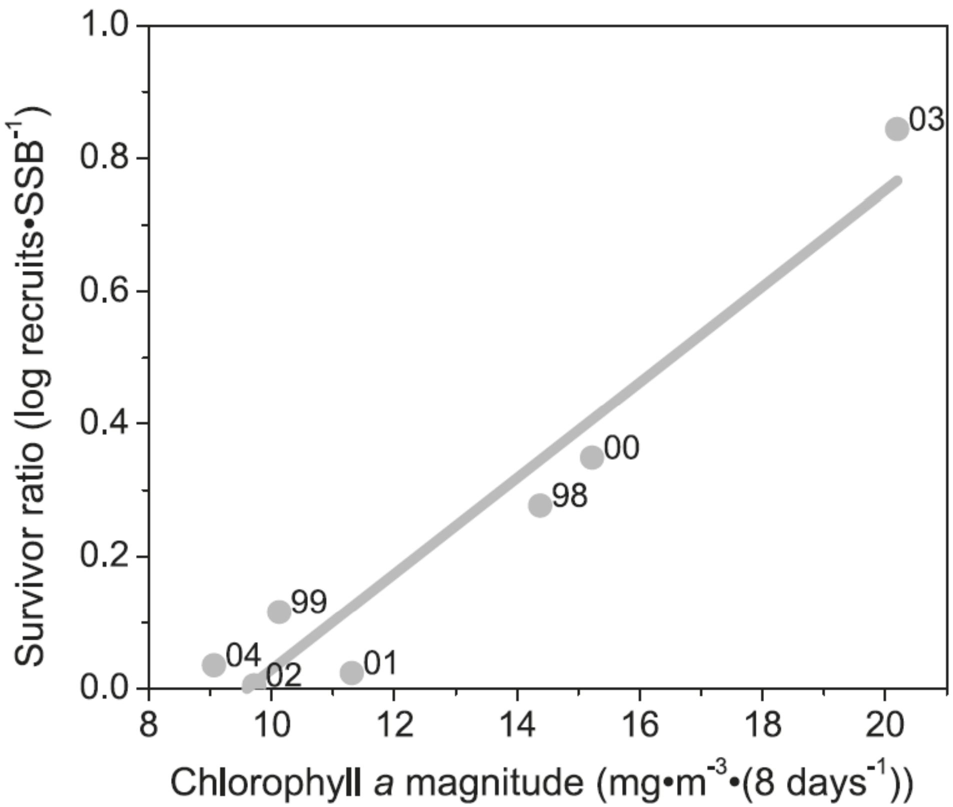
Fall bloom phenology and magnitude influences haddock recruitment on Georges Bank

Robert Leaf[1] and Kevin Friedland[2]

[1]University of Southern Mississippi
[2]National Marine Fisheries Service

The Parental Condition Hypothesis

Fig. 9. Relationship between haddock, *Melanogrammus aeglefinus*, survivor ratio and chlorophyll *a* magnitude of the fall bloom prior to spawning for year classes 1998–2004 ($R = 0.966$, $N = 7$, $P < 0.001$). Data points are labelled with two-digit years.



Friedland et al. 2008

The Parental Condition Hypothesis

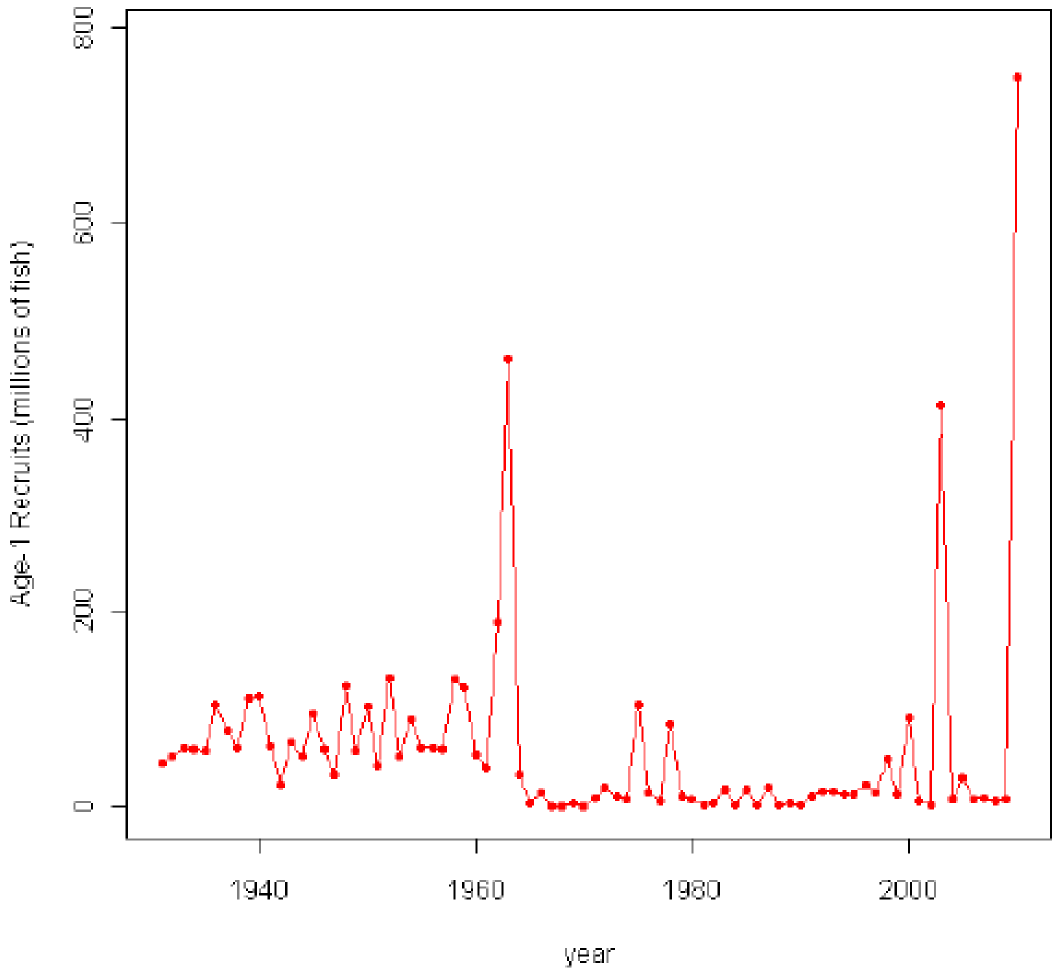
In words:

