

Summary and conclusions

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The national reports included here give, for the first time, an overview of HAB problems experienced by PICES member countries of the northern North Pacific and the state of knowledge in each. Although PICES has focused on the northern North Pacific (as reflected in the choice of the logo for the Organization), HAB phenomena do not respect such boundaries. For example, tropical ciguatera fish poisoning occurs within the warmer waters of countries such as China and the United States and there are tropical shellfish poisonings and fish killers that also extend beyond the southern limits of the current PICES member countries. To include warmer North Pacific waters we have invited scientists in Mexico to provide a national report to supplement those of member countries. In the future, we hope that other countries within or adjacent to the region will be linked by this or similar organizations. Ultimately it is hoped that all these will contribute to a synoptic, global review under the auspices of the IOC-UNESCO program, GEOHAB and the International Society for the Study of Harmful Algae (ISSHA).

From the country reports a number of general conclusions are evident. Serious HAB problems occur in all member and adjacent countries. These include human health hazards from various forms of shellfish poisoning that are not only of similar type but are often caused by the same organisms, even to the species level. Before noting some of these, attention should be drawn to name changes that may confuse the picture. We allowed the use of original species and genus names in the country reports. However the reader should be aware that all the toxic *Nitzschia* species in older literature are now in the genus *Pseudo-nitzschia* (always hyphenated), *Protogonyaulax* species are now all in *Alexandrium*. Several HAB species of

Gymnodinium are now in other dinoflagellate genera such as *Karenia* (*brevis*, *mikimotoi*), *Karlodinium* and, most unfortunately because of the potential for genus/species confusion *Akashiwo* (*sanguineum*). The IOC has recently provided a list of all HAB species and their synonyms on its website.

Although taxonomic citation may vary, we know that similar species of *Alexandrium* cause paralytic shellfish poisoning (PSP) in all the PICES countries. In warmer waters of both the eastern and western North Pacific, tropical members of the same genus cause PSP, as well as *Pyrodinium bahamense* var. *compressum* and *Gymnodinium catenatum*. Similar species of the diatom genus *Pseudo-nitzschia* produce, or have the potential to produce, domoic acid (amnesic shellfish poisoning and its counterpart in benthic crustaceans and planktivorous fish) in all the member countries. The diarrheic shellfish poison producers of the dinoflagellate genus *Dinophysis* are also common. Fish and shellfish killers are almost as ubiquitous. Raphidophyte (chloromonad) flagellates of the genera *Heterosigma*, *Chattonella* and *Fibrocapsa* kill farmed fish in areas where there is major aquaculture activity, with the latter two genera more prevalent in the warmer waters. The dinoflagellate, *Noctiluca scintillans*, is ubiquitous in the coastal waters of the region but only seems to be a serious problem when it blooms within the confines of shrimp farms, such as those of southern China, where its effects can be catastrophic. Some fish killers, such as *Cochlodinium polykrikoides* and closely related species, seem to be predominantly problems in Korea (where it is the main source of severe losses), Japan and British Columbia. *Heterocapsa circularisquama* is so far only a destroyer of shellfish in Japan.

As noted earlier, human illness from ciguatera fish poisoning, caused by benthic dinoflagellates, primarily *Gambierdiscus toxicus*, is limited in the PICES region to the warmer waters of the U.S. and China, such as Hawaii and in the South China Sea. However, it is widespread in other tropical countries including Mexico and the Philippines. Additionally, the import of fish from tropical sources, e.g., Hong Kong, as well as tourist exposure while visiting the tropics, causes this illness to be more far-reaching to most temperate countries. These facts lend credence to earlier assertions that there is no coastal country in the world that does not have one form of HAB or another, or most likely several. Cyanobacteria, which are the predominant group causing HABs in freshwater, are less of a problem in the marine environment although microcystins, known only to be produced by cyanobacteria so far, have turned up in B.C. salmon farms. *Trichodesmium*, a common and abundant tropical cyanobacterium, is not usually harmful but can be if it enters the confined waters of shrimp ponds (China and S.E. Asian countries) and the Mexican report identifies others as being a serious problem in shrimp farms.

Combining the information from adjacent countries can provide a much more complete view of the scope of HAB problems and may even provide insights into important ecological questions that would not be apparent from viewing one country alone. In Figure 40 we show the PSP data for Washington State alone, and in combination with British Columbia for the same year. Not only is the scope of high PSP evidently much wider in the combined picture, but it also reveals an interesting difference between the outer coasts of the two. PSP is effectively absent in 1999 from the open Washington coast but commonly present on the west coast of Vancouver Island.

In order to draw realistic comparisons between countries, the standardization of terminology and methodologies is of urgent importance, not only in the PICES region, but also throughout the world. A major discrepancy involves interpretation of the term "red tide". In some countries this refers only to fish or shellfish killers, but in others it may even include bloom-forming phytoplankton that are non-harmful but are a local economic problem.

