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# The global phenomena of harmful algal blooms (HAB): Environmental and socioeconomic impacts

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***Highlights:*** *Add a max. of 5 short sentences as highlights of text study.*

**Keywords:** Harmful algal blooms, toxicity, environmental impacts, socioeconomic impacts

## 1. Introduction

Harmful algal blooms (HAB) are an ancient and natural phenomena that generally reflects the monospecific, and on rare occasions, the multispecific outgrowth of microalgae in marine coastal areas, estuaries, open waters and freshwater environments. The bloom of several species of HAB are triggered by a complex variety of environmental factors and cause mild to severe impacts on aquatic organisms and human health (Zingone and Oksfeldt Enevoldsen, 2000; Moore et al, 2008). Noxious HAB reach such high cell densities that they interfere with recreational activities, photosynthesis and cause mass mortalities among aquatic organisms induced by hypoxia or anoxia. On the other hand, toxic HAB synthesize potent toxic compounds and bioactive exudates that lead to severe damage of the aquatic fauna with numerous pathologies and mass mortalities reported mainly for fish and shellfish, but also with episodic mortalities of marine mammals, birds, and other animals depending on the food web. Additionally, these toxins can be bio-accumulated and bio-amplified throughout food webs to humans with several globally distributed events of fish- and shellfish-mediated intoxications, such as diarrheic shellfish poisoning (DSP) and paralytic shellfish poisoning (PSP). At the same time, many industries are affected following HAB outbreaks. Closures of shellfish beds, loss of production in fisheries and aquaculture farms, severe reductions in local and even regional tourism and associated service industries, public illness, medical treatments and advisories all together result in important economic losses per outbreak; at the same time, public resources are diverted towards monitoring programs (Smayda, 1990; Hallegraeff, 1993; Anderson, 1995; Van Dolah, 2000). In the present paper, the environmental and socioeconomic impacts of HAB are reviewed and case studies of their effects and toxicity mechanisms in important shellfish species of ecological and economic importance are presented.

## 2. Material and Methods

Several globally-distributed species of HAB implicated in both human poisonings, and fish and shellfish-kills were considered in this study. Species of the genera *Alexandrium*, *Dinophysis*, *Karenia*, *Heterocapsa*, *Chattonella*, and *Heterosigma* were cultured under controlled laboratory conditions in F/2 medium, modified F/2 medium or modified SW3 medium (Nishitani et al., 2004). Several bivalve mollusc species were used to assess the impacts of the HAB species on their survivalship, physiological and reproductive performances, and to determine the toxicity mechanisms of the HAB species. Liquid chormatography tandem mass spectrometry (LC-MS/MS) was used to determine the toxins produced by the HAB species (Oshima, 1995; Suzuki et al. 1998). *In-vivo* and *in-vitro* exposure experiments of oocytes, embryos, larvae and adults of the Japanese pearl oyster, *Pinctada fucata martensii*, the mediterranean mussels, *Mytilus galloprovincialis*, the manila clam, *Ruditapes philippinarum*, the Pacific oyster, *Crassostrea gigas*, the noble scallop, *Mimachlamys nobilis*, and the Japanese scallop, *Mizuhopecten yessoensis* were carried out under controlled laboratory conditions. Light and scanning electron microscopies were used to

assess the phenotipic effects of the HAB species on several early-developmental stages and the phatologies induced in several organs of adults (Basti et al., 2011; 2013). Spectrophotometry was used to assess the cytotoxicity of the HAB species in oocytes and the oxidative stress in larvae and hepatopancreas of adult bivalves (Basti et al., 2015).

## 3. Results and Discussion

Differential effects of the HAB sepcies on the life stages of the bivalve molluscs considered in this study were elucidated. Species of the genera *Heterosigma* and *Chattonella*, wich are known to cause worldwide fish-kills in aquaculture farms, showed toxic effects on larvae of Japanese pearl oyster, with involvement of mucus traps that reflect potential effects also on bivalve mollusc reproduction (Basti et al., 2016). The shellfish-killer, *Heterocapsa circularisquama*, showed extensive cytotoxicity in gametes, embryos and larvae of Japanese pearl oyster (Basti et al., 2011; 2013) and several organs of Manila clams and Mediterranean mussels (Basti et al., 2011; Basti et al., 2015). Species of the genera *Alexandrium* that are not known to produce PSP toxins showed cytotoxicity to oocytes and lytic activity in embryos of Japanese pearl oyster which reflect the involvement of uncharacterised biaoctive compounds (Basti et al., 2015). Oxidative stress responses in larvae of Japanese pearl oyster, and adult Pacific oyster, Japanese and noble scallops were modulated following exposures to *Chatonella*, *Heterocapsa circularisquama*, *Karenia mikimotoi*, and *Dinophysis* sp.

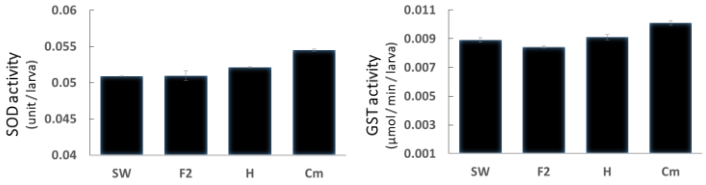


**Fig. 1.** Modulation of anti-oxidant enzymes, superoxide dismutase (SOD) and gluthatione-*S*-transferase in larvae of Japanese pearl oyster following exposure to the harmful algae *Heterocapsa circularisquama* (H) and *Chattonella marina* (Cm).

## 4. Conclusion

Several toxicity mechanisms of different HAB species involved in world-wide human poisonings, mass mortalities of fish and shellfish with mild to severe ecosystematic impacts have been elucidated in our case studies. Harmful algal blooms are witnessing range expansion in several aquatic environments associated with both anthropogenic and climate-driven changes in the physical and chemical properties of aquatic environments that would affect their ecophysiology, toxinology and therafter their environmental and socioeconomic impacts.

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