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Risk Evaluation Of Dredging And The Potential For Harmful Algal Bloom Initiation In Whangarei Harbour

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1. SUMMARY AND RECOMMENDATIONS

The seasonal restriction on dredging in Whangarei Harbour could be relaxed for the following reasons:

- The risk that dredging on the scale planned will increase the likelihood of toxic algal blooms through the re-suspension of resting cysts is small.
- Concern over the possibility of re-initiating an algal bloom like that which led to the neurotoxic shellfish poisoning outbreak in 1992-93 is unfounded. This is because the species that caused this event, has no known benthic resting cyst in its life cycle.
- Other potential effects from dredging, such as encouragement of macro-algae growth by nutrient enrichment or smothering of shellfish beds, are probably more likely undesirable consequences than generation of harmful micro-algae blooms. The magnitude of these effects depends on the scale of the activity. However, high summer is probably the least desirable time due to temperature stresses on shellfish populations and the opportunity for macro-algae (e.g. *Ulva*) to grow to nuisance proportions.
- There is no credible international evidence that dredging is a significant factor in the generation of nuisance micro-algae blooms, although degraded water quality from increased nutrient enrichment does promote their development and persistence.
- Cysts of the toxic dinoflagellate species that are most likely to be of concern (*Alexandrium* spp., *Gymnodinium catenatum*) are present in Whangarei Harbour. However, evidence from observations on blooms of *G. catenatum* elsewhere in New Zealand indicate these are usually initiated by cyst germination during mid winter-early spring.
- High numbers of cysts of a particular species would have to be present within the sediments for re-suspension from dredging to have the potential to initiate a bloom. Establishment of a high density cyst population would be preceded by a bloom that deposited these cysts. From historical phytoplankton monitoring data, there is no indication that toxic dinoflagellate blooms of cyst-forming species have occurred in the harbour in recent times.
- Examination of shellfish-biotoxin monitoring records (NZ Food Safety Authority), show that the incidence of shellfish toxins (excluding domoic acid in scallops) in Whangarei Harbour is very low.
- There is no reason to suppose that there is a higher risk of blooms developing in Whangarei Harbour than in any other similar environment in New Zealand where toxic dinoflagellate cysts are know to exist and dredging is routinely carried out (e.g. Manakau Harbour).
- The current shellfish-biotoxin and toxic phytoplankton monitoring programmes (industry and New Zealand Food Safety Authority (NZFSA) in Whangarei Harbour provide a level of surveillance that ensures toxic algal bloom events will not go undetected.
- A systematic survey would provide more certainty regarding assessment of the risk of toxic blooms arising from cyst beds in the harbour.

2. THE BRIEF

To provide advice on:

- The relationship between dredging activities and algal blooms with particular regard to water temperature and season.
- Whether extending the dredging period to 22 December from November will significantly increase the risk of algal bloom.
- Advice on guidelines and consent conditions as to when dredging should and should not take place.
- The general risk of Harmful Algal Blooms (HABs) in Northland's CMA.
- Whether the most relevant environmental performance indicators are being monitored and would improved monitoring quantify the risk of HABs.

3. BACKGROUND

An extensive toxic algal bloom affected the north-east coast of the North Island during the summer of 1992-1993 and caused food poisoning to a large number of people (>100) who ate shellfish contaminated with the toxins (MacKenzie *et al*. 1995, Jasperse, 1993). The effects of the bloom extended from the Firth of Thames/Coromandel area to at least as far north as Bream Bay and Whangarei Harbour. The shellfish poisoning was subsequently identified as being due to a class of toxins known as brevetoxins, that are produced by some species of planktonic dinoflagellates. The event was unique as it was the first time these toxins had been observed outside the USA. Cockles and clams collected from Snake Bank in Whangarei Harbour, and from the beaches of Bream Bay, had high levels of contamination and provided much of the material that was used to eventually chemically identify the toxins involved in the incident.

As a result of the bloom the Northland Regional Council imposed restrictions on dredging in Whangarei Harbour outside winter months. This was done in the belief that dredging at other times, especially during the summer "high risk period", might lead to the generation of new blooms by re-suspending the resting cysts of the micro-algae that caused the problem into the water column. Over recent years the cut off dates of these restrictions has crept forward into September, then October and now November. Consent currently allows dredging to take place between May and November.

