PSP:

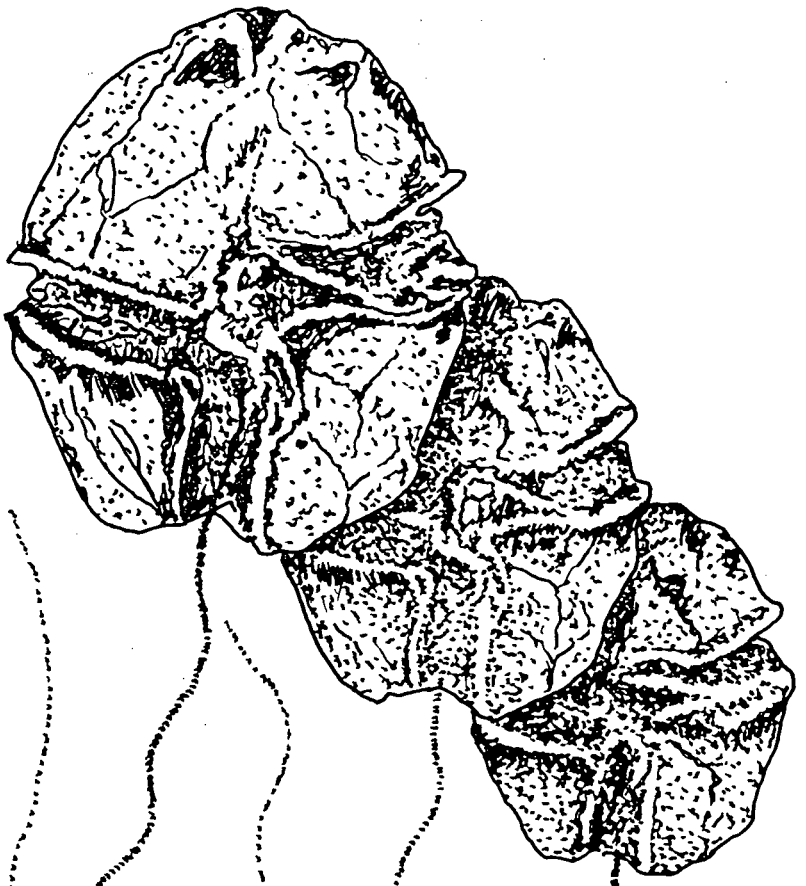
POISON

FOR

FUNDY

SHELLFISH

CULTURE



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- **FACT:** the risk of molluscan shellfish contamination by paralytic shellfish toxins is high nearly everywhere in Canada's southern Bay of Fundy, one of the richest shellfish areas in the world.
- **FACT:** *Gonyaulax* blooms and paralytic shellfish toxins do not impair the *growing* of shellfish in the Bay of Fundy because *Gonyaulax* is a satisfactory food organism and the toxins have little effect on shellfish. However, the toxins have a major impact on the marketing of all filter-feeding shellfish except the sea scallop, from which only the toxin-free adductor muscle is marketed.
- **FACT:** There is no economically viable method for detoxifying or depurating paralytic shellfish toxins in molluscan shellfish, nor is there any known antidote for the toxic effects in humans. Thus the cost of inspecting shellfish for paralytic shellfish toxins must be taken into account in the cost/benefit analysis of shellfish culture operations in areas affected by the dinoflagellate *Gonyaulax*.

Paralytic shellfish poisoning (PSP) is a potentially fatal food poisoning that affects humans and other vertebrates that consume molluscan shellfish which have accumulated toxins from any of several species of marine dinoflagellates. In eastern Canada the dinoflagellate responsible for PSP is Gonyaulax excavata (also called *G. tamarensis, G. excavata* var. *tamarensis, Protogonyaulax tamarensis*, and *Alexandrium fundyensis*).

