	0.051
Haddock	0.266	0.038
Longhorn sculpin	0.392	0.022

HAPC: Sites 18 - 19:

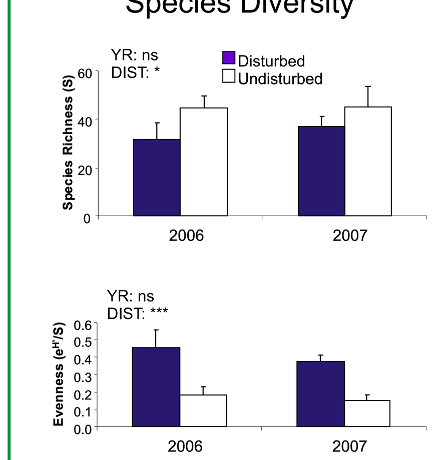
Species	Sites 18 - 19 *rho*	Probability
Winter skate	0.153	0.182
Little skate	0.023	0.468
Haddock	-0.079	0.689
Winter flounder	-0.019	0.542
Longhorn sculpin	0.132	0.177

- Significant correlations between the benthic macrofaunal community and demersal fish diets were detected, although these results were primarily seen in the Northeast Peak region (*e.g.* haddock and longhorn sculpin).
- The absence of correlation observed for the five fish species of HAPC Sites 18 and 19 may be due to subtle differences in sampling efficiency between the Naturalists' dredge and demersal fish stomachs given that feeding differences were detected across fishing disturbance levels (winter flounder; see below).

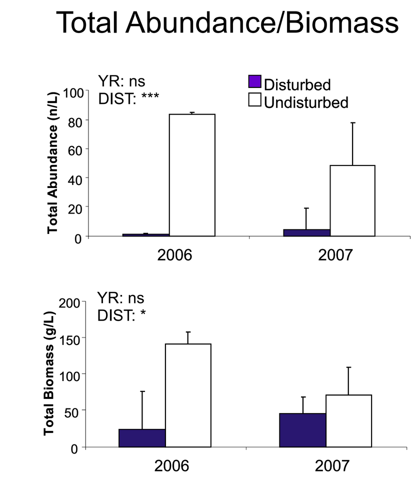
RESULTS: Benthic Macrofauna

Northeast Peak:

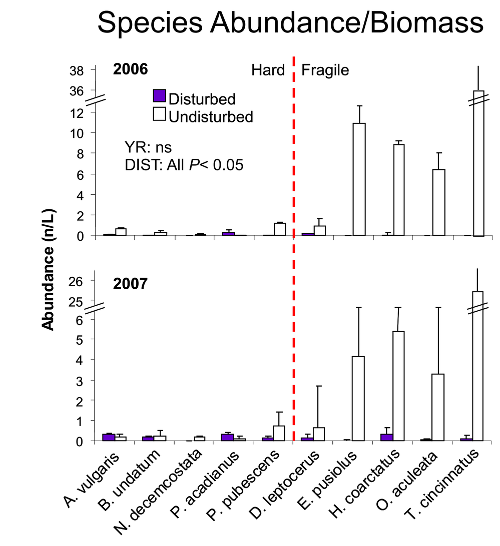
Species Diversity



Total Abundance/Biomass

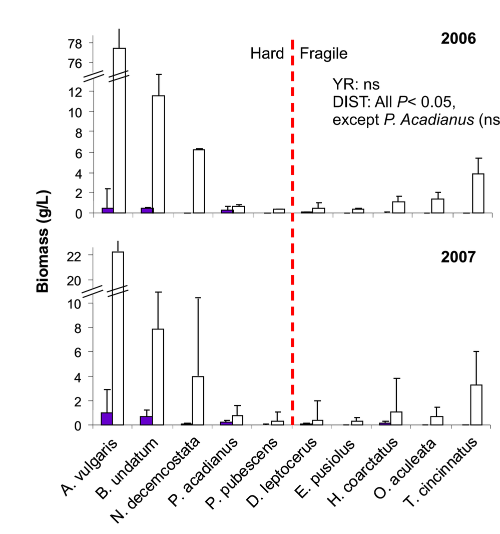


Species Abundance/Biomass



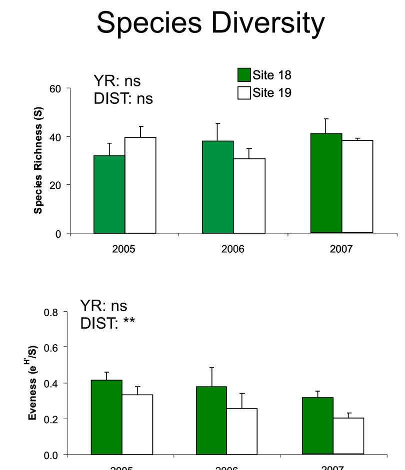
*P< 0.05; **P< 0.01; ***P< 0.001; ns = not significant

- Species richness (S) was statistically higher in the undisturbed area; however, evenness diversity ($e^{H'}/S$) was greater in the disturbed area.
- Total and individual species abundance and biomass of benthic macrofauna were higher in the undisturbed area with the exception of *Pagurus acadianus* (Acadian hermit crab; greater abundance in the disturbed area.
- Those species most negatively affected by mobile bottom fishing gear generally were taxa with fragile body structures (*e.g.* Polychaeta, *Hyas* sp., and Ophiuroidea).

