The Effects of the Invasive Ascidian *Didemnum vexillum* on the Benthic Macrofauna and Feeding Habits of Winter Flounder (*Pseudopleuronectes americanus*) on Northern Georges Bank

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Major Objectives

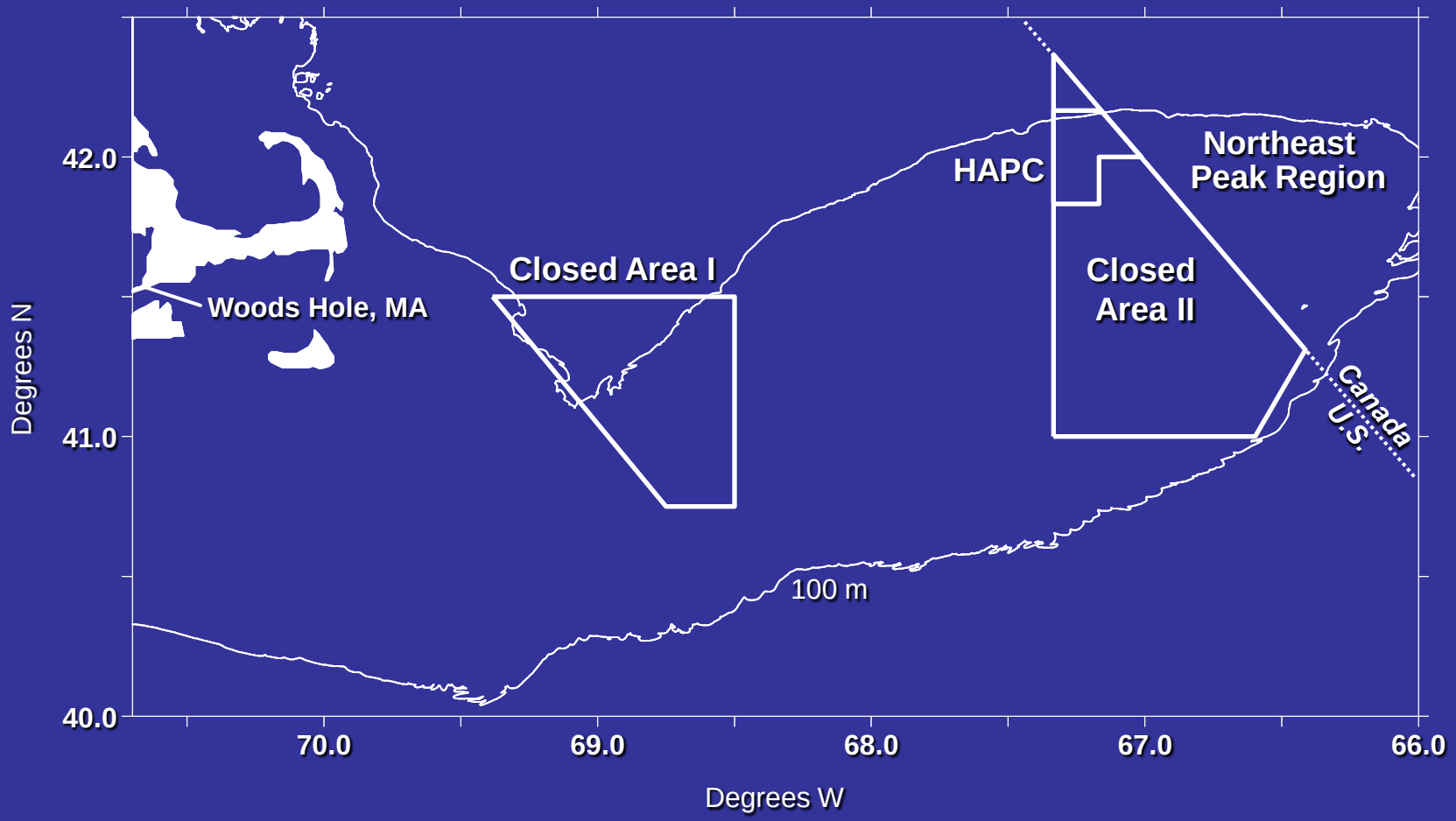
- Examine northern Georges Bank communities subjected to contrasting levels of *Didemnum vexillum*:
    1. Benthic macrofauna
    2. Winter flounder diet
        - Alteration of predator-prey dynamics

Rationale

- Global concern for *D. vexillum*, particularly in North American waters
- Evidence of impact on Georges Bank benthic communities, but second-order effects on commercially valuable resources (i.e. groundfish) unexamined

