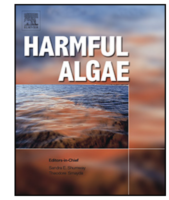
Harmful Algae 51 (2016) 26–39

Contents lists available at ScienceDirect

Harmful Algae

journal homepage: www.elsevier.com/locate/hal



Two decades of *Pseudo-nitzschia* spp. blooms and king scallop (*Pecten maximus*) contamination by domoic acid along the French Atlantic and English Channel coasts: Seasonal dynamics, spatial heterogeneity and interannual variability

Bérengère Husson [a], Tania Hernández-Fariñas [b], Romain Le Gendre [c], Mathilde Schapira [d], Annie Chapelle [e,*]

[a] IFREMER, REM-EEP-LEP, BP 70, 29280 Plouzané, France
[b] Station Biologique de Roscoff (Roscoff Marine Station)- Place Georges Teissier, 29680 Roscoff, France & Centre Ifremer de Brest - Pointe du Diable, 29280 Plouzané, France
[c] IFREMER, Unité de Recherche Lagons, Ecosystèmes et Aquaculture Durable (LEAD-NC), BP 2059, Nouméa 98846, New Caledonia, France
[d] IFREMER, LER/N, Avenue du Général de Gaulle, 14520 Port en Bessin, France
[e] IFREMER, Dyneco/PELAGOS, BP 70, 29280 Plouzané, France

ARTICLE INFO

Article history:
Received 2 March 2015
Received in revised form 30 October 2015
Accepted 30 October 2015
Available online 2 December 2015

Keywords:
Pseudo-nitzschia spp.
Domoic acid
King scallop
Interannual variability
Seasonal dynamics
Environmental parameters

ABSTRACT

King scallop contamination (*Pecten maximus*) by domoic acid, a neurotoxin produced by some species of the diatom *Pseudo-nitzschia*, is highly problematic because of its lengthy retention in the bivalve tissue, leading to prolonged fishery closures. Data collected within the French Phytoplankton and Phycotoxin monitoring network (REPHY) over the 1995–2012 period were used to characterize the seasonal dynamics and the interannual variability of *P.-nitzschia* spp. blooms as well as the contamination of king scallop fishing grounds, in six contrasted bays distributed along the French Atlantic coast and English Channel. Monitoring revealed that these toxic events have become more frequent since the year 2000, but with varying magnitudes, frequencies and timing depending on the bay. Two bays, located in southern Brittany, exhibited both recurrent contaminations and high *P.-nitzschia* abundances. The Brest bay and the Seine bay were intermittently affected. The Pertuis Breton exhibited only one major toxic event related to an exceptionally intense bloom of *P.-nitzschia* in 2010, and the Saint Brieuc bay neither showed significant contamination nor high *P.-nitzschia* abundance. While high *P.-nitzschia* abundance appeared to be correlated to scallop toxicity, this study highlights the difficulty in linking *P.-nitzschia* spp. blooms to king scallop contamination through monitoring. Indeed, *P.-nitzschia* was determined at the genus level and data regarding species abundances and their toxicity levels are an absolute prerequisite to further assess the environmental control of ASP events. As results describe distinct *P.-nitzschia* bloom dynamics along the French coast, this may suggest distinct controlling factors. They also revealed that major climatic events, such as the winter storm Xynthia in 2010, can trigger toxicity in *P.-nitzschia* over a large spatial scale and impact king scallop fisheries all along the coast.

1. Introduction

The pennate diatom *Pseudo-nitzschia* (Heterokonta, Bacillariophyceae) is a cosmopolitan genus that has been linked to many toxic events worldwide (e.g. Trainer et al., 2012). To date, a dozen species of this genus have been identified as being able to produce domoic acid (DA) (e.g. Bates and Trainer, 2006; Lelong et al., 2012), a potent neurotoxin responsible for Amnesic Shellfish Poisoning (ASP) syndrome in humans after the consumption of contaminated filter feeders (Bates et al., 1998; Wright et al., 1989). Symptoms of this poisoning are more or less severe gastrointestinal and neurological disorders and may even lead to death in the most extreme cases (Jeffery et al., 2004). Toxic *P.-nitzschia* (*PSN*) outbreaks are also responsible for massive mortalities in marine wildlife, such as marine mammals and sea birds, through the trophic transfer of the toxin (e.g. Scholin et al., 2000; Lefebvre et al., 2002a,b; Shumway et al., 2003; Bargu et al., 2012; Lefebvre et al., 2012). Toxic *PSN* blooms therefore represent an expanding risk for