Fall bloom providing better overwintering
feeding conditions for pre-spawning adults hypothesis

Fall bloom of large magnitude→
Increased benthic flux, September-November →
Improved feeding for haddock spawners, October-January →
Production of more and/or better condition gametes →
Higher recruitment of haddock

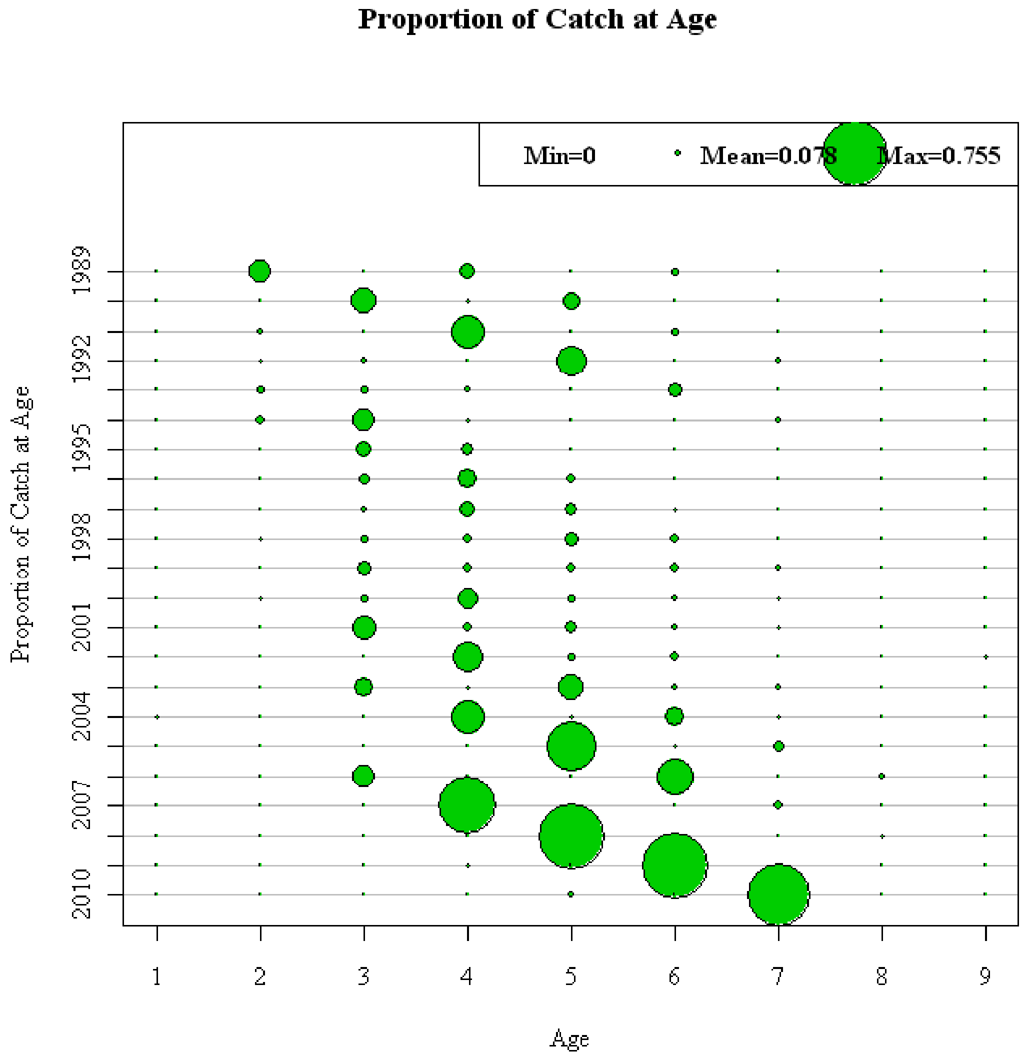
Friedland et al. 2008

Why revisit the Parental Condition Hypothesis?