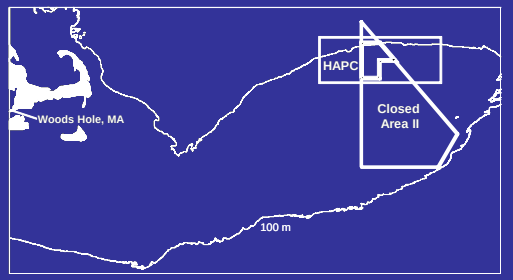
Methods

Sampling Regions of Georges Bank



- *D. vexillum* first documented on Georges Bank in 2002

Methods

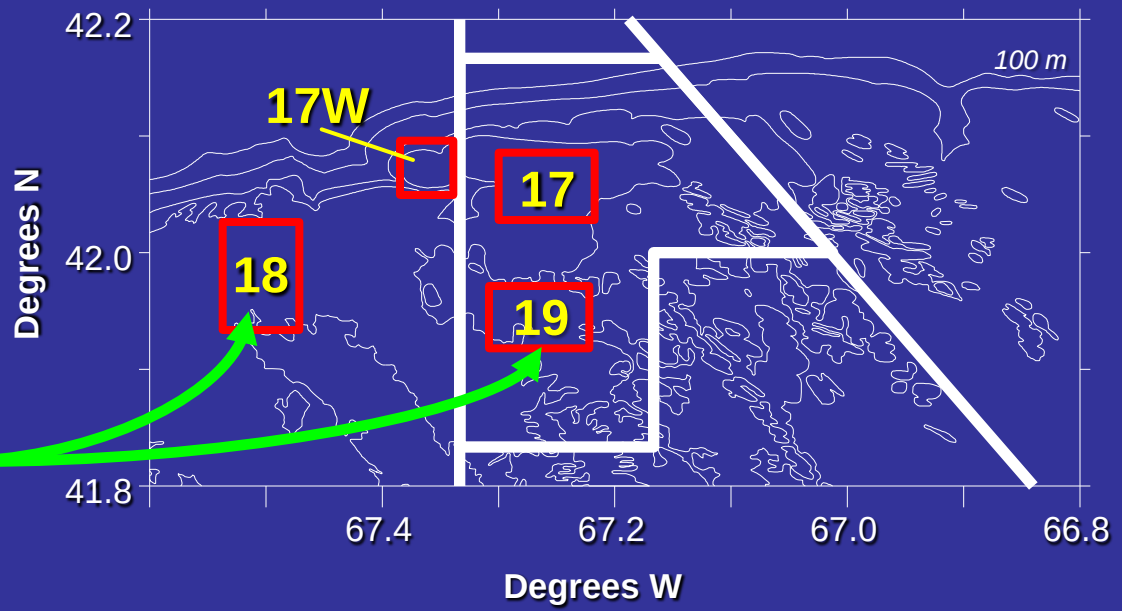


Sampling Sites

- HAPC (4), depth: 45-55 m, gravel/cobble substrate
- Similar substrate type, depth, and bottom fishing disturbance
- *D. vexillum* presence/absence (Sites 17W-18, 17-19)
- Combined coverage > 230 km^2 at Sites 18 and 19
- Collie et al. 1997, Hermsen et al. 2003, Collie et al. 2005

Didemnum vexillum

P. Valentine and D. Blackwood



Methods

Station Sampling:

- Benthic macrofauna: 1-m Naturalist dredge (2004-08; 2-3 per site)
- Demersal fish: NEFSC Yankee 36 Trawl (2004-07; 1-4 per site), and 4-Seam Trawl (2008; 2-3 per site)
- Fish Stomachs: Examined at sea (volumetrically) and preserved for lab processing (2004-08)

FRV Bigelow

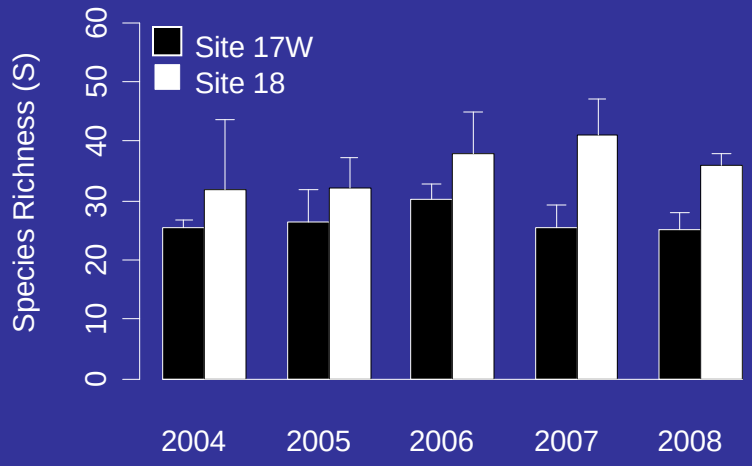
Methods

Data Analysis: Year and *D. vexillum* level as fixed effects

- Benthos: Standardized abundance (n/L) and biomass (g/L), two-way ANOVA
  - Diversity indices (species richness and evenness)
  - Total abundance and biomass per station
  - Top 10 species abundance and biomass

- Winter Flounder Diet: Stomach contents standardized as proportion of predator mass or total stomach content
  - Power analysis: Cumulative trophic diversity curves
  - Total stomach content index, Kruskal-Wallis
  - Diet similarities, 10-12 major prey taxa for winter flounder, Bray-Curtis similarity index, nMDS, ANOSIM, SIMPER

Results: Benthic diversity



Species Richness : 17W-18

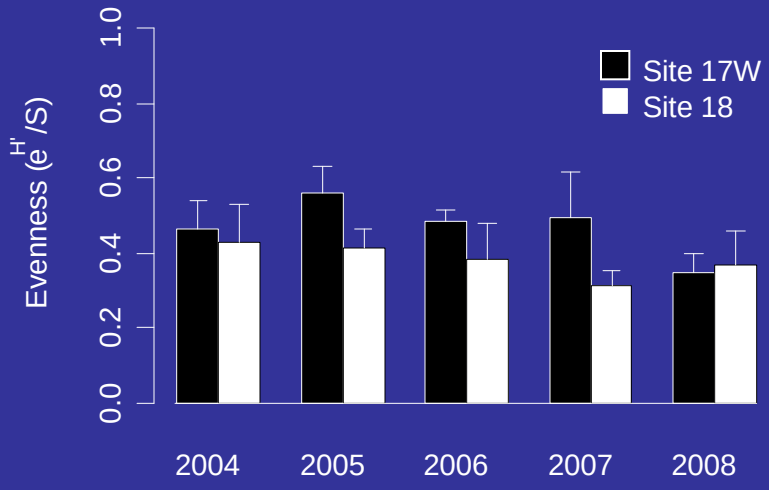
Source of variation:	Year	Site	Int.	Error
DF	4	1	4	21
F	1.480	26.000	1.020	
P	0.243	<0.001	0.421	

