MCCIP Marine Climate Change Impacts Partnership

Topic

Harmful algal blooms (HABs)

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Executive summary

While the relative contributions of climate and enhanced nutrients to HAB formation are still under debate there is now a general consensus that ocean climate forcing is the dominant factor.

HABs have increased in some areas of the north-east Atlantic over the past 50 years, as the seas around Great Britain and Ireland have become warmer, especially since the mid-1980s. I There is regional variability within this trend and some places, such as the east coast of Britain, have experienced reduced incidences of HABs.

Expected higher temperatures, which may lead to better growth conditions, and increased stability, leading to increased water clarity in the future, has the potential to favour the growth of some toxic and other HAB species in UK waters. However, for some HAB species such as *Dinophysis*, there is still a lack of knowledge on the controls of its life cycle.

The effects of storms (decreasing stability, lower light levels) and increasing nutrients due to greater runoff are less predictable and will most likely favour some species and be detrimental to others. Some of the UK regions that are likely to be more susceptible to hydroclimatic fluctuations such as the eastern

Irish Sea and estuaries such as the Fal are also thought to be vulnerable to elevated nutrient concentrations.

The geographic extent of **phytoplankton** species distribution has the potential to change as it has for other species, and the possibility of **alien species** is increased with the changing environment. There are still some uncertainties as to what governs the mechanisms that promote this range expansion.

Full review

Background

The majority of species causing HABs are flagellates. These organisms tend to grow and reproduce more rapidly with higher temperatures due to direct physiological effects and indirectly through increased stability of the water column. In some areas the latter may also be caused by lower salinities due to precipitation or river runoff and exceptionally calm conditions. A variety of different HAB genera are observed in UK waters which have a number of different harmful effects. Some genera produce shellfish toxins such as *Alexandrium (PSP)*, *Dinophysis (DSP)*, and *Pseudo-nitzschia (ASP)*. When these toxins accumulate in shellfish they can render them unfit for human consumption. There are extensive monitoring programs in place to test the shellfish flesh and ensure food safety, although at present they are only reactive.

Other species, such as *Karenia mikimotoi,* can form high density **ichtyotoxic blooms** which may result in mortalities in farmed fish. These high biomass blooms can also impact **benthic organisms** due to **anoxia** during bloom decay. Bloom decay of the **haptophyte** *Phaeocystis* can form unsightly foam on the water surface and along beaches. The life cycle of some species such as Alexandrium includes a cyst stage which can lay dormant for several years, until the appropriate conditions occur. The impacts of climate change on HABs, particularly in coastal areas where long term time series are scarce, are difficult to predict.

What is already happening

In some areas of the north-east Atlantic, based on results from the **Continuous Plankton Recorder** survey (1958-2002), reported blooms of selected HAB species are increasing, especially since the major hydroclimatic change (**regime shift**) that occurred in the mid 1980s (refer to the plankton section). The increase is not spatially homogenous and is primarily restricted to specific habitats affected by lower salinities, such as the Norwegian Trench, and much higher temperatures, such as the German Bight. A general decrease in blooms has been recorded along the eastern coast of Great Britain. Bloom events measured by the CPR survey also show strong similarities with other **phytoplankton** surveys. Some years stand out, such as 1988, and appear to be related to an increased incursion of oceanic water from the Atlantic.

What could happen in the future

The major environmental variables associated with climate change that will affect HABs are:

- Increase in temperature.
- Increase in the frequency of storms.
- An increase in amount of flooding, particularly during the summer months.
- Alterations in the coastline due to sea level rise.

It is at present difficult to assess the timescale that such changes will occur over as knowledge is imprecise as to the exact dependence of each species on any climatic variable. In addition, changes in the overall **zooplankton** and phytoplankton community structure in areas such as the North Sea may indicate a more complex impact of climate on harmful algal species in UK waters.

Increase in temperature (All time scales). Increases in temperature have already been observed to impact the structure of phytoplankton communities, with a change in the phenology (timing) of dinoflagellates observed in CPR records (Edwards & Richardson 2004).

