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Deep-Sea Research II 52 (2005) 2843–2855

DEEP-SEA RESEARCH
PART II

www.elsevier.com/locate/dsr2

Interannual variability of *Alexandrium fundyense* abundance and shellfish toxicity in the Gulf of Maine

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Accepted 22 June 2005
Available online 10 October 2005

Abstract

Six years of oceanographic surveys of *Alexandrium fundyense* concentrations in the Gulf of Maine are combined with shellfish toxicity records from coastal monitoring stations to assess covariations of these quantities on seasonal to interannual time scales. Annual mean gulf-wide cell abundance varies by less than one order of magnitude during the time interval examined (1993–2002). Fluctuations in gulf-wide annual mean cell abundance and shellfish toxicity are not related in a consistent manner. This suggests that interannual variations in toxicity may be regulated by transport and delivery of offshore cell populations, rather than the absolute abundance of the source populations themselves.

Keywords: Phytoplankton; Red tides; Paralytic shellfish poisoning

1. Introduction

The causative link between blooms of *Alexandrium fundyense*[1] and outbreaks of paralytic shellfish poisoning (PSP) in the Gulf of Maine has been known for many years. Nevertheless, the mechanisms regulating interannual variability in PSP outbreaks have remained obscure. Some years, toxicity is extremely high, reaching levels that require extensive closures of harvesting areas. Other years, toxicity is virtually absent, or is well below quarantine levels (Shumway et al., 1988). One obvious hypothesis is that interannual variations in shellfish toxicity are caused by interannual variations in the abundance of vegetative *A. fundyense* cells. Testing of this hypothesis requires concurrent records of both cell abundance and shellfish toxicity, and it is only relatively recently that such data have become available. Although shellfish monitoring programs in the Gulf of Maine have been in place since the late 1950s (Shumway et al., 1988), systematic surveys of the abundance and distribution of *A. fundyense* were first undertaken in the 1980s (Martin and White, 1988). Herein we

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[1]Both *A. tamarense* and *A. fundyense* occur in the Gulf of Maine (Anderson et al., 1994). We consider these to be varieties of the same species (Anderson et al. 1994; Scholin et al. 1995). Neither antibody nor oligonucleotide probes can distinguish between them, and only detailed analysis of the thecal plates on individual cells can provide this resolution. This is not practical for large numbers of field samples. Accordingly, for the purpose of this study, the name *A. fundyense* is used to refer to both forms.

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doi:10.1016/j.dsr2.2005.06.020

compare seasonal to interannual trends in cell abundance with toxicity records from selected coastal monitoring stations for 6 years between 1993 and 2002. For a detailed description of PSP toxicity during 1997–2001 see Bean et al. (2005).

Note: As this article was going to press, an extraordinary bloom of *A. fundyense* took place in southern New England (Anderson et al., 2005c). Unfortunately, final cell counts and toxicity records were not available in time to be included in the present analysis. Therefore it is not yet possible to assess the impact of the 2005 bloom on the conclusions of this study.

2. Methods

Abundance of *A. fundyense* was estimated from near-surface shipboard observations (Fig. 1, upper panel), and shellfish toxicity records were derived from selected coastal monitoring stations (Fig. 1, lower panel). Toxicity measurements were based on the blue mussel *Mytilus edulis*, using the standard mouse bioassay (Association of Official Analytical Chemists, 1984). These data were kindly provided by the Maine Department of Maine Resources (http://www.state.me.us/dmr/) and the Massachusetts Division of Marine Fisheries (http://www.mass.gov/dfwele/dmf/).

Shipboard surveys of *A. fundyense* cell abundance ranged from single transects to spatial grids that cover large portions of the Gulf of Maine (Fig. 2). Detailed descriptions of these surveys are provided in Townsend et al. (2001), Anderson et al. (2005a), Keafer et al. (2005a, b) and Townsend et al. (2005b). Although vertical distributions of *A. fundyense* can exhibit pronounced subsurface maxima tens of meters deep (Townsend et al., 2005a, 2001), we focus herein on near-surface cells because of their more direct impact on shellfish in the intertidal zone.

The near-surface depth intervals sampled were not uniform among the different studies, nor were the methods used to enumerate the cells (Table 1). Although there are significant methodological differences in the various data sets (geographic scope, depths sampled, and cell counting methods), these do not preclude assessment of seasonal and interannual variability in the mean abundance of *A. fundyense*. Specifically, the data from each survey are used to estimate the mean *A. fundyense* concentration on a per-cruise basis. Weekly toxicity data from the coastal stations are treated in the same way. In both cases, confidence intervals around the estimated means are computed assuming the data are normally distributed.

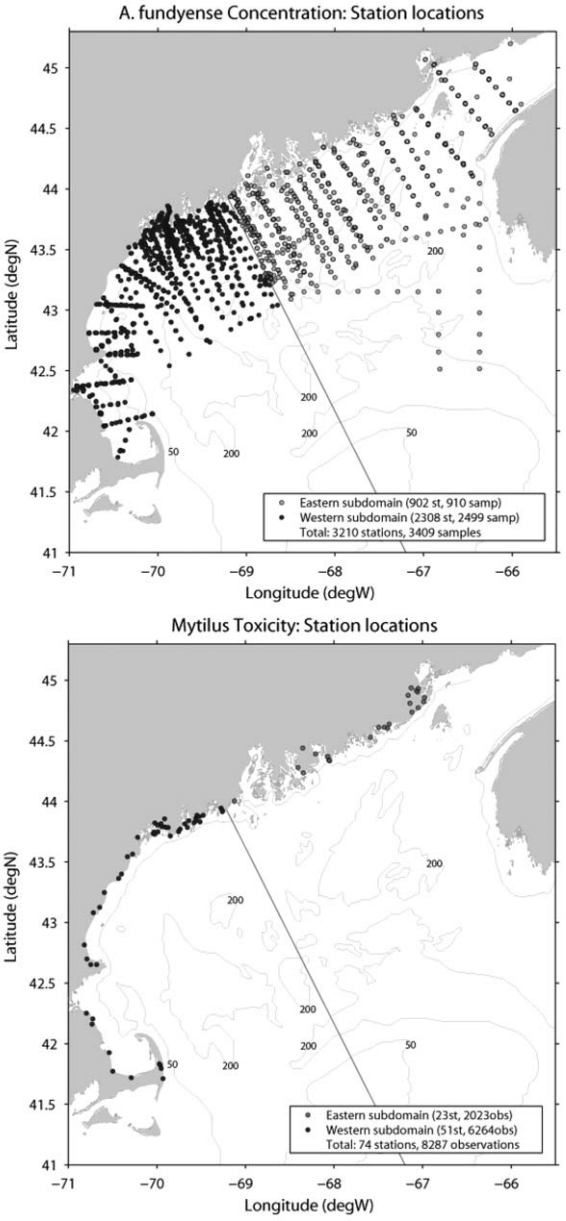

Fig. 1. Sampling locations for *A. fundyense* (top) and shellfish toxicity (bottom). Eastern and western subdomains are indicated.

3. Results

Cell abundance observations reveal a complex mixture of regional, seasonal, and interannual variability (Fig. 3). Some data sets resolve seasonal blooming of *A. fundyense* in specific geographic