Species Richness : 17-19

Source of variation:	Year	Site	Int.	Error
DF	3	1	3	19
F	5.360	7.170	1.880	
P	0.008	0.015	0.167	

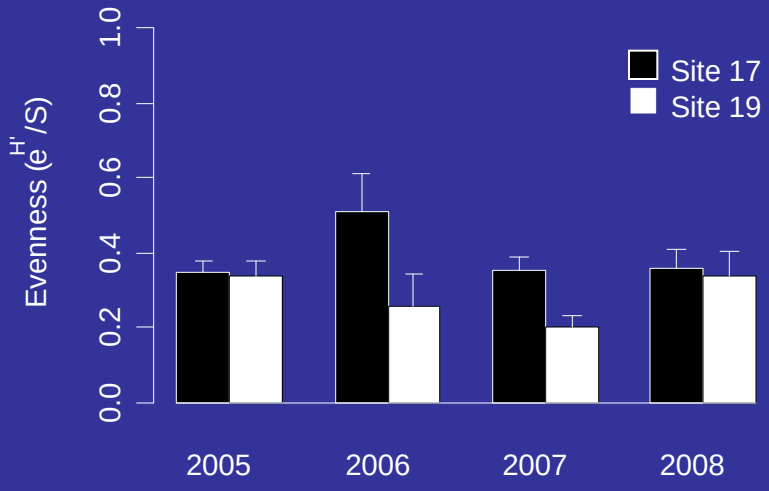
Error bars represent 2XSE

Results: Benthic diversity



Evenness: 17W-18

Source of variation:	Year	Site	Int.	Error
DF	4	1	4	21
F	3.040	12.520	1.960	
P	0.040	0.002	0.138	

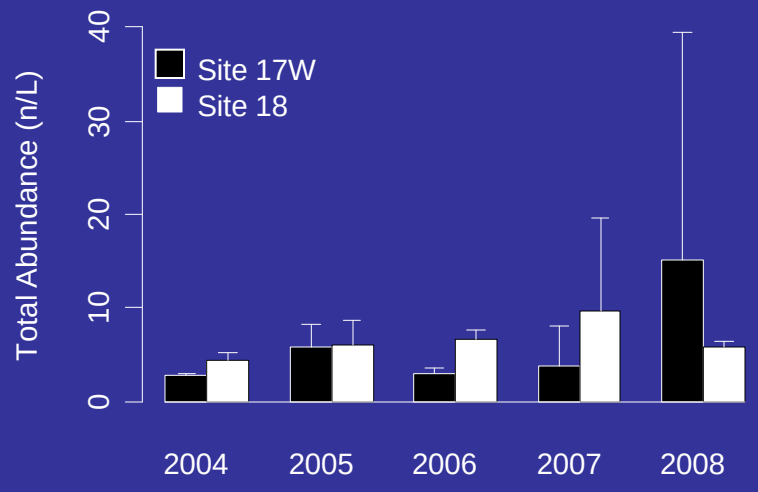


Evenness: 17-19

Source of variation:	Year	Site	Int.	Error
DF	3	1	3	19
F	4.130	23.710	6.770	
P	0.021	0.0001	0.003	

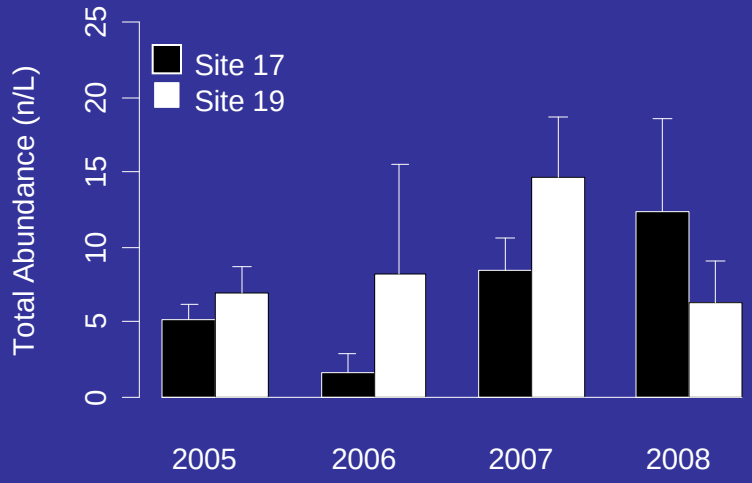
Error bars represent 2XSE

Results: Benthic Abundance



Total Abundance (n/L): 17W-18

Source of variation:	Year	Site	Int.
NUM DF	4	1	4
DEN DF	3.590	7.640	3.590
F	8.690	2.760	5.190
P	0.037	0.137	0.081

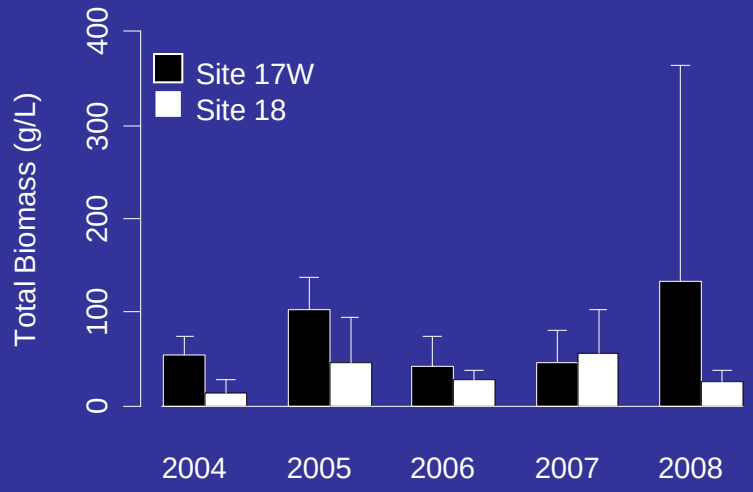


Total Abundance (n/L): 17-19

Source of variation:	Year	Site	Int.	Error
DF	3	1	3	19
F	11.290	9.480	10.720	
P	<0.001	0.006	<0.001	