Temperature increases in coastal waters have the potential to increase the range in which HAB species not currently detected in UK waters could survive. Examples would be selected species, responsible for Paralytic Shellfish Poisoning such as *Gymnodinium catenatum, Alexandrium catenella,* ichtyotoxin producing species e.g. *Heterosigma* and also the **epiphytic** and sand-dwelling toxin producing species such as *Ostreopsis, Coolia* whose harmful effects are at present restricted to the Mediterranean in the European context. However, difficulties in predicting rates of range expansion and long distance dispersal events make it difficult to anticipate when, or if, these species will appear in UK waters. In addition, increases in temperature also give rise to greater stability and potentially increased water clarity, which can favour dinoflagellates over other plankton.

Increase in storms (Medium and Long). Many HAB species are flagellates, whether dinoflagellates or from a range of microflagellate taxa. The ecology of these organisms favours stratified environments. This ecological niche will be modified and as yet the consequences cannot be predicted with certainty. On the one hand the temporary breakdown in stratification due to the effect of mixing from storms may dissipate a bloom, while other conditions might be modified which could promote a bloom of a different species. For example, the Fastnet storm of 1979 received notoriety due to the mortalities and damage caused during the Fastnet Yacht Race. What is not widely known is that the storm was immediately followed by a very extensive bloom of *Karenia mikimotoi* (referred to then as *Gyrodinium aureolum*) are of extremely high cell densities. Blooms along this coast have occured on several occasions in Irish waters but of varying intensities (Silke et al., 2005). Conversely, increases in storms and rainfall may also increase the duration of cloud cover which may reduce the quantity of light available to phytoplankton (Dale *et al.,* 2006).

Coastal Flooding (All time scales). An increase in summer rainfall will increase the salinity stratification element of inshore waters and well as introduce nutrients into the system via 'run off'. Locally salinity will be reduced, and this has the potential to impact the HAB species which could flourish in such conditions. These may include certain *Prorocentrum* spp. as well as some harmful microflagellates which often bloom in a salinity stratified environment during warm periods, such as *Heterosigma and Chrysochromulina.* It is possible that these may be specific localised events (Smayda, 2006). While recent predictions indicate a general decrease in summer rainfall this is regionally patchy and previous predictions indicated an increase.

Alterations in coastline (Long term due to sea level rise). Sea level rise will result in localised increased coastline length and the regional probability of more retention zones which favour the growth of HABs.

Natural variability vs human induced climate change

Long term time series data are essential in order to assess the variation in the intensity and duration of HABs and allow any relationship with changes in climate to be made. Time series of relevant length (> 30 years) are relatively scarce in UK waters, particularly in coastal zones. Data from the open oceans in the NE Atlantic and North Sea has shown decadal variation in the distribution of HABs and frequency of occurrence and there is evidence for decadal variations in climate (Edwards *et al.* 2006). High frequency coastal phytoplankton monitoring over the last 10 years has shown considerable inter and intra-annual variability in the occurrence of harmful algal species around the UK coast.

It is the presence of natural variability that makes predictions for the future possible. For those HAB species that respond to climate forcing predictions can be made from comparing events in past years to assessing how often the climatic forcing will be similar to those events in the future. There have been decadal changes in plankton composition with a significant regime shift in the mid 80s.

Relative importance of climate change to other human pressures

There is no doubt that the construction of harbours and marinas has increased the biogeography and bloom occurrences of HAB species which thrive in retention zones in specific locations. This is of particular note around the northern perimeter of the Mediterranean. The species that take advantage of these modifications are typically those which have a dormant sediment stage in the life cycle, notably *Alexandrium.* Construction of harbours and marinas, which may increase in certain areas around the coasts of Britain and Ireland as a response to warmer conditions, or else the construction of tide barriers or other coastal defences against sea level rise, will alter the local hydrodynamics and, potentially increase the number of coastal retention areas. Even at the smallest scale of a marina, this will increase the number of suitable habitats of harmful species.