The toxins this organism produces – saxitoxin, neosaxitoxin, and a number of gonyautoxins – are among the most potent non-protein toxins known, producing death of vertebrates by progressive paralysis until respiratory failure occurs. During the annual blooms of the dinoflagellate, filter-feeding shellfish such as mussels and clams accumulate the toxins while feeding on the dinoflagellates. The toxins do not generally affect the shellfish, and the shellfish appear normal despite high toxin loads. Highly toxic shellfish represent a serious health hazard. Human death occurs within 3 to 12 hours of ingestion, and no antidote to the poison is yet available.

THE BAY OF FUNDY

PSP has been a problem in eastern Canada for several hundred years. Shellfish toxicity records for the Bay of Fundy date from the 1940s and constitute the longest such series in the world. These indicate that shellfish toxicity is nearly an annual event in this area.

The general seasonal pattern of shellfish toxicity is as follows: a rapid accumulation of toxins during June or July, a gradual decrease in toxin content over the next several weeks or months, and low toxin levels through some or all of the fall season and through the winter and spring. Often the toxicity levels in the summertime exceed the public health safety threshold of 80 micrograms of saxitoxin per 100 g of shellfish meat and the shellfish areas must be closed to harvesting. Some years are much worse than others, with shellfish toxicity reaching levels so high that a small number of contaminated shellfish would kill a human. During the mid- to late 1970s there was a pattern of intensification of shellfish toxicity in the Bay of Fundy which appears to have discontinued in recent years. However, the harvesting of wild shellfish from some areas has still not returned to a more normal September through May schedule because of persistence of toxicity at levels above the safety threshold.

SHELLFISH ACCUMULATE PSP TOXINS

All filter-feeding molluscan shellfish can accumulate paralytic shellfish toxins from feeding on the toxin-containing dinoflagellates. Certain carnivorous molluscs such as drills, moon snails and whelks can also accumulate the toxins by preying on filter-feeding molluscs that contain the toxin. All seven species of molluscan filter-feeders considered as candidates for commercial culture in the Bay of Fundy can become contaminated with paralytic shellfish toxins, but apparently to different degrees.

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Blue mussels become highly toxic within a few days, but also lose their toxin loads rapidly (within a few weeks) when the toxic dinoflagellates disappear from the plankton community. Soft-shell clams (*Mya arenaria*) can become highly toxic, although not generally as toxic as mussels in the same area. Clams require more time to accumulate high levels of toxins (several weeks), but also require longer to cleanse themselves of toxins they have accumulated (several weeks to several months).

Quahaugs (*Mercenaria mercenaria*) and oysters (*Crassostrea virginica*) do not appear to become as highly toxic as mussels and clams, probably because *Gonyaulax* does not seem to be among their preferred food items. Scallop viscera can become extremely toxic, but the part of *Placopecten magellanicus* that is eaten in North America, the adductor muscle, remains virtually free of toxin at all times.

TOXIN ACCUMULATION

The major mechanism by which filter-feeding shellfish acquire paralytic shellfish toxins is the ingestion of the motile vegetative cells of *Gonyaulax excavata* which form the summertime bloom. The dinoflagellates generally occur in abundance in the upper 5 meters of water, but sometimes at greater depths, so that any filter-feeding shellfish in suspension culture would be vulnerable to toxin accumulation.

It has recently been recognized that toxin can also accumulate in shellfish during non-bloom months. Circumstantial evidence strongly suggests that "off-season" toxin accumulation results from the ingestion of the overwintering cysts of *Gonyaulax*, which also contain the toxins. The cysts are formed during the summer bloom, descend through the water column, and settle in the sediments in a state of dormancy throughout the fall and winter until rising water temperatures in the spring trigger their encystment into motile vegetative cells which swim to the surface and repeat the process. Concentration of *Gonyaulax* cysts in Bay of Fundy sediments can reach several thousand per cubic centimeter, especially in the fine mud deposits in the deep waters to the northeast of Grand Manan. Cyst resuspension, resulting from storm surges or fishing activities, followed by ingestion of cysts by shellfish could provide the mechanism for "off-season" toxin accumulation.