Brooks et al. 2012

Recruitment events critical to Georges Bank Haddock



Brooks et al. 2012

A revisit with extensions

Retest the effect of fall bloom magnitude on haddock recruitment

Examine the spatial dynamics of the fall bloom on recruitment

Test the effect of bloom phenology (fall bloom timing) on recruitment

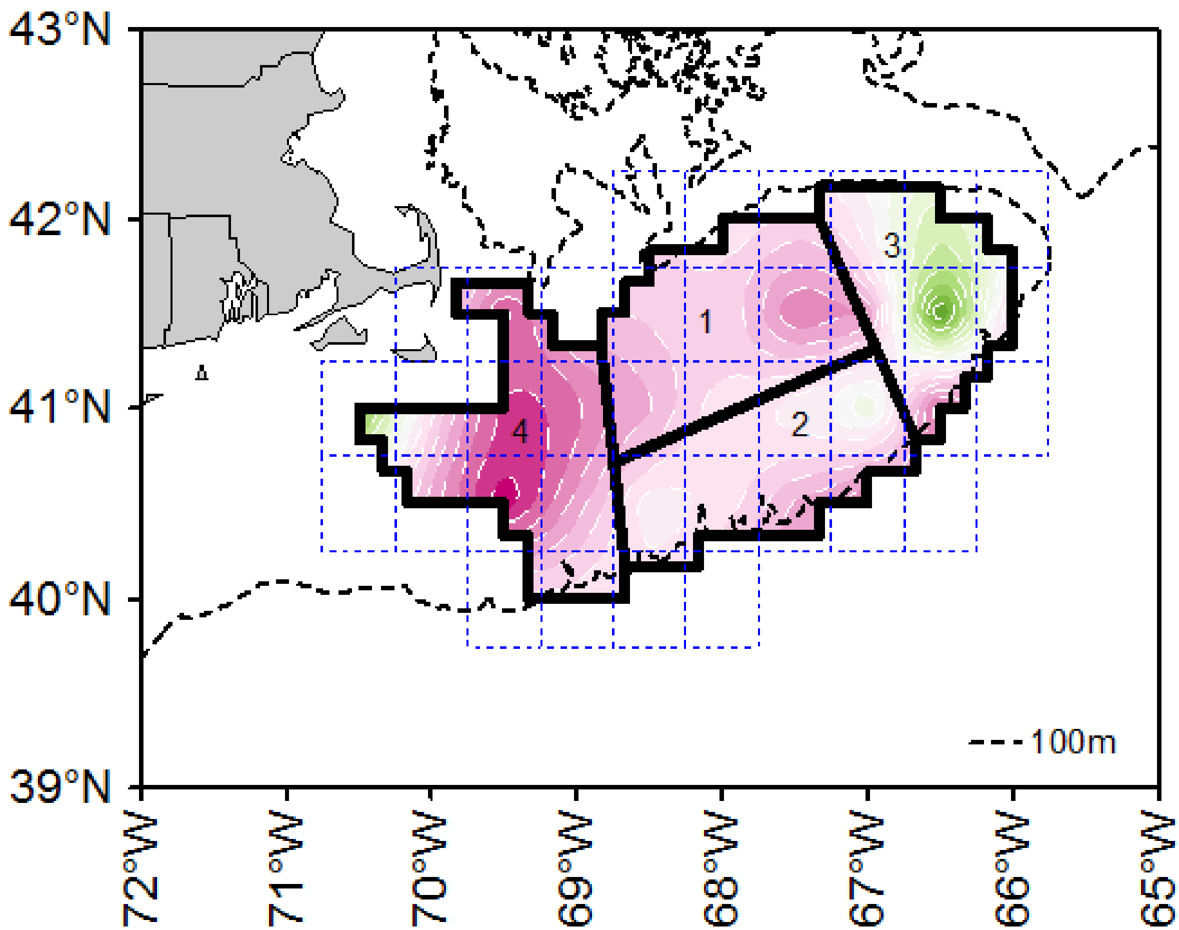
Recruitment benchmark

Recruitment

Year	SSB, mt	R, 10^3	R/SSB	log R/SSB
1998	50807	49156	0.968	-0.014
1999	59528	11668	0.196	-0.708
2000	73600	90866	1.235	0.092
2001	87872	5551	0.063	-1.199
2002	100258	2870	0.029	-1.543
2003	119310	412375	3.456	0.539
2004	108126	7985	0.074	-1.132
2005	126290	28833	0.228	-0.641
2006	225173	7123	0.032	-1.500
2007	252065	9365	0.037	-1.430
2008	238744	4773	0.020	-1.699
2009	210557	7605	0.036	-1.442
2010	167279	748016	4.472	0.650