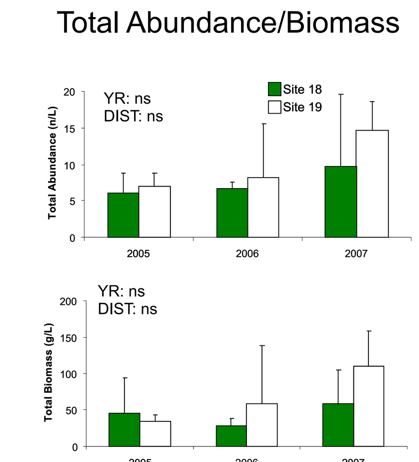


HAPC: Sites 18 - 19:

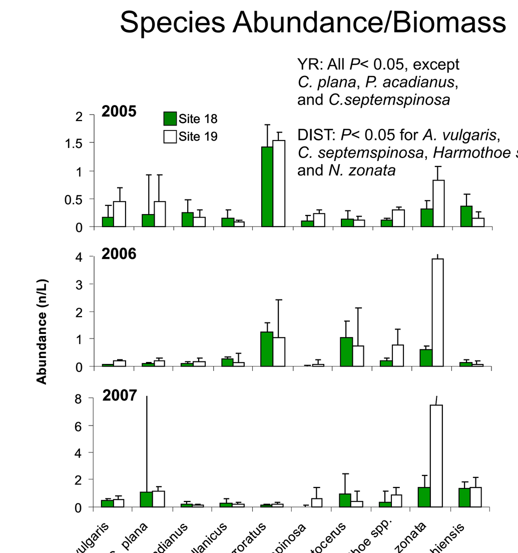
Species Diversity



Total Abundance/Biomass

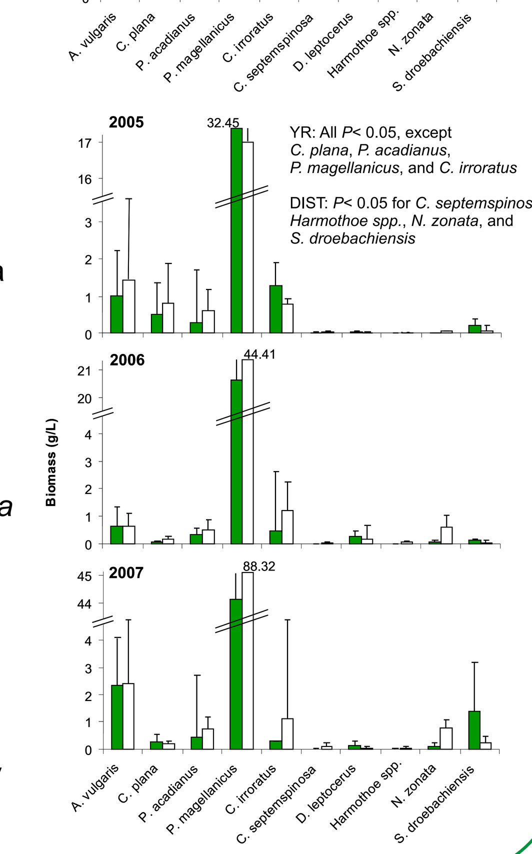


Species Abundance/Biomass



*P< 0.05; **P< 0.01; ***P< 0.001; ns = not significant

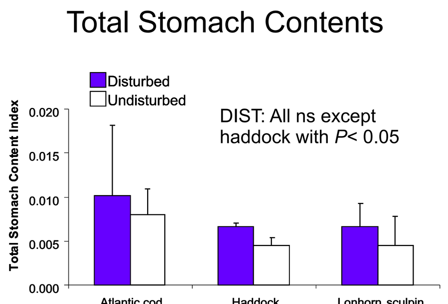
- The effect of bottom fishing disturbance on the benthos was less dramatic at HAPC Sites 18 and 19 compared to the Northeast Peak region.
- Species richness (S) was not statistically different across Year and Fishing Disturbance levels; however, a significantly larger evenness diversity ($e^{H'}/S$) was observed in the disturbed area (Site 18).
- Individual species abundance and biomass differences were observed across Year and Fishing Disturbance levels with greater amounts of errant polychaetes (*Harmothoe spp.* and *N. zonata*) and *C. septemspinosa* recorded in the undisturbed area (Site 19). In contrast, the factors tested had no significant effect on the response variables: total benthic macrofauna abundance and biomass.
- The extensive presence of the invasive ascidian *Didemnum vexillum* at Sites 18 and 19 is likely an additional effect driving these results. Work is currently underway to isolate and examine this factor.