These non-harmful blooms commonly occur in other countries but would not be included in each country's HAB reports. Some countries restrict reports of harmful algal blooms to those algae known to produce a toxin. Others distinguish "toxic red tides" from non-toxic ones where harm can be caused by non-toxic factors such as oxygen depletion. The word "toxin" may have different meanings, being synonymous to ingested poison by humans in some countries, but in others including, for example, the brevetoxins which kill fish in Florida.

It is evident that care should be taken in comparing lists of "red tide" species from different countries and particularly total numbers. Similarly, the number of incidents reported may be "sightings" rather than ecologically separate events and are thus dependant on the frequency and comprehensiveness of the observer network employed. Interannual reports can only be compared if the observation protocol is the same each year. Such considerations are obviously critical to the formation of large, multinational databases.

Fortunately the monitoring of PSP toxin levels in shellfish employs fairly standard methodology. Most countries follow the AOAC mouse bioassay method, with a closure level of 80 µg per 100g of shellfish meat in nearly all North Pacific countries. An exception is in the Philippines where, due to the greater concern about very young victims, a lower closure level of 40 µg is used. However, there are significant differences in the species of shellfish tested. This is unfortunate for the purposes of comparison, since different shellfish concentrate different levels of toxin for varying lengths of time. Mussels pick up toxins rapidly upon exposure and lose it the most rapidly, whereas butter clams, for example, retain PSP toxins for long periods of time. Razor clams retain domoic acid for months, whereas mussels depurate this toxin quickly.

In some countries, long-term data sets are of limited value because the species of shellfish routinely monitored has changed with time. Increasingly, for reasons of economy and convenience, many monitoring programs use mussels as "sentinel species" to test for shellfish