Ensemble of spatial analyses of the fall bloom

1) Ecoregion, 2) subareas of ecoregion, 3) 0.5° grid



Fall bloom data and parameters

Data: SeaWiFS and MODIS 9km 8-day chlorophyll data

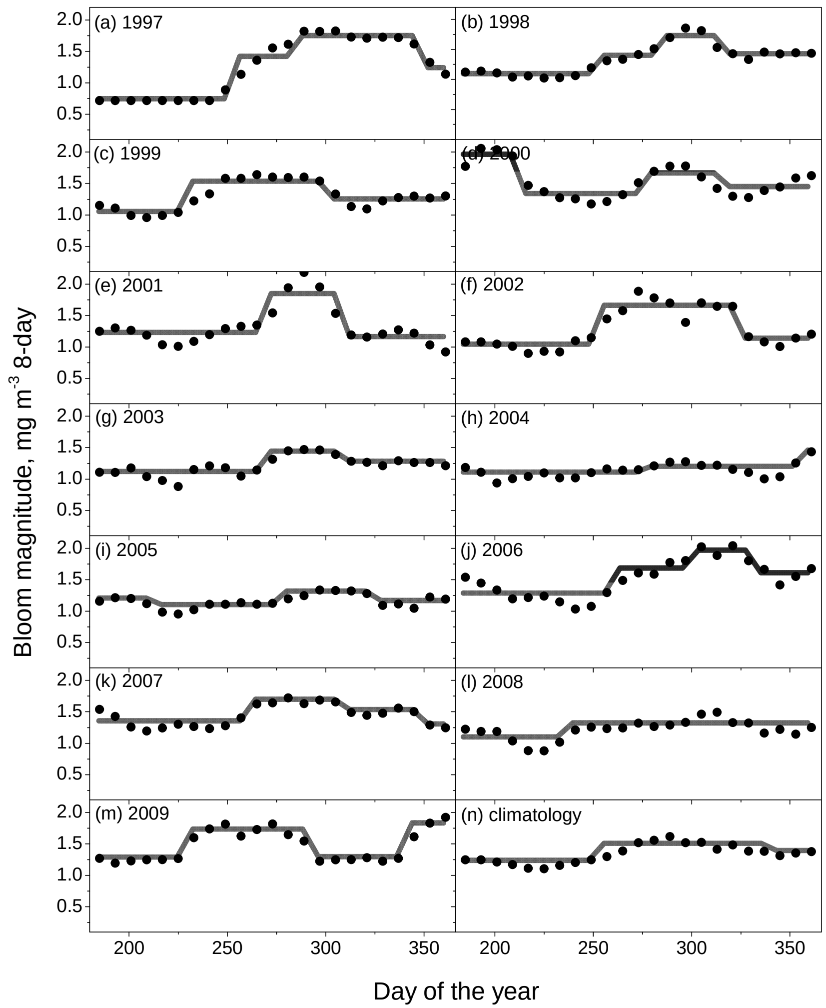
Bloom start date-first day of the first 8-day period of the bloom identified with STARS

Intensity-average chlorophyll during the bloom

Magnitude-integral of chlorophyll during the bloom

STARS means for the ecoregion

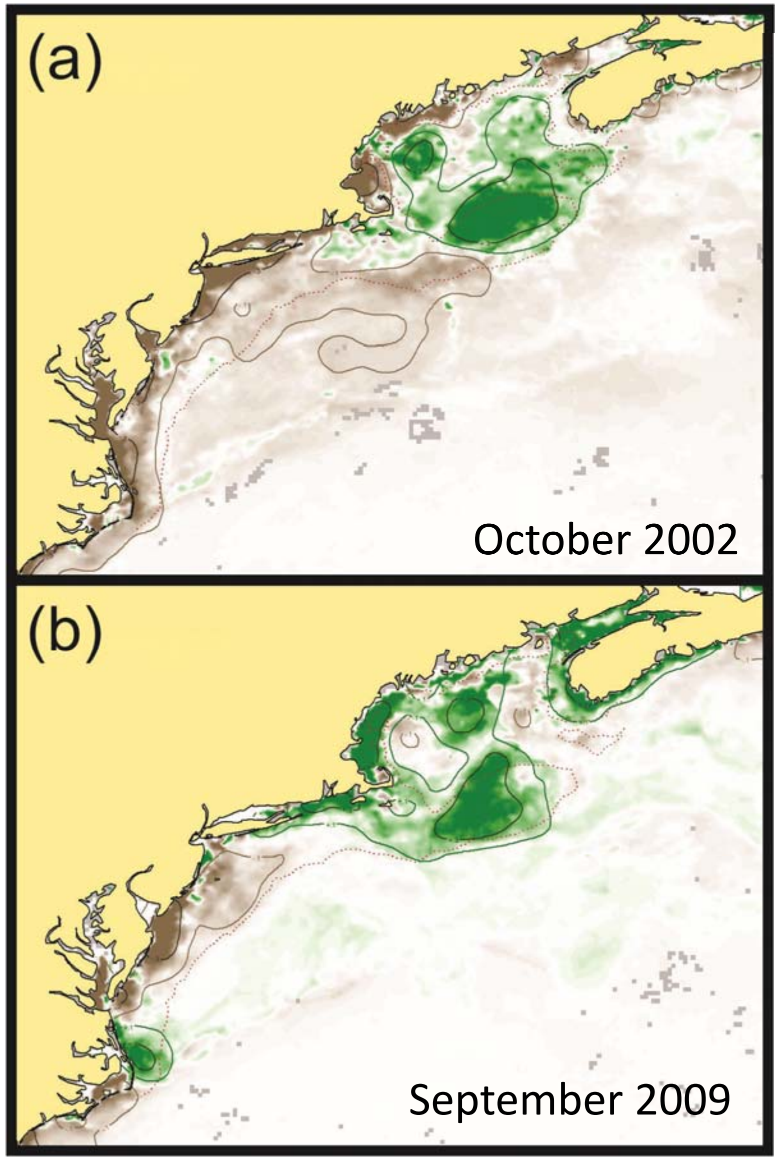
Years with and without a detectable bloom