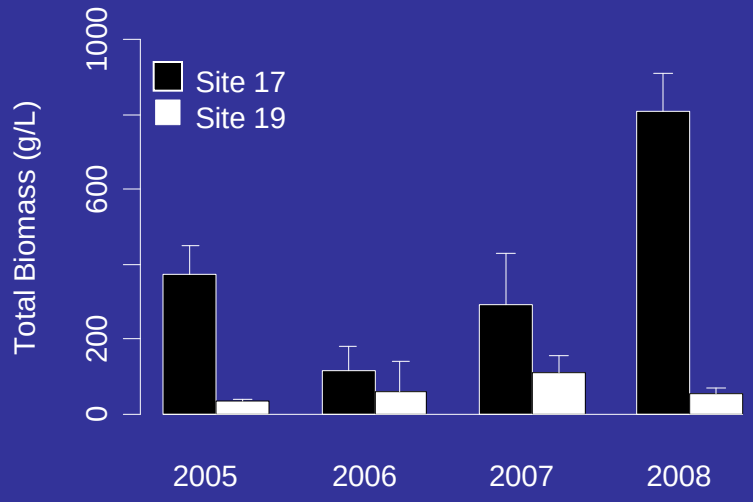
Error bars represent 2XSE

Results: Benthic Biomass



Total Biomass (g/L): 17W-18

Source of variation:	Year	Site	Int.
NUM DF	4	1	4
DEN DF	4.700	12.400	4.700
F	3.72	18.900	3.020
P	0.098	0.001	0.135

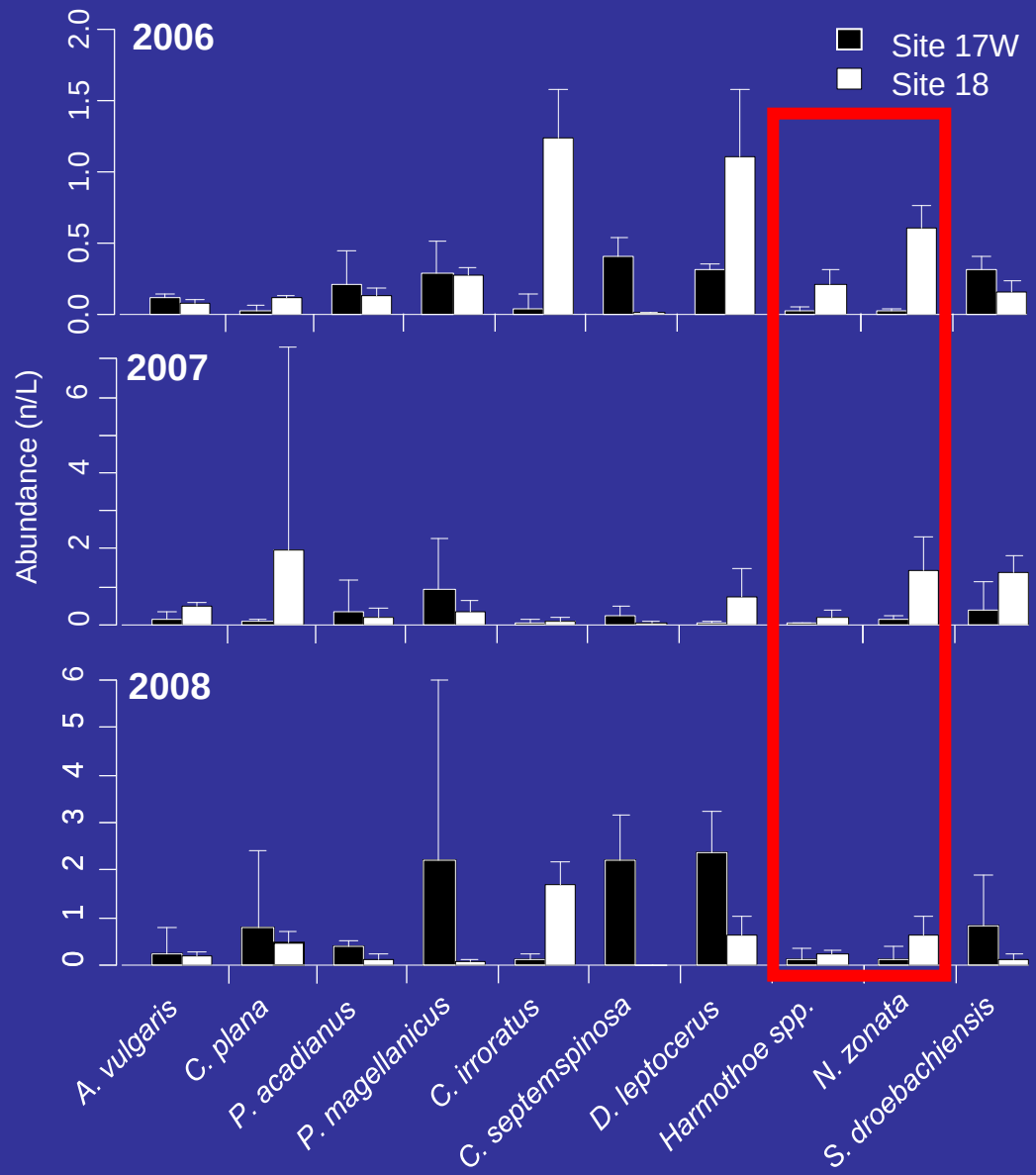


Total Biomass (g/L): 17-19

Source of variation:	Year	Site	Int.	Error
DF	3	1	3	19
F	6.460	100.630	9.440	
P	0.003	<0.001	0.001	