Shellfish culture operations which employ suspension techniques may be able to avoid problems of off-season contamination with paralytic shellfish toxins because the shellfish could be

suspended clear of cyst-laden sediments. However, even with suspension techniques there would still be some risk of off-season contamination because of occasional persistence of toxins acquired during the summer bloom. In years with intense *Gonyaulax* blooms, shellfish toxin loads can become so high the shellfish cannot cleanse themselves of the toxins to safe levels before the water temperature starts to decline in the fall. Then, because their metabolic rate decreases, further natural depuration of the toxins becomes difficult and the toxins may persist in the shellfish at levels above the public safety threshold during the fall and winter, with further depuration not occurring until the following spring. The same situation may result if the *Gonyaulax* bloom occurs late in the summer season – in late August or September. Although this persistence of shellfish toxicity into non-bloom periods is not generally the case, the risk should be noted.

SITE SELECTION

The danger that cultured shellfish will become contaminated with paralytic shellfish toxins is high along the entire southern Bay of Fundy, including the New Brunswick coast southward of Saint John, Deer Island, Campobello, Grand Manan and that part of the coast of Nova Scotia which is on the Bay of Fundy. This is because *Gonyaulax* blooms in the Bay of Fundy are usually large scale events, covering the entire south-central area. The whole southern Bay of Fundy behaves largely as a unit in terms of the kinetics of shellfish toxicity, as demonstrated by shellfish toxicity records from 1944 until the present.

Locating a shellfish culture operation within Passamaquoddy Bay, especially toward the head of the Bay in the vicinity of St. Andrews, would seem to afford some degree of protection from exposure to *Gonyaulax*. Only occasionally do toxicity levels in natural stocks of soft-shell clams in this area rise above the safety threshold. However in the past two years there has been a rapid rise in toxicity levels during May and June sufficient to warrant closure to harvesting of shellfish.

By moving the farm into the fresher water of the St. Croix estuary the danger from *Gonyaulax* can be minimized, but the risk of bacterial contamination is increased.

The head of the Bay of Fundy (northeast from Saint John) presents little problem from *Gonyaulax*, but shellfish culture is made difficult by the heavy silt content.

Until the summer of 1986 it was thought that shellfish culture along the Atlantic coastline of Nova Scotia would be clear of the PSP problem, but during June and July there was shellfish toxicity in the Shelburne Harbour area of Nova Scotia. Dangerous levels of toxins were present in blue mussels for several weeks, and plankton samples confirmed the presence of *G. excavata* in the plankton community during this period. This is the first instance in which shellfish toxicity has been recorded along the southern stretch of the Nova Scotia coastline.

EFFECT ON SHELLFISH CULTIVATION

Considering the culturing aspect rather than the marketing aspect of potential shellfish culture operations in the Bay of Fundy, the annual blooms of *Gonyaulax* have a positive effect. *Gonyaulax* is a satisfactory food organism for filter-feeding molluscs, and the toxins they carry do not seem to affect the shellfish. The dinoflagellate's external cellulosic plates are easily removed so the remaining protoplast is digestible. During the summer period, particularly during the month or so when *Gonyaulax* is abundant in the plankton, the *Gonyaulax* population serves as a major food source for filter-feeding molluscs.

MARKETING PROBLEMS

The greatest impact of PSP on the potential for development of molluscan shellfish culture in the Bay of Fundy is marketing. Shellfish toxicity represents a significant marketing constraint for all species considered candidates for shellfish culture in the Bay of Fundy, with the exception of the sea scallop. One can be assured that the level of paralytic shellfish toxins in mussels or clams, and probably in quahaugs and oysters as well, cultured anywhere in the southern Bay of Fundy will at some time exceed the safety threshold, rendering them unmarketable. The contamination, and the marketing constraint, will probably last for several weeks to several months each year between May and September. However, there is presently an undefinable risk that in some years contamination above the quarantine level may last for a longer period.

In short, the success of mussel or clam farming in the Bay of Fundy will depend heavily upon whether the operations can make sufficient profit marketing their product during the 9 months from September to May. In some years their products may be safely marketed for a longer period, but there is no guarantee.