Observed and climatological bloom parameter estimates

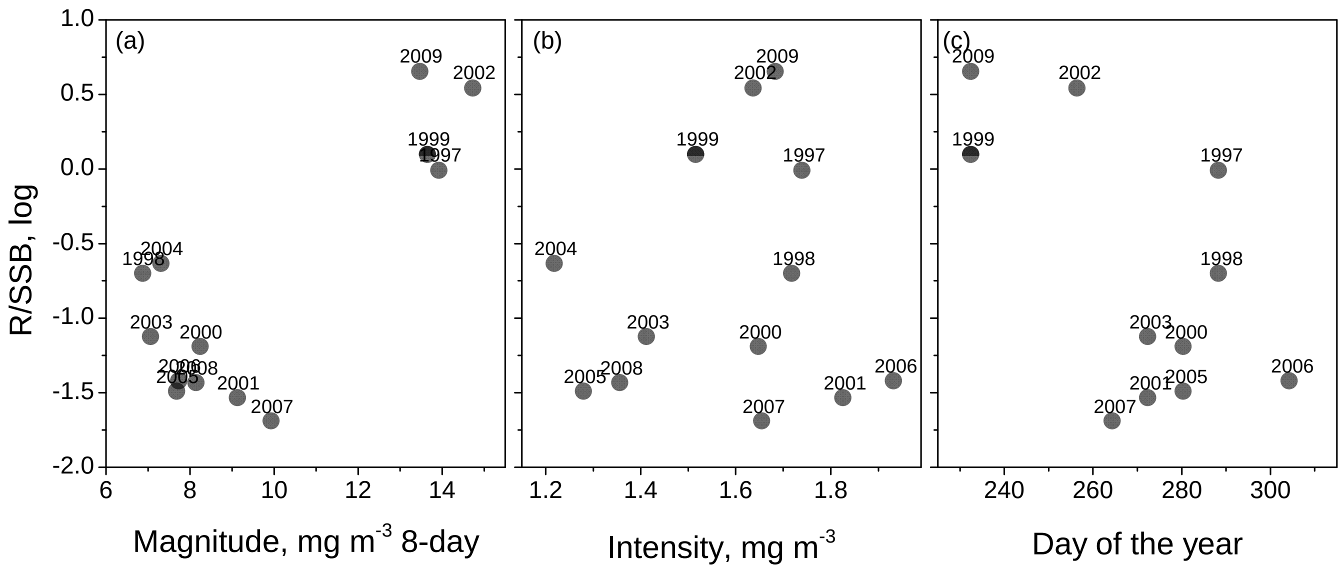
	Observed Blooms				Climatological Bloom		All Years	
Local	Start	End	Number	Duration	Start	End	Magnitude	Intensity
Georges Bank	272.3	312.3	11	6.0	273	313	9.58	1.62
Area 1	257.0	301.0	6	6.5	257	297	13.38	2.17
Area 2	274.1	314.1	7	6.0	273	313	7.45	1.29
Area 3	255.9	297.0	7	6.1	257	297	8.18	1.35
Area 4	277.6	319.9	7	6.3	281	321	9.28	1.51

Bloom Anomalies

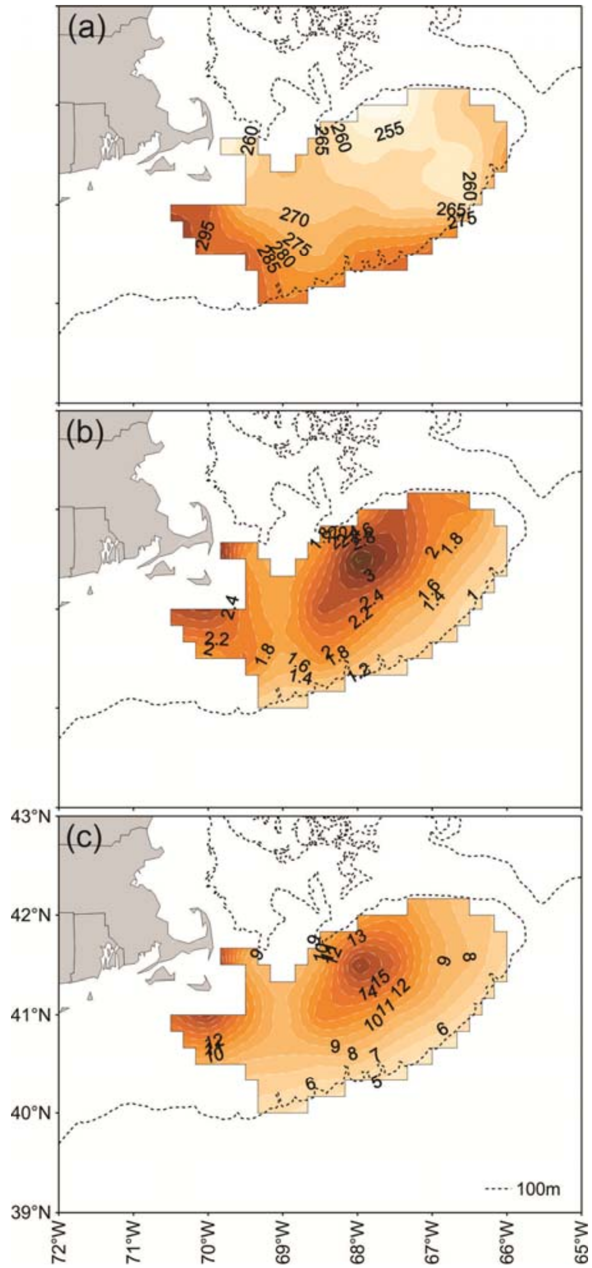


Correlation between bloom parameters and recruitment

	Magnitude		Intensity		Start Date		
Local	R	p	R	p	R	p	N
Georges Bank	**0.80**	**0.00**	0.07	0.81	**-0.61**	**0.05**	11
Area 1	**0.70**	**0.01**	0.30	0.31	-0.76	0.14	5
Area 2	0.21	0.49	0.23	0.45	-0.25	0.60	7
Area 3	0.47	0.11	0.22	0.46	-0.61	0.15	7
Area 4	0.00	0.99	-0.11	0.73	0.86	0.06	5