Error bars represent 2XSE

Results: Benthic Species Abundance

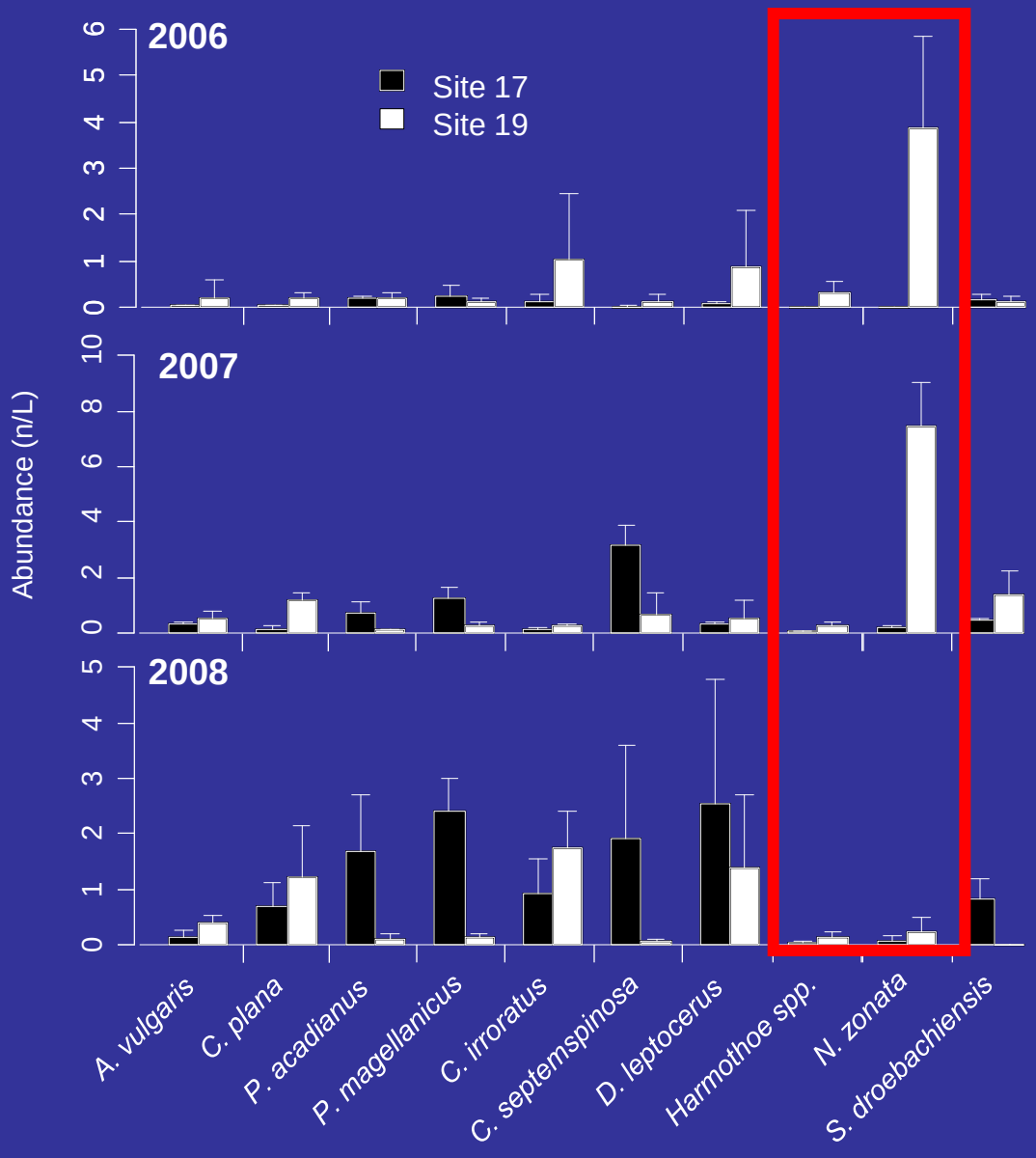


Species	Year(F)	Site(F)	Int.(F)
A.vulgaris	16.13**	0.15	5.26
C. plana	4.10	4.11	1.31
P. acadianus	2.17	12.77**	0.86
P. magellanicus	4.43**	63.99***	7.28**
C. irroratus	7.05*	92.84***	6.24*
C. septemspin.	13.86**	86.02**	16.44**
D. leptocerus	14.55*	0.01	7.42
Harmothoe spp.	8.28*	27.79**	2.99
N. zonata	5.53*	87.21***	1.20
S. droebachien.	15.31**	2.48	9.15*