This paper discusses the rationale for reviewing the restriction on the period during which dredging is permitted.

4. RESTING CYSTS AND TOXIC DINOFLAGELLATE ECOLOGY

Dinoflagellates are motile, microscopic, single cell organisms that are common in coastal and oceanic sea waters throughout the world. Many species are photosynthetic, they form an important part of the global phytoplankton community and are food for many marine animals. A few produce secondary metabolites that accumulate in filter feeding shellfish and can result in food poisoning if these are consumed by humans.

Table 1. A summary of the various groups of dinoflagellates responsible for the production of toxins and the presence of resting cysts in their life cycle

Dinoflagellate	Toxin type	Cyst type
Alexandrium spp.	Saxitoxin and analogues (Paralytic shellfish toxins), Spirolides	Smooth walled resting cysts
Gymnodinium catenatum	Saxitoxin and analogues (Paralytic shellfish toxins)	Micro-reticulate resting cyst
Protoceratium reticulatum *Gonyaulax* spp.	Yessotoxins	Spiny resting cysts
Karenia spp.	Breve-toxins (Neurotoxic shellfish toxin), Gymnodimine, Uncharacterised toxins	No known resting cysts
Dinophysis spp.	Okadaic acid and analogues (Diahrretic shellfish toxins), Pectenotoxins	No known resting cysts
Azadinium sp.	Azaspiracids	No known resting cysts
Ostreopsis spp.	Palytoxin and analogues	No known resting cysts

Many dinoflagellates species are still undescribed and the complete life cycle of only a few are known in detail. About 10% of dinoflagellates, including some toxic species, are known to produce dormant resting cysts that result from sexual conjugation (Table 1). These cysts have tough cell walls that enable the dinoflagellate to avoid extinction during unfavourable growth conditions in the water column and ensure the repopulation of the habitat when conditions become favourable again. Encystment is commonly believed to be induced by nutrient limitation but other factors (e.g. allelopathic interactions, temperature, irradiance, lunar cycles *etc*.) may also play important roles. Cysts of different species may have long (several months) or short (days) mandatory dormancy periods before they can germinate.

4.1. Conditions necessary for dinoflagellate cyst germination

The conditions necessary for dinoflagellate cyst germination may vary between species and genera from place to place. Germination is controlled by complex interactions between internal cellular processes, including an endogenous clock, and response to environmental factors such as temperature, light, salinity and oxygen availability.

Low temperatures (~4°C) inhibit cyst germination but the range of temperatures over which germination is possible is wide (e.g. 6-25°C), though the hatched cells may not survive at the highest temperatures. Rates of germination increase up to an optimum temperature (e.g. 10-12°C in *Scrippsiella trochoidea*), after which there is no further increase (Binder & Anderson, 1987). Temperature in itself is probably not a limiting factor in the temperate environment of Whangarei Harbour where cysts may be able to germinate at any time of year.

Some species require a distinct minimum light intensity and temperature for germination while others can germinate in the dark, although light is essential for the survival and subsequent cell division of the germlings. As well as light intensity, day-length may also influence the timing of germination.

Germination is inhibited by anoxic conditions although cysts can survive for many years in anoxic sediments.

In some species the release from the mandatory dormancy period set by its biological clock is enough to initiate germination, without any change in external conditions. The duration of dormancy periods is not affected by temperature.

The activities of burrowing benthic animals may influence cyst germination by bringing cysts from anoxic deeper layers up to the oxygenated sediment surface.

Re-suspension of cysts into the water column by natural events such as storms, upwelling and bottom currents may play important roles in bloom initiation in some regions, however studies have shown (e.g. Kremp 2001) that different species respond differently to turbulence and re-suspension. In some species germination is enhanced in other it is not.

The constraints that are imposed on cyst germination by anaerobosis and light limitation, once cyst are deposited in the sediments, probably means that relatively few cysts will eventually germinate naturally. It is the release of these constraints by re-suspension of cysts into the water column that is the root of the concern regarding the potential impact of dredging.