Observed bloom parameter estimates for gridded data



Fall bloom Start

Intensity

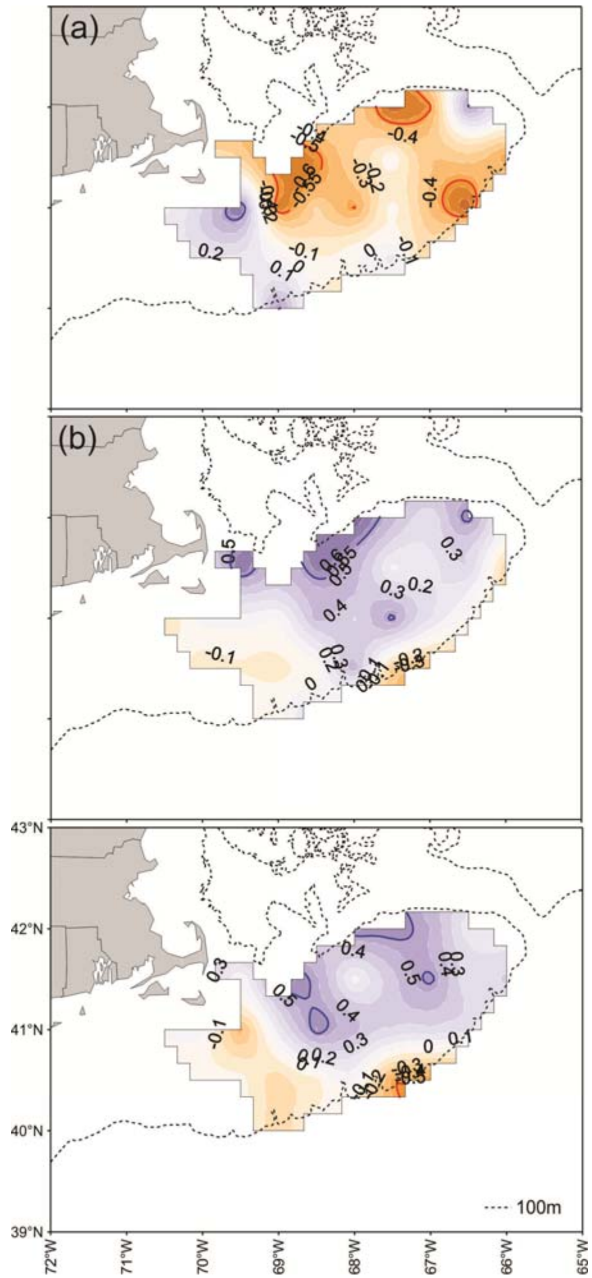
Magnitude

Correlation between bloom parameters and recruitment