*p <0.05
**p <0.01
***p <0.001

Error bars represent 2XSE

Results: Benthic Species Abundance

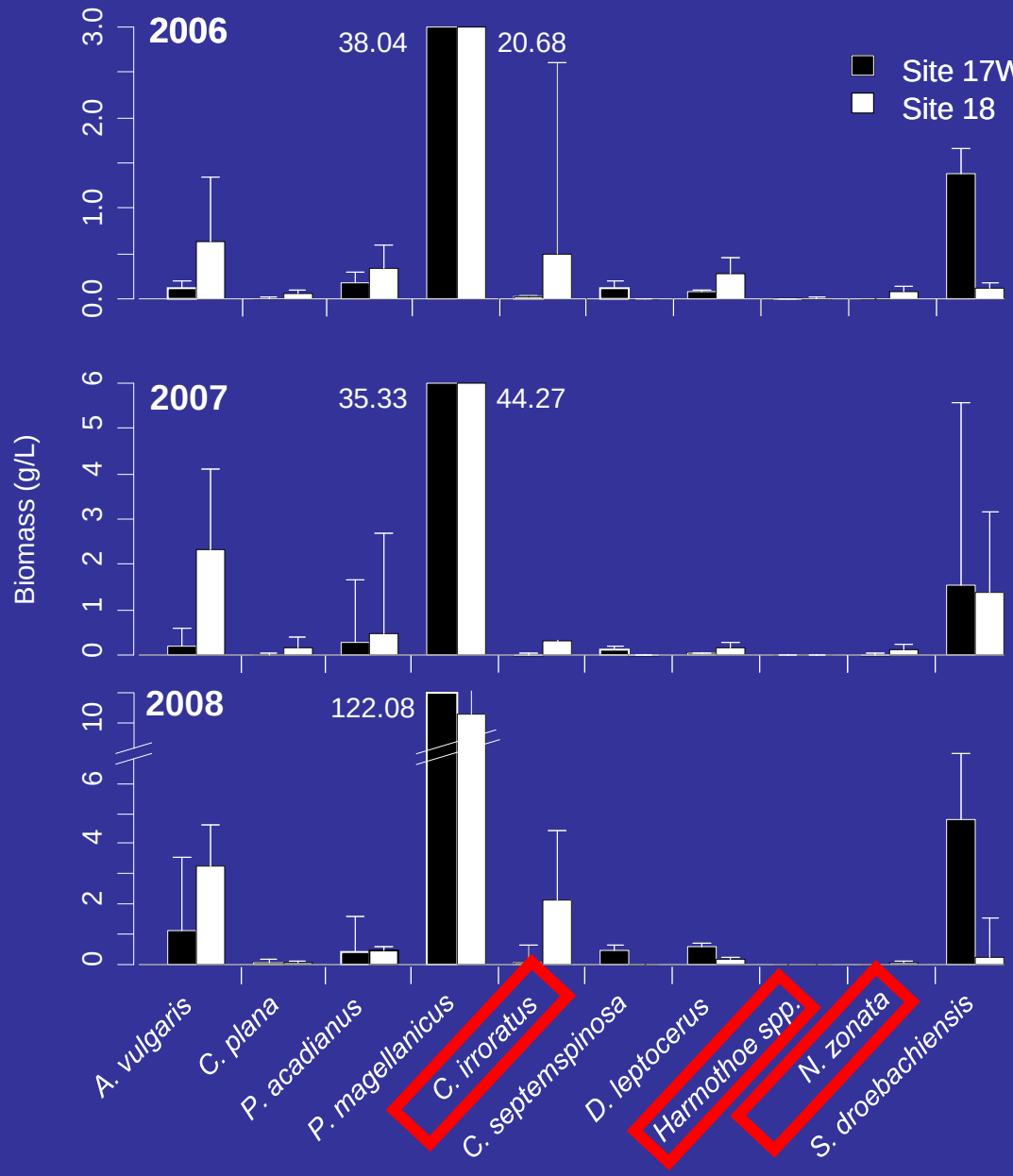


Species	Year(F)	Site(F)	Int.(F)
A.vulgaris	9.82***	35.49***	2.70
C. plana	31.17***	60.40***	3.25*
P. acadianus	6.52**	100.85***	14.03***
P. magellanicus	17.86***	176.51***	9.56**
C. irroratus	16.42**	63.85***	11.00***
C. septemspin.	28.50**	27.32**	17.58*
D. leptocerus	14.59**	0.63	2.18
Harmothoe spp.	1.39	49.35**	2.05
N. zonata	90.46***	430.23***	33.21***
S. droebachien.	13.20**	4.98	15.61**