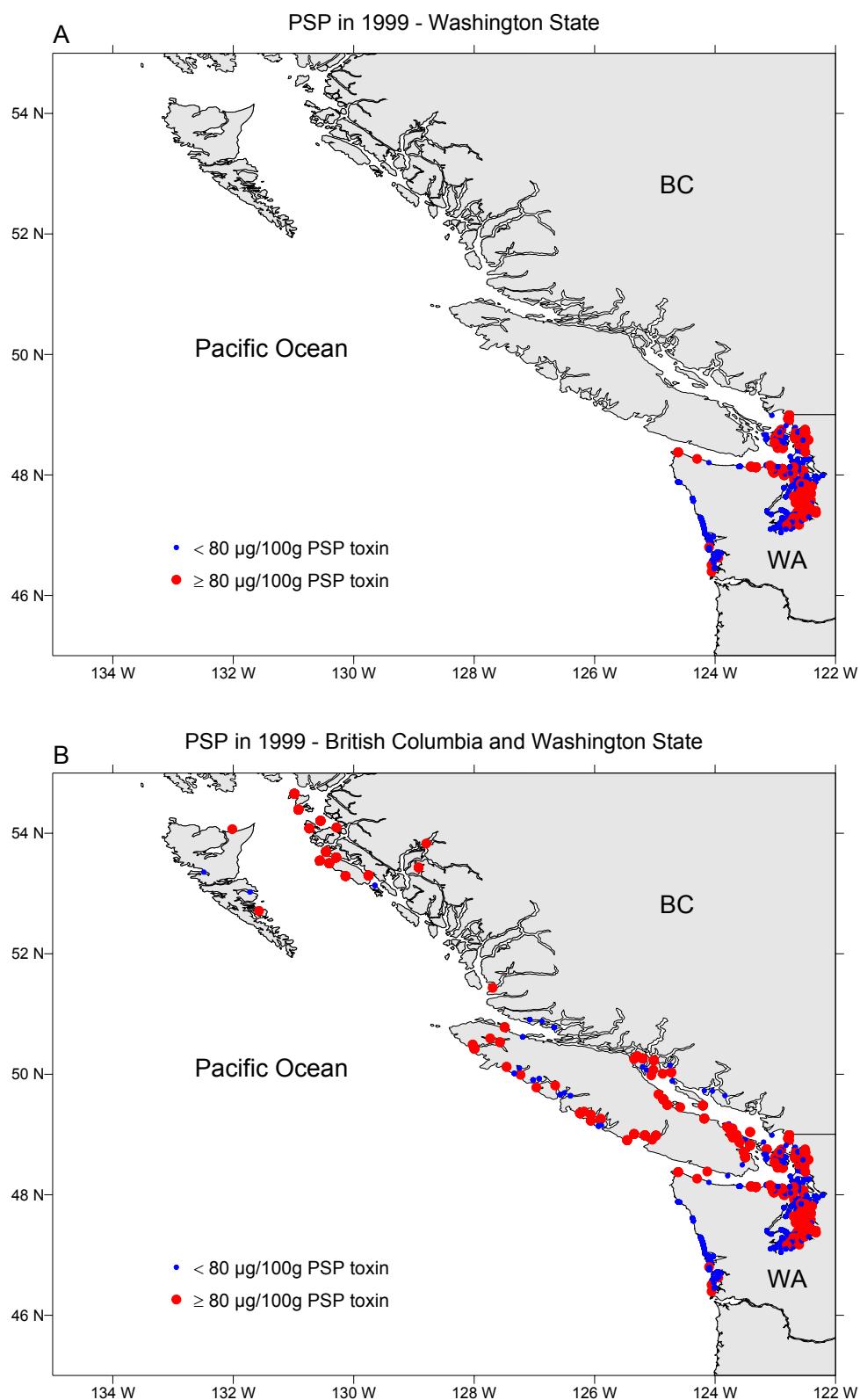


Fig. 40 PSP on the coasts of Washington State and British Columbia in 1999. A: Washington State alone. B: PSP data in the two regions combined.

toxins since these are the standard indicators of pollutants in “world mussel watch” programs. In most member countries, at least some plankton monitoring is carried out. While plankton monitoring programs alone are unlikely to serve as reliable methods of protection on a large scale, within limited areas, such as those of high aquaculture or shellfish harvest, they can provide early and supplemental warning and are essential for the understanding of the ecology of HABs.

Logistical and financial problems cannot be ignored in the management of HABs, given that some coastlines such as British Columbia, Alaska and northeast Russia are impossible to monitor comprehensively because of their length, complexity and difficulty of access. Typically blanket closures are issued for these remote coastal areas. Unfortunately, this can have an unwanted suppressive effect on the development of regional harvesting and aquaculture in economically deprived areas. Local people within these blanket closure areas tend to disregard management dictates and rely instead on traditional folk wisdom. The authorities, while acting responsibly, in fact lose control and respect.

Most reports focus on monitoring and prediction efforts in management, but a few have also provided information on mitigation efforts, such as the use of flocculents to sink blooms or algicidal bacteria and viruses as means of HAB control. These practical approaches are still in early development but clearly need to be encouraged where conditions make them feasible.

Interesting and important ecological questions arise from reviewing the national reports. For example, PSP appears to be less prevalent north of the Aleutians in Alaskan waters and more prolonged in northern British Columbia. The open coast of Washington, Oregon and California seem to be subject to PSP primarily in embayments whereas the B.C. outer coast has plentiful toxicity (Fig. 40 above). Are these observations actually artefacts of low sampling intensity or are they real? If so, why? There is a provocative sequence in timing of *Pseudo-nitzschia* blooms from south to north up the west coast of North America (Fig. 41). Is this due to a physical linkage, such as

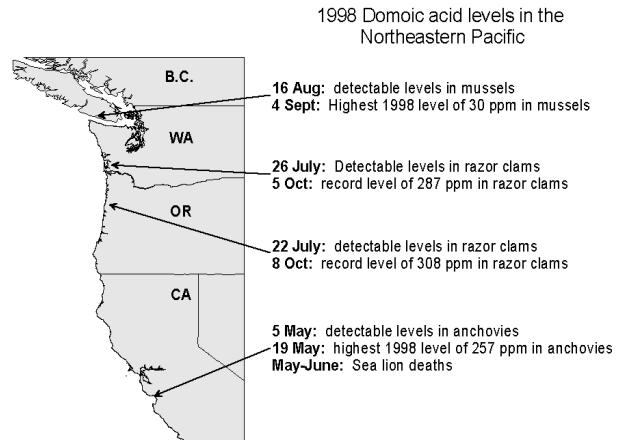


Fig. 41 The sequence of timing of first occurrence and maxima of domoic acid on the west coast of North America in 1998.

subsurface northward advection of toxic cells or is it a progressive triggering of local blooms following a seasonal progression whose timing is later in the north?

Although the primary direction of surface flow is southward throughout the summer months when these HABs are a problem, the northward reversal due to a shallow manifestation of the California Undercurrent, known as the Davidson Current, could provide northward advection of phytoplankton cells. Related to this is the question as to why certain local areas experience blooms much earlier than others?

Questions that occupy a central position in recent HAB literature are whether HABs are increasing in intensity (frequency, abundance and area) and spreading to new, previously unaffected areas. Some authors unjustifiably seem to assume that both are an established fact on a global scale. Others argue that factors such as increased awareness and local increases in aquaculture activity are contributing to false impression of environmental change for the worse.

No one disputes that the number of reports has been increasing exponentially in the past few decades. Several reports here shed light on these important questions. Some areas have undoubtedly had increases in HABs, of which

a good example is *Cochlodinium* blooms on the southern coast of Korea.

The Seto Inland Sea of Japan apparently experienced a dramatic rise in phytoplankton blooms in the 1970s, followed by a decline, but harmful blooms remained at a fairly constant level throughout. PSP seems to be cyclic in many countries, with particularly bad years often being

strong El Niño years, although a causal link has not been established. These and other important and exciting questions will no doubt continue to occupy a central position in HAB studies in the future. Multinational reports such as this one will provide a larger perspective from which to view HABs and increase awareness of the need for international co-operation.