Identification of seasonal and multi-annual trends of bivalve toxicity by PSTs in Portuguese estuarine and coastal waters

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Temporal and spatial trends of paralytic shellfish toxins (PSTs) in bivalves from Portuguese estuarine and coastal waters, and connectivity of bivalve toxicity among the harvest areas, were examined using long-term data from the national biotoxin monitoring programme. Data from the period between 1994 and 2012 were chosen for commercial bivalve species sensitive to PSTs (*Mytilus* spp., C*erastoderma edule, Donax trunculus* and *Spisula solida)* and for areas exhibiting recurrent episodes of bivalve toxicity. Bivalve toxicity data point to an irregular multi-annual variation of PSTs episodes, most likely associated with the inter-annual variability of favourable oceanographic conditions triggering the bloom formation of *Gymnodinium catenatum*. Episodes in the southern coast of Portugal were less recurrent. However, the values above the PST regulatory limit displayed a seasonal signal with a peak between autumn and early winter and, in some years, an additional enhancement in summer. A connectivity index of bivalve toxicity was defined among the surveyed areas, on the basis of the number of weeks per month that bivalves showed elevated toxicity values. High connectivity was obtained among Aveiro, Mondego and Óbidos, suggesting the import of *G. catenatum* cells from blooms formed or reaching the coastal waters adjacent to these estuaries.

Introduction

Paralytic shellfish toxins (PSTs) are a broad group of neurotoxins produced by species of harmful marine dinoflagellates belong to the genera *Alexandrium*, *Pyrodinium* and *Gymnodinium*. During blooms of that species, bivalves concentrate toxins in their tissues. Human consumption of contaminated bivalves by PSTs may result in neurological and gastrointestinal illnesses. The association of *G. catenatum* blooms with paralytic shellfish poisoning episodes was firstly reported in NW Spain, Pacific coast of Mexico, Australia, Japan (Hallegraeff et al., 2012), and Portugal (Franca and Almeida, 1989). In Portuguese coastal waters, the record of *G. catenatum* blooms has been also associated with the relaxation of coastal upwelling that occurs recurrently in the western region, and slow currents or inshore eddies that contribute to the maintenance of this species near the coast (Moita el al., 2003; Pitcher et al., 2010). The main objective of the present work is to examine whether the occurrence of PST episodes in Portugal between 1994 and 2012 exhibited multi-annual or seasonal variation signal. The hypothesis was tested for mussels, cockles, wedge clams and white clams regularly sampled in transitional and coastal waters of Portugal. In addition, the connectivity of toxicity episodes among more regularly surveyed areas was examined.

Material and Methods

Toxin concentrations and corresponding toxicity values were obtained from the biotoxin monitoring programme database. The sampling representativeness on a monthly (SR_M, %) and yearly (SR_Y, %) basis was calculated for each bivalve species and production area. On the basis of SR_M and SR_Y were defined confidence levels associated with the sampling periods. The proportion of samples with elevated toxicity (TS_M and TS_Y, %) was calculated by dividing the number of samples presenting toxicity values above the regulatory limit per month or year, by the number of samples collected in that period of time, month or year. To assess the possible interconnection of PST episodes among two or three estuarine or coastal areas,

a connectivity index (CI) for bivalve toxicity on a monthly basis was defined. The score of CI (0 to 4) was based on the number of weeks per month that bivalve species showed toxicity values above RL concomitantly in each area.

Results and discussion

The PST episodes were more recurrent in the west coast of Portugal, where blooms of *G. catenatum* have been reported (Moita et al., 2003; Vale et al., 2008). Most likely, the toxic cells generated offshore that are displaced towards the coast tend to be tidally advected into the estuarine systems as Aveiro, Mondego and Óbidos (Fraga et al., 1998). The import of toxic cells and their maintenance or development under high salinity conditions is facilitated by the elevated tidal influence (mesotidal systems) and low freshwater inputs. Consequently, bivalves from these estuarine systems are quickly exposed to the toxin-producing species imported from adjacent coastal waters. Despite the high water volume exchanged daily between Formosa and the adjacent sea (Falcão and Vale, 2003), the toxicity episodes in this lagoon were rarer, in line with the sporadic *G. catenatum* blooms in the adjacent coastal zone. A salient aspect of this study is the prolonged period (1996-2004) of low bivalve toxicity by PSTs. Toxin concentrations in the whole tissue of mussels, cockles, white clams and wedge clams were often undetected (bioassay) or below the limit of detection, suggesting that *G. catenatum* did not bloom or if cells flourished offshore they were not transported to the surveyed coastal. This observation is in line with previous works pointing to massive *G. catenatum* blooms off the western Portuguese coast in 1976, 1985, 1994 and 1995, contrasting to lack of blooms for the years in between (Moita et al., 2003, Amorim et al., 2004). The toxicity episodes in the western coast of Portugal were frequently manifested during autumn and early winter. The signal of these episodes remained for three to four weeks per month in autumn 2007 and winter 2008. Moreover, mussel and cockle toxicities exceeded the RL in June-July of 2008, providing an additional signal of toxicity. Along the 18 years of survey, the summer toxicity episodes were much less regular than in the autumn. The seasonal occurrence is related to *G. catenatum* blooms generated in the Iberian coast (Estrada et al., 1995; Vale et al., 2008), triggered by upwelling events from April through September. The interconnections of toxicity episodes were searched for the periods 1994-1995 and 2005-2009 for the following possibilities): Aveiro-Mondego-Óbidos (using both mussel and cockle), Aguda-Aveiro (white clam versus mussel) and Culatra-Formosa (wedge clam versus cockle). The scores of IC for Aveiro-Mondego-Óbidos (mussel) reached 3 to 4 (in a scale 0-4) in December 1994 and between October 2007 and August 2008, while mean values in the remaining years were below 1. The short distance between Aveiro-Mondego and Mondego-Óbidos (approximately 85 km) facilitates the quasi-simultaneous occurrence of toxicity episodes among these systems. The connectivity was evident in 2007-2008, when elevated toxicity persisted for a long period. These results reinforce the hypothesis of those estuarine systems import *G. catenatum* cells from nearby coastal waters.

References

Amorim, A., Dale, B., 2006. African Journal of Marine Science, 28:193–197.

Estrada, M. 1995. *In* Harmful Marine Algal Blooms, pp. 157–162, Ed. by P. Lassus, G. Arzul, E. Erard, P. Gentien, C. Marcaillou. Lavoisier, Paris.

Falcão, M., Vale, C. 2003. Ciencias Marinas 29 (4):425-433.

Fraga, S., Anderson, D.M., Bravo, I., Reguera, B., Steidinger, K.A., Yentsch, C.M. 1998. Estuarine, Coastal and Shelf Science, 27 (4):349-361.

Franca, S., Almeida, J.F. 1989. *In* Red Tides: Biology, Environmental Science and Toxicology, pp. 89-92 Ed. by T. Okaichi, D.M. Anderson, D. Nemoto, Elsevier, New York.

Hallegraeff, G.M., Blackburn, S.I., Doblin, M.A., Bolch, C.J.S. 2012. Harmful Algae, 14: 130-143.

Moita, M.T., Oliveira, P.B., Mendes, J.C., Palma, A.S. 2003. Acta Oecologica, 24: S125-S132.

Pitcher, G. C., Figueiras, F.G., Hickey, B.M., Moita, M.T. 2010. Progress in Oceanography, 85: 5-32.

Vale, P., Botelho, M.J., Rodrigues, S.M., Gomes, S.S., Sampayo, M.A.M. 2008. Harmful Algae, 7:11-25.