*p <0.05
**p <0.01
***p <0.001

Error bars represent 2XSE

Results: Benthic Species Biomass

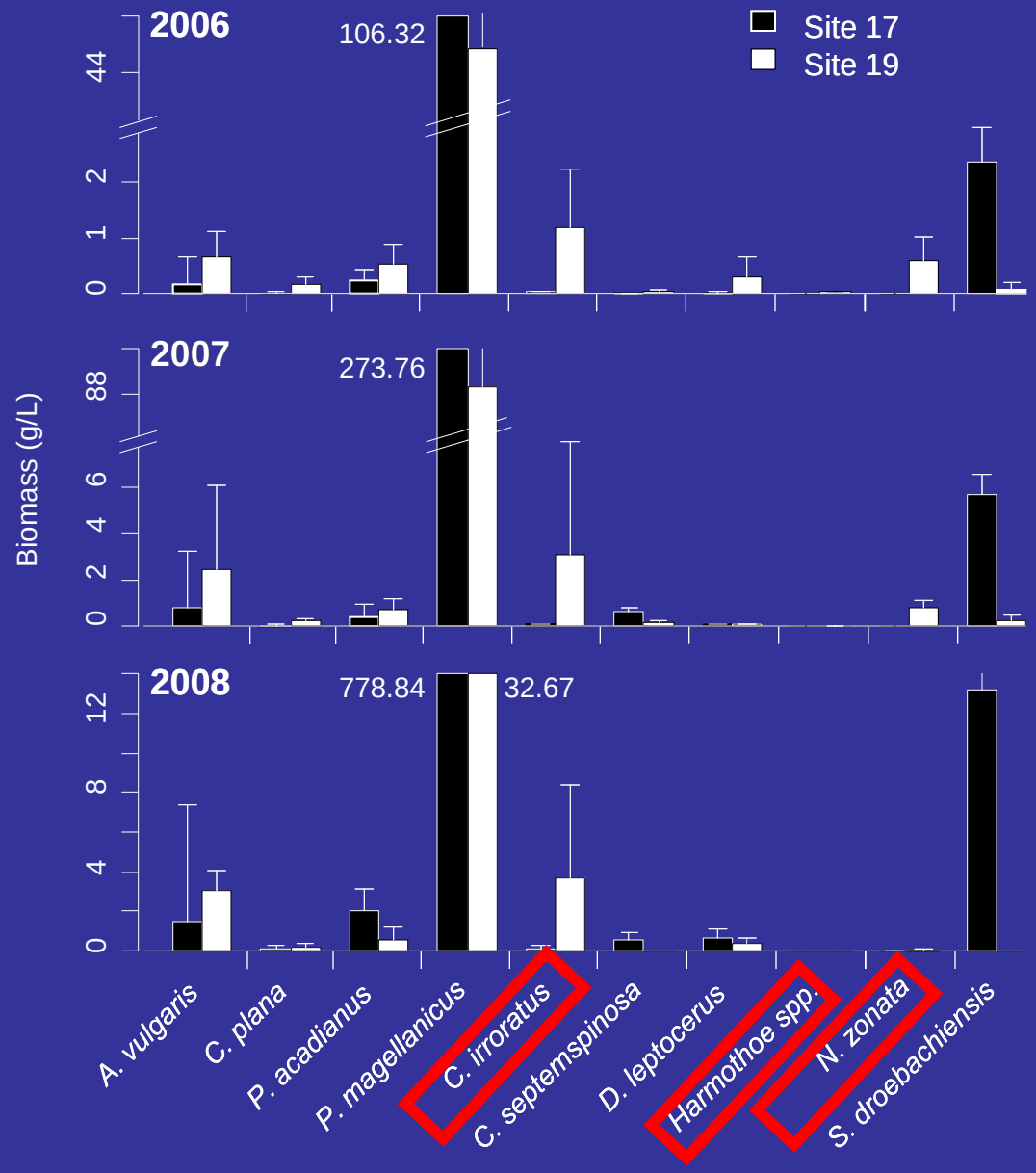


Species	Year(F)	Site(F)	Int.(F)
A.vulgaris	8.71***	20.89***	3.28*
C. plana	4.36	14.15*	4.16
P. acadianus	0.42	0.24	0.18
P. magellanicus	1.92	27.03**	4.76**
C. irroratus	2.52	76.73***	0.94
C. septemspin.	14.08**	60.82**	13.80*
D. leptocerus	23.33**	5.55*	14.15**
Harmothoe spp.	1.32	16.92**	0.57
N. zonata	8.04***	133.93***	2.15
S. droebachien.	8.03*	43.27***	3.78