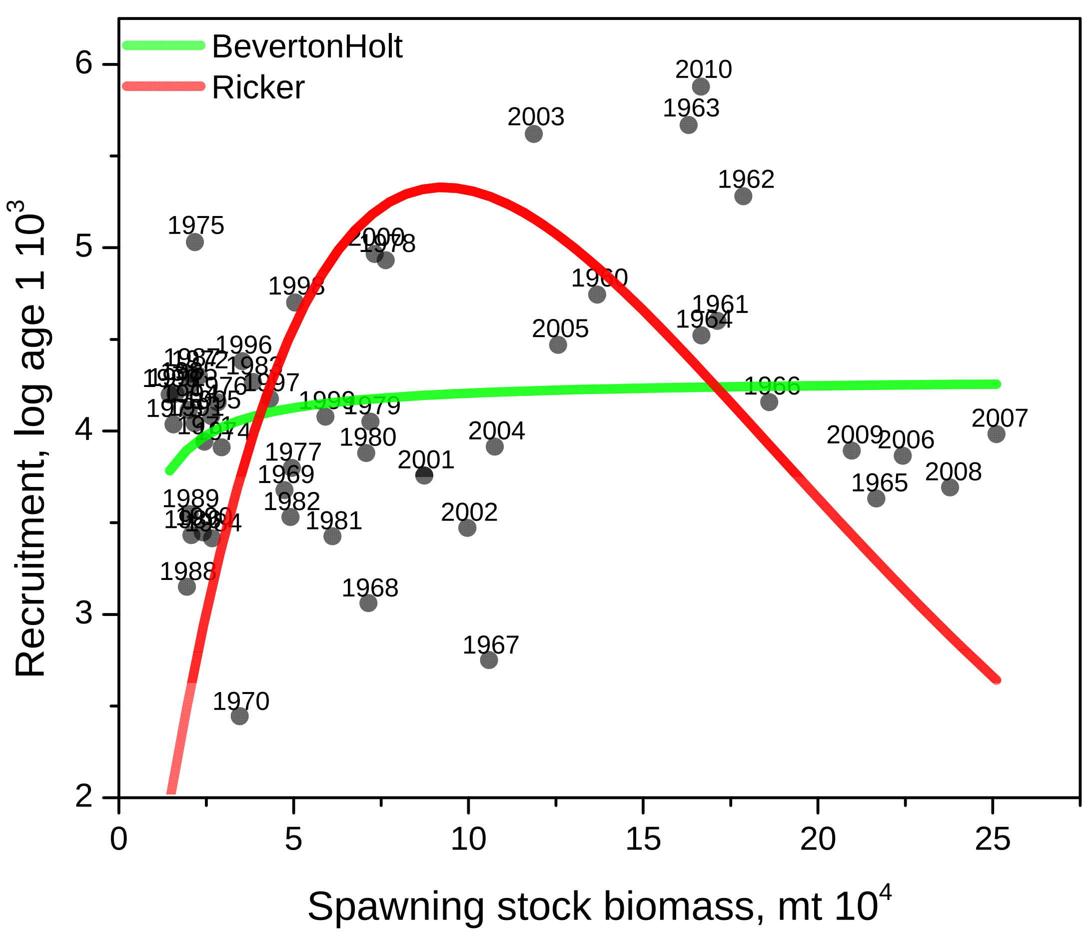
Fall bloom Start

Intensity

Magnitude



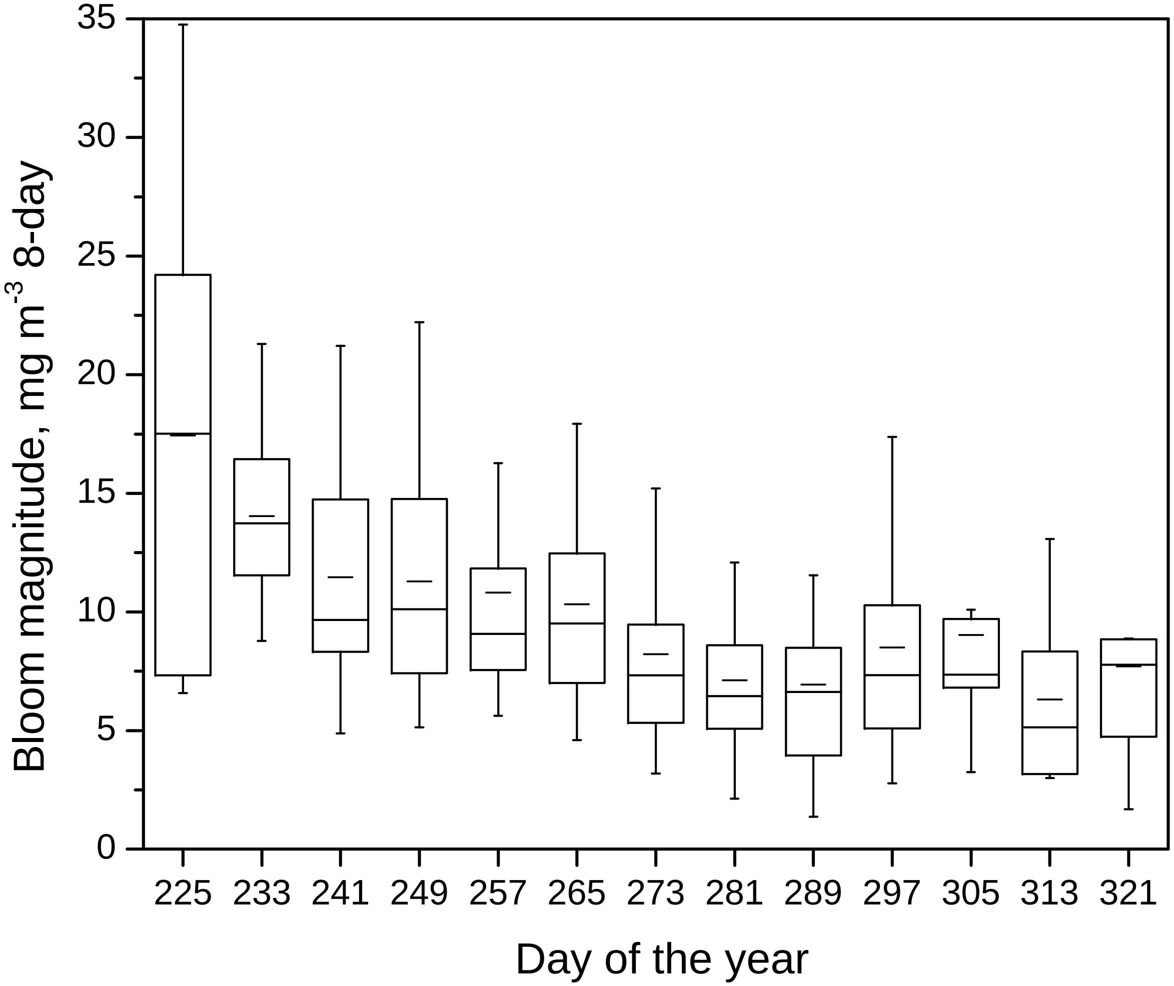
Spawner recruit relationship for Georges Bank haddock