A similar situation probably exists for quahaugs and oysters in the Bay of Fundy, although less is known about the kinetics of accumulation and removal of paralytic shellfish toxins in these organisms.

SCALLOPS SAFER

The impact of PSP on the marketing of cultured molluscs is not as severe for scallops as for other filter-feeding molluscs. Although the sea scallop viscera, particularly the hepatopancreas (digestive gland), can become extremely toxic, the adductor muscle, which is the commonly marketed item in North America, does not accumulate dangerous levels of the toxins. Scallop adductor muscles, at least those from the sea scallop, can be safely marketed year-round. Thus from the point of view of PSP problems, scallops are the prime candidate for commercial shellfish culture in the Bay of Fundy.

In many countries scallops are eaten whole, that is, viscera as well as adductor muscle. For the natural scallop stocks in the Bay of Fundy this would not be possible because of paralytic shellfish toxins. Those grown in suspension culture, however, might eliminate the toxins in the same manner as mussels and clams, presenting the possibility that the remainder of the scallop (locally termed "rims and roes") might be marketable during some part of the year.

DEPURATION

No method has yet been developed for reliable and economic detoxification of paralytic shellfish toxins in wild or cultured molluscan shellfish. Natural depuration of toxins to safe levels generally requires several weeks to several months, depending primarily upon the shellfish species involved, how toxic they were to start with, and the water temperature. Mussels are able to cleanse themselves of the toxins fairly rapidly compared to other shellfish, sometimes within a few days.

Several years ago the use of ozonated seawater to detoxify paralytic shellfish toxins in shellfish appeared promising, but more rigorous experiments with soft shell-clams at different times of the year have since shown no indications of detoxification upon exposure to ozonated seawater.

Presently there are no proven options for minimizing uptake of toxins by shellfish and maximizing elimination of toxins, aside from locating facilities in *Gonyaulax*-free areas, which is virtually impossible in the southern Bay of Fundy except for locations well up in a river system.

INSPECTION

Shellfish cultured in the Bay of Fundy would require frequent inspection for paralytic shellfish toxins, especially during the summer. Frequent inspection would be critical for mussel culture enterprises because mussels can accumulate the poisons so rapidly. To avoid the danger of mussel poisoning, and because the local market for wild mussels has been so small, the federal government Inspection Branch has for years enforced a year-round closure on the harvesting of mussels from the Bay of Fundy. Any plans for shellfish culture within the Bay of Fundy would have to be developed in concert with the Inspection Branch to ensure that an appropriate inspection protocol is established to protect the consumer as well as the producer.

The costs associated with inspecting shellfish for paralytic shellfish toxins can be considerable. They include not only the costs of sampling and sample processing by trained technicians, but the costs and inconvenience of maintaining a colony of laboratory mice for bioassay tests. Regardless of who bears these costs, the shellfish grower or the government, the costs must be included in the total economic assessment of shellfish culture schemes.

Shellfish growers will need to take protective measures against losses of shellfish which may endanger the general public. At certain times of the year shellfish farmers may find themselves with tonnes of dangerously toxic shellfish, and they must take precautions to ensure the toxic shellfish are not stolen or removed by storms, ice, or other natural phenomena. In a severe PSP incident in the Phillipines in 1983, in which 21 people died and 278 became ill, many of the victims had eaten extremely toxic cultured mussels which were washed up on the shore after a typhoon destroyed the culturing rafts.

DSP

In recent years diarrhetic shellfish poisoning (DSP), as well as PSP, has caused increasing problems for shellfish resource utilization around the world. DSP is caused by several species of dinoflagellates within the genera *Dinophysis* and *Prorocentrum*. Their toxins accumulate in shellfish and cause severe, debilitating diarrhea in humans who have eaten the shellfish. There have as yet been no reports of DSP in Canada, but because of the serious economic losses to shellfish farmers in western Europe and Japan from DSP, prospective shellfish growers in the Bay of Fundy should be aware of the threat.

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