* Corresponding author. Tel.: +33 298224356.
E-mail address: annie.chapelle@ifremer.fr (A. Chapelle).

http://dx.doi.org/10.1016/j.hal.2015.10.017
1568-9883/

both human health and activities such as fisheries and aquaculture, as well as for marine wildlife worldwide (Hallegraeff, 1993; Glibert et al., 2005).

Over the last decade, ASP events have strongly impacted fisheries in European waters (EFSA, 2009). Toxic *PSN* blooms have resulted in prolonged closure of king scallop (*Pecten maximus*) harvesting in Ireland (Bogan et al., 2007a,b), Scotland (Campbell et al., 2001; Gallacher et al., 2001), Portugal (Vale and Sampayo, 2001), Spain (Arévalo et al., 1998; Fraga et al., 1998) and France (Nézan et al., 2006). King scallop contamination by DA is highly problematic because of its lengthy retention in the bivalve tissue, which in extreme cases can last more than one year (e.g. Doucette et al., 2006; Blanco et al., 2002). In France, *P. maximus* fishing grounds are distributed along the French Atlantic and English Channel coasts, with a production ranging between 15,000 and 20,000 t per year. Since the first detection of DA in mussel tissues in 1998 (i.e. 0.5 $\mu g\,g^{-1}$ of wet weight, hereafter ww; Amzil et al., 2001), DA levels are systematically monitored in king scallop tissues before and during harvesting periods, within the framework of the French Phytoplankton and Phycotoxin monitoring network (REPHY). In addition, phytoplankton community composition is monitored at a fortnightly or monthly frequency. When *PSN* densities exceed the alert threshold of 100,000 cells l^{-1}, DA analysis are systematically carried out in king scallop tissues. Since 2004, several ASP events, characterized by DA concentrations well above the European Union regulatory limit (i.e. >20 $\mu g\,g^{-1}$ ww), have been observed along the French coast, leading to extended closures of many harvesting sites and causing serious economic losses for the French fleet (Belin et al., 2013).

Given its potential impact on local economies and human health, a better knowledge of the spatial and temporal dynamics of *PSN* blooms and ASP events affecting French scallop fisheries is an absolute prerequisite to further assessing the determinism of the *PSN* toxic blooms, and ultimately to developing predictive models of toxigenic *PSN* blooms. Despite the large available dataset from the REPHY monitoring network, seasonal dynamics and interannual variability of *PSN* blooms have not yet been described. This study represents the first step towards an improved understanding of toxic *Pseudo-nitzschia* bloom dynamics and ASP events along the French coast.

In this context, the objectives of this study were to (i) describe the seasonal dynamics of *Pseudo-nitzschia* spp. blooms in six contrasted bays scattered along the coast, (ii) to estimate scallop contamination by domoic acid over an interannual time scale and investigate a possible link with the intensity of *PSN* blooms and (iii) to finally discuss the potential role of environmental factors influencing toxic *PSN* outbreaks along the coast.

2. Materials and methods

2.1. Study sites

This study was conducted in six bays scattered along the French Atlantic and English Channel coasts (Fig. 1). Among the different sampling stations monitored within the REPHY, one station was selected in each bay (Table 1). The choice of these stations was conditioned by (i) the time range and frequency of the available data sets, (ii) the presence of exploited scallop fishing grounds, (iii) the recurring observation of *PSN* within the phytoplankton community and (iv) the representativeness of hydrological features encountered in the bay. The data collected at these selected sampling stations was used throughout the manuscript. For the sake of clarity, the term 'bay' will be used thereafter.

Despite these common features, the study sites exhibit very different hydro-climatic and biological characteristics (Figs. 1 and 2 and Table 2).