Increased levels of nutrients and changing nutrient ratios in coastal waters may also have an effect; some of the UK regions that are likely to be more susceptible to hydroclimatic fluctuations such as the eastern Irish Sea and estuaries such as the Fal are also thought to be vulnerable to elevated nutrient concentrations. In these areas some HAB species may be reinforced or accentuated by **anthropogenic** nutrient input. While the relative contributions of climate and enhanced nutrients to HAB formation are still under debate there is now a general consensus that hydroclimatic forcing is the dominant factor. There is evidence that, for a specific species (*Chryso chromulina*) which prefers brackish conditions, the N:P ratio is a factor in determing the toxicity (Dahl *et al.,* 2005). This species is not presently observed in the UK in large numbers.

Current debate

In relation to mariculture the relative impact of some toxic HAB species *e.g. Dinophysis,* is relative to the quantity of other food sources available to the shellfish (Dahl *et al.,* 2001). In contrast, some species such as *Alexandrium tamarense* (North American strain) can have a negative impact on the farmed mussel industry even when present in low cell densities. Thus the impact of individual HAB species should also be considered in the wider context of change to the entire plankton assemblage. In this instance broader scale changes due to acidification and thermal stress become important (Portner & Knust, 2007)

Regional variations

Considerable regional diversity exists in the HAB species that occur around the UK coast with some species, such as *Alexandrium tamarense* (North American strain), confined to more northerly latitudes while the non toxic *A. tamarense* (Western European strain) is found in more southerly regions of the UK (Higman et al 2001). This indicates that climatic change impacts on HABs in UK waters may have a regional effect. For some HAB species, such as *Karenia mikimotoi*, transport around the coast may be important and conditions in the more offshore areas must also be accounted for (Davidson *et al.,* 2007). The latitudinal range within the UK should also be considered as differences in daylength between the southern and more northerly UK coasts and islands could also play a role. Studies on toxic *Pseudo-nitzschia seriata* cells isolated from Scottish waters showed enhanced growth rate, cell yield and total toxin production when exposed to longer daylength (Fehling *et al* 2005). There has been a shift in many zooplankton and fish species of 10° latitude over the past 30 years. Data from the CPR also shows changes to the composition of the zooplankton community in UK waters. This suggests that a variety of changes to the total plankton community can be anticipated which should also be considered when examining the impact of climate change on HABs.

Confidence assessments

'What is already happening' - Medium

A variety of different HAB species exist which have the potential to impact UK waters. Currently there are very different levels of knowledge about the biological controls of each one. There is a great deal of evidence available on the occurrence of HABs, and general agreement that there has been an increase in the reported number of HABs and that many of these are primarily linked to climatic forcing. Thus this leads to a **medium** on both axes (amount of information and agreement) as to the level of confidence in what has already happened (the same as in last years report card)

'What could happen in the future' - Medium

The paucity of long term time series data, coupled with the fact that most observations occur when blooms are already established, means there is little information on the processes that lead to their development and, depending on the species, a sparsity of knowledge on life cycle, cell division and environmental cues. There is therefore a lack of consensus on what the climate change effects are likely to be. Modelling is, in consequence, at an early stage of development although there is now a general consensus that hydroclimatic forcing is the dominant factor behind bloom variability.

The clear linkage with temperature related effects of the dominant group causing blooms means that the level of confidence that HABs may increase with climate change is high. However, because each species is sublty different, there is little consensus on which climate change factors are most important and there is low agreement on the importance of other affects such as nutrient supply.

Thus a moderate for evidence and moderate (it is climate but which elements) for agreement becomes a **medium** level of confidence overall.

Knowledge gaps

Understanding the life cycle of the principal species so that predictions can be made as to the likely changes due to climate change.

Understanding the rate of genetic adaptation to climate change.

Understanding the mechanisms of dispersion and range expansion of HAB species into UK waters.

Commercial impacts

At present HABs are major economic problems for shell fisheries in Northern Europe. These species exist in UK waters and can impact the aquaculture industry; at present because of the relatively small size of the UK mariculture industry (compared to Spain and France) economic impacts are restricted to the regional areas in which these mariculture industries are established. Predictions are for the industry to increase and thus any potential increase in shellfish toxin producing HAB species will affect the sustainability of these industries. The possible increase in bloom events such as *Karenia mikimotoi* or any other phytoplankton species, that can result in fish kills may have implications for the Irish and Scottish finfish aquaculture industries, which have been impacted by these events in the past.

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