*p <0.05
**p <0.01
***p <0.001

Error bars represent 2XSE

Results: Benthic Species Biomass

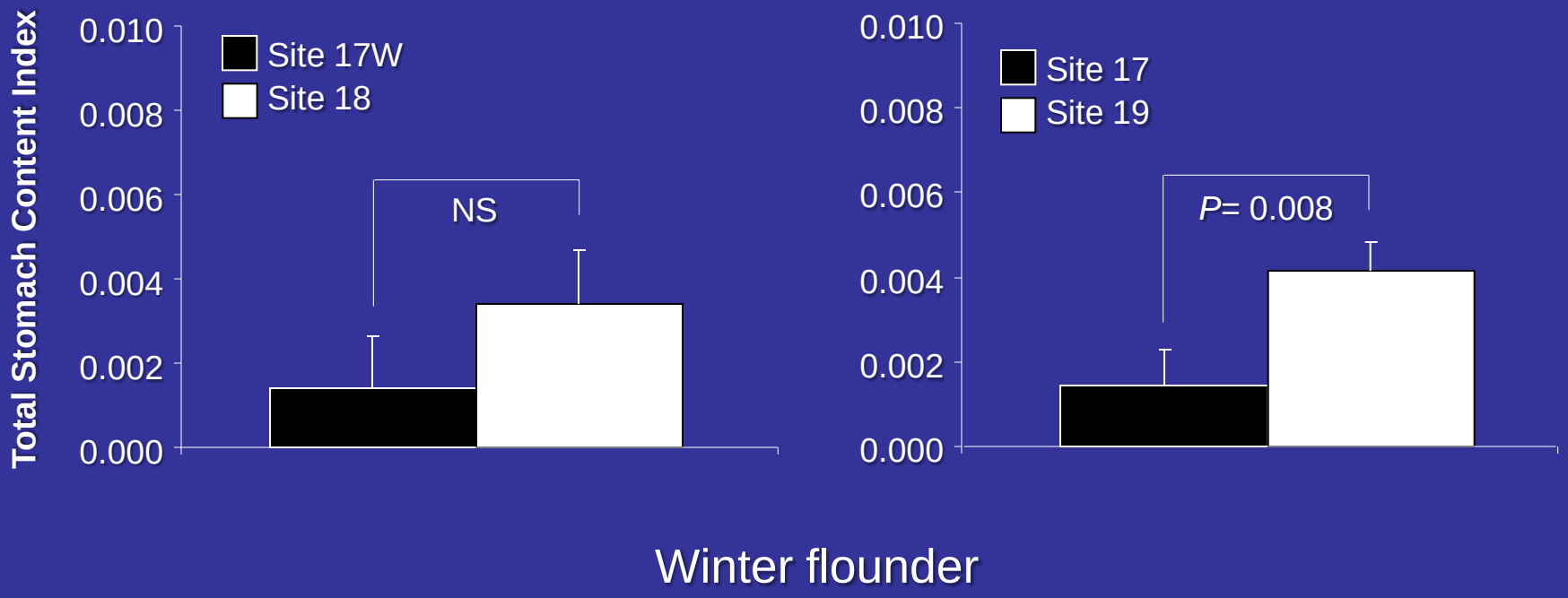


Species	Year(F)	Site(F)	Int.(F)
A.vulgaris	3.73*	7.64*	0.20
C. plana	3.18*	50.43***	3.72*
P. acadianus	7.16*	1.66	6.85**
P. magellanicus	10.31**	127.48***	15.78**
C. irroratus	7.65**	187.00***	0.52
C. septemspin.	24.16*	28.07**	14.59*
D. leptocerus	9.36*	0.04	1.85
Harmothoe spp.	1.64	62.08***	0.70
N. zonata	23.78*	101.96***	3.18
S. droebachien.	4.45	189.22***	6.91*

*p <0.05
**p <0.01
***p <0.001

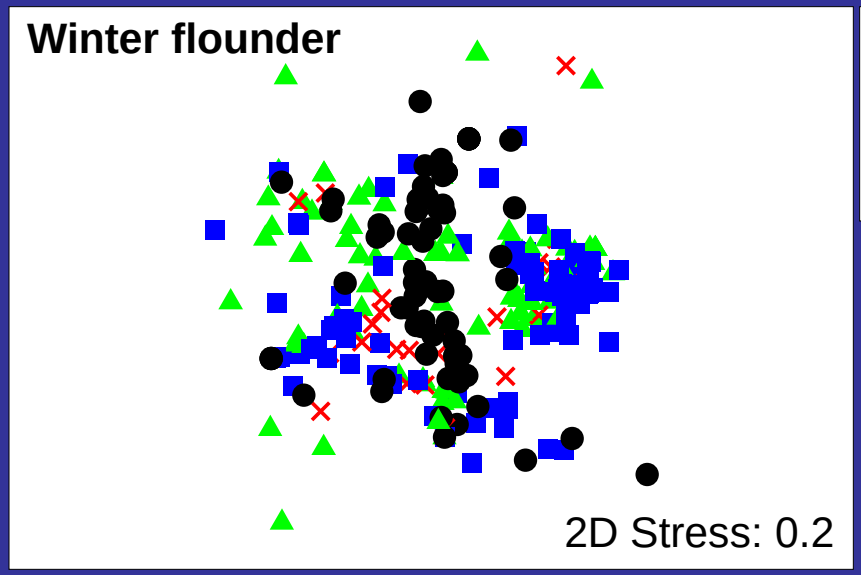
Error bars represent 2XSE

Results: Winter Flounder Diet, Total Stomach Content



Error bars represent bootstrap 95% CI

Results: Winter Flounder Diet Similarity



One-way ANOSIM	*Global R*	Prob.	Perm.
Sites 17W-18	-0.004	0.514	9,999
Sites 17-19	0.135	<0.001	9,999

Sites 17-19

	Mean Proportion		Similarity%		Dissimilarity		Percent
Taxa	Site 17	Site 19	Site 17	Site 19	Mean	Mean / SD	Contribution
Cancer spp.	0.0223	0.2383	8.97	14.39	15.65	1.02	19.08
Polychaeta	0.0764	0.1308	4.15	7.75	14.19	0.97	17.31
Anthozoa	0.1814	0.0009	3.14	1.93	13.85	0.81	16.89
Well-digested Prey	0.0565	0.0254	1.85	1.74	10.34	0.74	12.61
Gammaridea	0.0357	0.0286	1.69	0.84	9.36	0.65	11.42
Sand	0.0064	0.0168	1.63	0.8	5.75	0.52	7.02
Rock	0.0100	0.0036	0.70	0.56	3.97	0.62	4.84
Didemnum vexillum	0.0000	0.0121	0.16	0.33	3.28	0.35	4.00

Results: Diet Similarity

Other Species:

- Winter skate *(Leucoraja ocellata)*
- Little skate *(Leucoraja erinacea)*
- Haddock (*Melanogrammus aeglefinus*)
- Longhorn sculpin (*Myoxocephalus octodecemspinosus*)

Recurrent Dietary Trends:

- Statistical differences in diet composition detected for all species (17W-18 or **17-19**)
- *Cancer* spp. (2-4X increase in diet proportion where *D. vexillum* present)
- Polychaeta (1.5-4X increase in diet proportion where *D. vexillum* present)
- Few differences in Total Stomach Content Index

Conclusions

- *Didemnum vexillum* has a profound effect on the northern Georges Bank benthic macrofaunal community with notable increases in abundance and biomass for three taxa (*Harmothoe* spp., *Nereis zonata*, and *Cancer irroratus*)

- *Didemnum* provides an additional 3D substrate; mobile invertebrates reside within/underneath this matrix

- Winter flounder diets suggest marked diet variability within region that can be linked to prey availability as a result of the presence of *Didemnum*, and these effects are present in the diets of several groundfish species

Conclusions

- Feeding effects were more dramatic in areas closed to bottom fishing (inside HAPC of CAII)

- Although immediate feeding effects appear relatively favorable for multiple species examined, the chronic effects of *D. vexillum* on Georges Bank groundfish remain unknown

Acknowledgements

- URI, GSO Collie Lab (past and present)
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QUESTIONS?