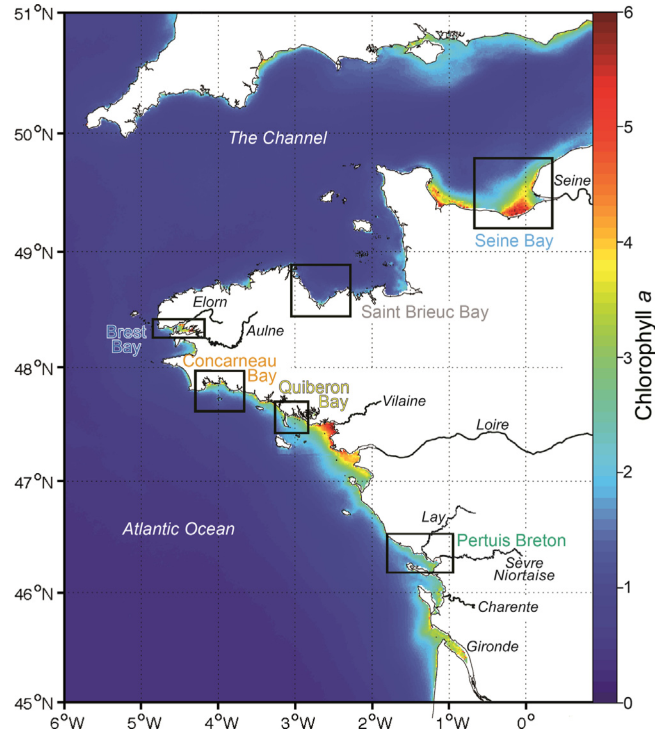


Fig. 1. Location of the six studied bays scattered along the French coast and annual average chlorophyll *a* concentrations ([Chl *a*]) over the 1998–2012 period (color bar). From the North to the South: (i) Seine bay, (ii) St Brieuc bay, (iii) Brest bay, (iv) Concarneau bay, (v) Quiberon bay and (vi) Pertuis Breton. Major rivers influencing the six bays are shown in italic. Annual average Chl *a* concentrations were estimated from ocean color using OC5 algorithm and daily composite product merging three satellites Chlorophyll *a* derived data (i.e. MERIS, MODIS/Aqua and SeaWIFS) over the 1998–2012 period (Saulquin et al., 2010). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The Seine Bay covers 4000 km^2 with a mean depth around 15 m and is characterized by a megatidal regime, with a tidal range reaching more than 7 m (Guillaud et al., 2000). The bay receives large freshwater inputs mainly from the Seine River (interannual mean flow = 510 $m^3\,s^{-1}$). The Seine bay exhibits the highest phytoplankton biomass out of the six study sites, with median interannual Chlorophyll *a* (Chl *a*) reaching 4.1 $\mu g\,l^{-1}$ at the chosen sampling station (Table 2). High Chlorophyll *a* levels are regularly observed in the Seine river plume during the productive seasons, with mean values reaching 20 $\mu g\,l^{-1}$ and extreme values peaking at 60 $\mu g\,l^{-1}$ (Cugier et al., 2005). Important freshwater inputs cause high winter nutrient concentrations with median values of 1 $\mu mol\,l^{-1}$, 23 $\mu mol\,l^{-1}$ and 43 $\mu mol\,l^{-1}$ for PO_4 (P), SiOH (Si) and dissolved inorganic nitrogen (N), respectively, with N/P always above the Redfield ratio (median of 44.1), highlighting important nitrogen enrichment (Fig. 2). King scallop harvesting in the Seine bay represents 50% to 70% of national production (i.e. 5000 to 15,000 t $year^{-1}$).

Table 1
Geographic coordinates and lowest astronomical tide (LAT) of the 6 sampling stations in each studied bays.

	Sampling station	Latitude	Longitude	LAT* (m)
Seine bay	Cabourg	49°18.50′N	0°07.54′W	5.0
St Brieuc bay	Loguivy	48°49.72′N	3°02.51′W	3.5
Brest bay	Lanveoc	48°18.56′N	4°26.91′W	18.5
Concarneau bay	Concarneau	47°50.00′N	3°56.99′W	20.0
Quiberon bay	Men erRoue	47°32.08′N	3°05.62′W	9.5
Pertuis Breton	L'éperon	46°16.38′N	1°14.03′W	1.0

* Lowest Astronomical Tide.