The few accounts in the harmful algae literature (e.g. Carrada *et al*. 1991; Hartwell, 1975), that specifically cite a relationship between dredging and the generation of micro-algae blooms as a result of cyst re-suspension, are speculative and unconvincing.

5. CONDITIONS LEADING TO THE 1993 TOXIC ALGAL BLOOM

The dinoflagellate responsible for the shellfish contamination in 1992-93 was not positively identified to species level at the time, although it is known that it belonged to the genus *Karenia* and was probably closely related to *K. mikimotoi* (Todd 2002). No *Karenia* species are known to have benthic resting cysts and the seed source that initiated the bloom probably originated in the plankton a long way offshore. *Karenia brevis*-brevetoxin blooms are a major and recurrent problem on the east coast of Florida. Despite intensive research over many years, no evidence has been found that these blooms originate from the germination of benthic resting cysts.

It is generally believed that the 1992-93 bloom was initiated and maintained by large-scale offshore oceanographic processes related to a negative phase in the southern oscillation index typical of El Niño conditions in the tropical Pacific (Rhodes *et al*. 1993). This resulted in the intrusion of offshore subtropical water onto the coast bringing with it an established phytoplankton community. Maintenance of a strongly stratified water column and the shoaling of nutrient enriched waters near-shore were also important factors.

Observations were made on the composition and distribution of the phytoplankton community within Bream Bay at the peak of the bloom on 11 January 1993, when shellfish on adjacent surf beaches and in Whangarei Harbour contained high levels of brevetoxins (MacKenzie 2008). At this time *Karenia* sp. formed a subdominant population within an abundant, diverse and highly stratified dinoflagellate community dominated by other non-toxic species. The salinity throughout the bay was high (35.1-35.2 psu) and uniform with depth. Salinities throughout much of Whangarei Harbour were likewise high and *Karenia* sp. was only found in low numbers in water with salinity below 34.8 psu. Temperature stratification resulted in a strong pycnocline between 10 and 20 meters across Bream Bay. The highest concentrations of dinoflagellates occurred within and just above the pycnocline and cells may have been actively transported shore-wards within it. Unusually high concentrations of nitrate, nitrite and phosphorus existed in waters below the pycnocline. Near-surface waters were depleted of nutrients with concentrations below the limits of detection. The shallow nutricline and high levels of inorganic nutrients in mid-ummer within Bream Bay suggest that the bloom in this region was being sustained by intrusion of deep nutrient enriched offshore waters.

Phytoplankton blooms occur all the time in coastal waters and are part of the natural dynamics. Occasionally particular species become dominant that produce biotoxins that may be harmful to other marine flora and fauna, or accumulate in filter feeders and are harmful to consumers. The influence of the east Auckland current and interaction of warm subtropical waters and cooler temperate waters over the Northland shelf may make this region more prone than most to the development of large-scale blooms of species favoured by highly stratified conditions. However, data from the toxic phytoplankton and shellfish-toxin monitoring programmes do not suggest that the Northland coastal marine area is more prone than any where else in New Zealand to these problems.

6. TOXIC *GYMNODINIUM CATENATUM* BLOOMS IN NEW ZEALAND

In 2002 a survey of marine species in Whangarei Harbour (Inglis *et al*. 2006) was carried out that included some sampling for dinoflagellate cysts at Port Whangarei and Marsden Point. The report lists the identification of the cysts of 3 common indigenous (non-toxic) dinoflagellate species and one toxic, cryptogenic species (*Gymnodinium catenatum*). The *G. catenatum* cysts were identified in samples collected at the Marsden Point wharf. This is the only record of *G. catenatum* cysts on the east coast of the North Island between North Cape and Cape Colville. However, no special significance can be attached to this as there has been little sampling in the region. In 2000-2001 *G. catenatum* cysts were documented to be widespread and abundant along the entire North Island west coast.

The assignment of *G. catenatum* as a cryptogenic species means, that although this species has previously been recorded in New Zealand, its identity as native or non-indigenous is ambiguous. The most recent evidence from cysts in radio-isotope dated sediment cores (Irwin *et al*. 2003) suggests that it is either truly indigenous or has been present in New Zealand since at least the early 20th century.