RESULTS: Demersal Fish Diet

Northeast Peak:

Total Stomach Contents

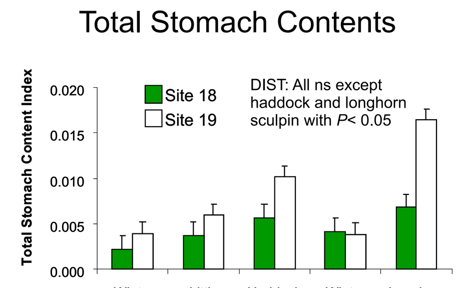


One-way ANOSIM

Species	Northeast Peak *Global R*	Probability
Atlantic cod	0.055	0.052
Haddock	0.019	0.022
Longhorn sculpin	0.094	0.001

HAPC: Sites 18 - 19:

Total Stomach Contents



One-way ANOSIM

Species	Sites 18 - 19 *Global R*	Probability
Winter skate	0.015	0.243
Little skate	0.015	0.194
Haddock	-0.191	1.000
Winter flounder	0.182	<0.001
Longhorn sculpin	-0.035	0.788

SIMPER

Haddock

Taxa	Mean Proportion Dist.	Mean Proportion Undist.	Similarity% Dist.	Similarity% Undist.	Dissimilarity Mean	Percent Contribution
Ammodytes sp.	0.1516	0.0818	44.12	27.37	18.40	21.43
Gammaridea	0.0520	0.0321	22.02	28.61	11.96	13.92
Placopecten magellanicus viscera	0.0435	0.0143	11.68	5.17	10.66	12.41
Polychaeta	0.0081	0.0286	5.12	12.99	8.33	9.70
Hyas crabs	0.0036	0.0168	1.72	7.28	6.50	7.57
Ophiuroidea	0.0064	0.0121	3.53	6.19	6.47	7.54
Decapoda crab	0.0121	0.0001	5.01	0.07	4.54	5.28
Gastropoda	0.0001	0.0049	0.16	3.92	3.06	3.57
Rock	0.0025	0.0025	3.81	3.27	3.03	3.53

Longhorn sculpin

Taxa	Mean Proportion Dist.	Mean Proportion Undist.	Similarity% Dist.	Similarity% Undist.	Dissimilarity Mean	Percent Contribution
Hyas crabs	0.0395	0.3003	7.23	66.41	21.15	25.66
Ammodytes sp.	0.2822	0.0476	51.10	15.18	20.29	24.61
Pandalidae	0.2383	0.0321	38.63	6.72	18.99	23.04
Pagurus acadianus	0.0016	0.0286	0.00	6.16	6.90	8.37
Paguroidea	0.0004	0.0254	0.22	4.10	6.25	7.58
Decapoda crab	0.0036	0.0100	0.36	1.43	5.23	6.34
Cancer crabs	0.0121	0.0000	2.45	0.00	3.63	4.40

*P< 0.05; **P< 0.01; ***P< 0.001; ns = not significant

SIMPER

Winter flounder

Taxa	Mean Proportion Site 18	Mean Proportion Site 19	Similarity% Site 18	Similarity% Site 19	Dissimilarity Mean	Dissimilarity Mean / SD	Percent Contribution
Anthozoa	0.2643	0.0009	54.07	0.23	16.90	0.90	19.96
Cancer crabs	0.0100	0.2383	4.67	50.58	15.56	1.01	18.38
Polychaeta	0.0435	0.1308	12.36	27.25	13.39	0.95	15.82
Gammaridea	0.0711	0.0286	15.53	6.80	11.65	0.73	13.76
Well-digested prey	0.0168	0.0254	3.52	6.13	8.00	0.60	9.45
Didemnum spp.	0.0254	0.0121	6.32	1.96	7.09	0.59	8.37
Sand	0.0001	0.0168	0.06	2.94	4.13	0.41	4.88
Hydroids (Hydrozoans)	0.0036	0.0025	1.89	1.16	3.25	0.52	3.84
Rock	0.0016	0.0036	1.23	2.81	2.65	0.69	3.13

- Differences in demersal fish total stomach content were generally minimal when testing the effect of bottom fishing disturbance.
- However, dissimilarities in diet composition across fishing disturbance level were apparent for haddock and longhorn sculpin (Northeast Peak) and winter flounder (HAPC). In several cases, prey taxa that largely contributed to these diet differences were species less resilient to bottom fishing disturbance (*e.g. Hyas* crabs, polychaetes, and ophiuroids).
- Interestingly, a larger proportion of fish prey (*i.e. Ammodytes* sp.) was present in stomachs sampled in the disturbed areas (*e.g.* Northeast Peak), and this result was consistently observed for other sampling regions of Georges Bank not shown.

CONCLUSIONS

Bottom fishing has a profound effect on the northern Georges Bank benthic macrofaunal community.

Marked differences in the feeding habits of select demersal fishes were observed, linked to prey availability, and documented a second order effect of bottom fishing disturbance; however, our findings were species specific and less dramatic for the HAPC region.

Further investigation into the effect of *Didemnum vexillum* (invasive ascidian) at HAPC Sites 18 and 19 particularly with regard to the potential alteration of fish predator-prey dynamics in this region is of additional merit.

For further information please contact Brian Smith (Brian.Smith@noaa.gov).

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