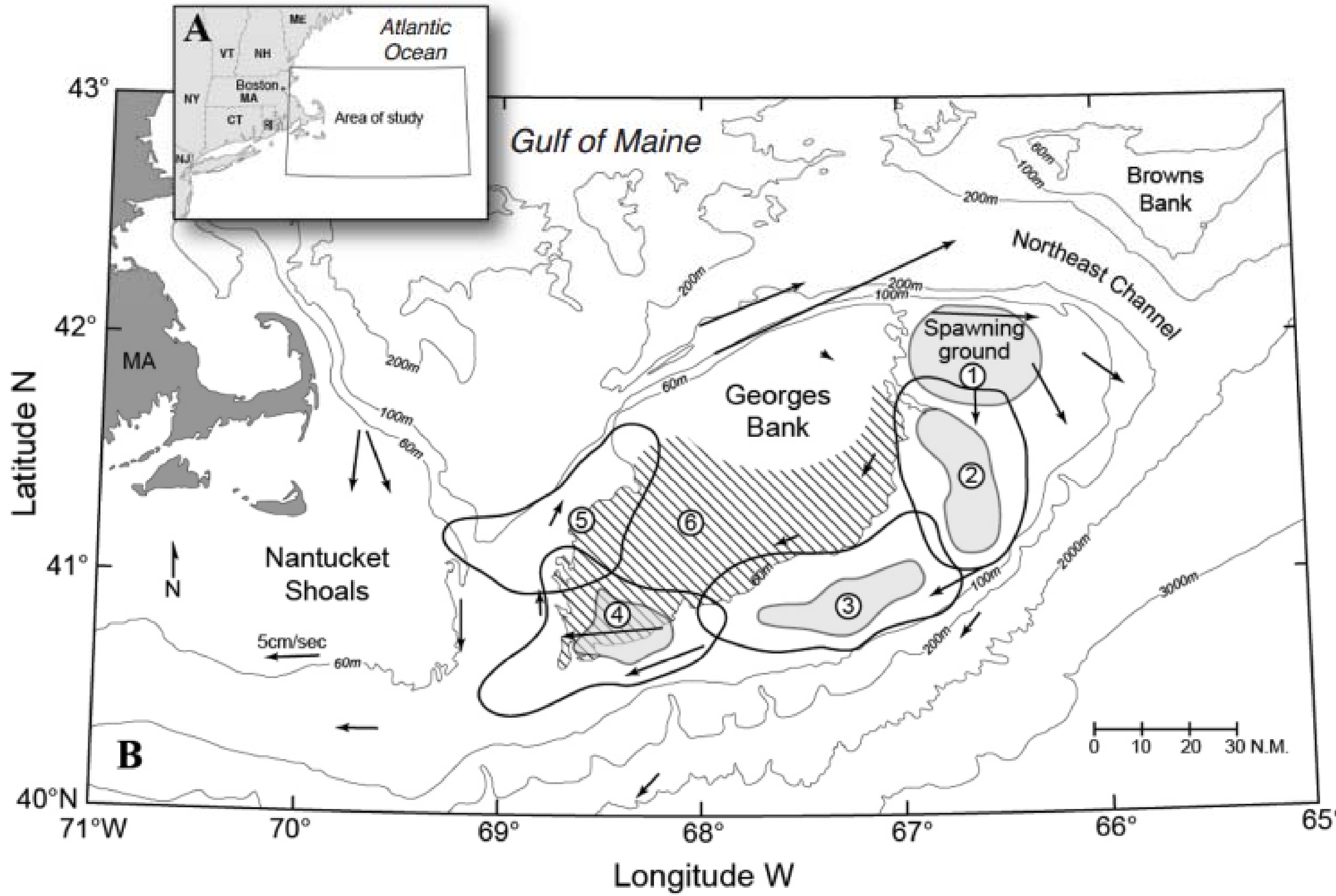
Spawner recruit relationship with environmental covariates

Model	Stock-Recruit equation	Covariate	AIC	α	β	ρ
Ricker Model 1	$R = \alpha S e^{-\beta S}$	--	18.36	2.380	0.078	
Ricker Model 2	$R = \alpha S e^{-\beta S} e^{\rho E}$	Magnitude	15.60	2.171	-0.085	0.021
		Intensity	19.74	1.858	-0.078	0.156
		Bloom start	17.98	6.562	-0.077	-0.004
		PC of covariates	13.10	2.238	-0.075	0.094
Ricker Model 3	$R = \alpha S e^{-\beta S} e^{\rho E}$	Magnitude	12.48	2.240	0.105	-0.030
		Intensity	19.65	2.381	0.096	-0.118
		Bloom start	18.57	2.292	0.002	0.128
		PC of covariates	15.59	2.271	0.075	-0.074
Beverton-Holt Model 1	$R = S/(\alpha s + \beta)$	--	17.87	0.097	0.018	
Beverton-Holt Model 2	$R = S e^{-\beta E}/(\beta + \alpha S)$	Magnitude	7.18	0.097	0.053	0.147
		Intensity	21.27	0.105	-0.044	-0.001
		Bloom start	13.34	0.107	-0.064	-0.117
		PC of covariates	7.50	0.102	-0.006	0.108
Beverton-Holt Model 3	$R = S/(\beta + \alpha S e^{\rho E})$	Magnitude	6.79	0.096	0.058	-0.159
		Intensity	21.27	0.105	-0.044	0.001
		Bloom start	13.34	0.107	-0.064	-0.117
		PC of covariates	7.51	0.101	0.001	-0.109
Beverton-Holt Model 4	$R = S/(\alpha S + \beta S e^{\rho E})$	Magnitude	12.54	0.106	-0.001	3.846
		Intensity	19.20	0.106	-0.058	-0.221
		Bloom start	19.02	0.097	0.029	0.924
		PC of covariates	13.22	0.108	-0.041	0.780

Bloom magnitude and timing



Fall bloom deposition and haddock spawner distribution



Lough and O'Brien 2012

A revisit of conclusions with extensions

The fall bloom continues to be a factor explaining Georges Bank haddock recruitment variability, especially exceptional, episodic recruitment

The fall blooms occurring on the northern flank of Georges Bank appears to most important to recruitment, consistent with the hypothesis that sinking organic matter is deposited in proximity to prespawning haddock

Early fall blooms appear to have the greatest effect on haddock recruitment consistent with the hypothesis that deposition that has time to make its way through the food web is most effective in affecting parental condition