Gymnodinium catenatum was the cause of widespread contamination of shellfish with paralytic shellfish toxins along the west and south east coasts of the North Island between May 2000 and February 2001 (Mackenzie and Beauchamp, 2001). Although its impact on human health was minor, it had a major impact on the shellfish industry throughout the country. This was because of prohibitions being placed on the movement of juvenile shellfish (e.g. Kaitaia spat) from affected to non-affected areas, primarily due to the risk of transporting *G. catenatum* resting cysts.

The first documented *G. catenatum* bloom in 2000 was initiated during winter, offshore, in the Tasman Sea in the vicinity of the Kaipara Harbour. It then progressively colonised the west coast from 90 Mile Beach to Cook Strait over about 6 months. *G. catenatum* blooms re-occurred on the west and east coasts of the North Island in the vicinity of the Manakau and Kaipara Harbours and in Hawke Bay in 2002 and 2003. The blooms were initiated, presumably through the germination of resting cysts, in May to July and generally declined during spring and summer. Since 2005 *G. catenatum* has been sporadically observed in the plankton in various locations but overall it has now become rather rare. The reason why it became such a prominent component of the phytoplankton in 2000-2001 is unknown, as is the combination of environmental conditions (e.g. light, temperature, nutrients) that triggered bloom development.

The significance of these observations, with respect to the timing of dredging in Whangarei Harbour, is that mid-winter invariably appears to be the most favourable period for the initiation of *G. catenatum* blooms in New Zealand. Dredging has been proceeding during these periods in Whangarei Harbour for years with no apparent problem.

For large numbers of *G. catenatum* cysts to exist in Whangarei Harbour sediments a prior, naturally initiated, bloom would need to occur. In this case the re-suspension of cyst by dredging would be unlikely to make much difference over the natural rates of cyst germination that would be taking place.

7. TOXIC PHYTOPLANKTON AND SHELLFISH-BIOTOXIN MONITORING IN WHANGAREI HARBOUR

The 1992-93 bloom led to the establishment of nationwide toxic phytoplankton and shellfish-toxin monitoring programmes, designed to protect public health and the shellfish-growing industry. In a reduced form, these programmes continue to the present day.

As part of the New Zealand Food Safety Authority's public health protection programme, phytoplankton samples are collected every week from Marsden Point (Site P021). Until 2007 samples were also collected from McLeod's Bay. These samples are examined and potential toxic or noxious species identified and counted at the Cawthron Institute, Nelson. Reports on all the sites sampled around the country are issued weekly. Marsden Point is an excellent sampling site because it enables easy access to water that is representative of a wider area within Whangarei Harbour and Bream Bay. If toxic algal blooms were to occur in the area they should be detected at this location.

An examination of the Marsden Point and McLeod's Bay phytoplankton records (courtesy of New Zealand Food Safety Authority) back to 2001 show a low incidence of cyst-producing toxic dinoflagellates in the plankton. No blooms of these species have been observed over this period.

Biotoxins in cockles are also regularly monitored at sites on Mair and Snake Banks and oysters at the farm at Parau Bay and scallops within Whangarei Harbour during the harvesting season. A search of the existing shellfish biotoxin records has revealed no evidence of paralytic shellfish poison (PSP) contamination of cockles in the harbour. This would be the most likely indicator that significant numbers of cyst-producing toxic dinoflagellates exist and bloom here.

Domoic acid, which is produced by planktonic diatoms, is occasionally detected in Whangarei Harbour scallops. Domoic acid is commonly observed in scallops throughout New Zealand and its incidence has no relationship to harbour dredging.

The current shellfish-biotoxin and toxic phytoplankton monitoring programmes in Whangarei Harbour provide a sufficient level of surveillance that will ensure that harmful algal bloom events do not go undetected.

Apart from the limited NIWA Port Survey (Inglis *et al*. 2006) there has been no analysis of dinoflagellate cyst type and abundance in Whangarei Harbour. A systematic survey would provide more certainty regarding assessment of the risk of toxic blooms arising from cyst beds in the harbour.

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