ICES WKHABAL REPORT 2010

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Report of the Workshop on harmful phytoplankton that could potentially be transported or introduced by ballast water (WKHABAL)

14 - 15 October 2010

ICES Headquarters, Copenhagen, Denmark

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International Council for the Exploration of the Sea
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Executive summary

The ICES Workshop on harmful phytoplankton that could potentially be transported or introduced by ballast water (WKHABAL) met in Copenhagen, Denmark from 14-15th October, 2010 and was attended by 11 participants from Denmark, Ireland, Sweden, the United Kingdom and the United States of America. The purpose of the meeting was to identify phytoplankton that could be transported via shipping vectors so that potential future invasive species could be identified and the risk managed.

The group produced two lists of phytoplankton, one marine and one freshwater based on the IOC –UNESCO Taxonomic Reference List of Harmful Micro Algae and on the Great Lakes Invasive Species List respectively. The marine list focussed on known toxic species and also included some nuisance (but non toxic) species, the freshwater list was focussed on species known to have been transported by shipping but that were not necessarily problem species in terms of toxicity. The difference in the focus of the lists was owing to the availability of information. These lists were then expanded to include information regarding the characteristics of the species that may make them more likely to survive a long journey in a dark ballast tank. This included characteristics such as cyst forming ability and whether the species was phototrophic or heterotrophic. Where this information is known it could help identify which species were more likely to survive transport in ballast tanks.

In addition to the lists the group also prepared background information that is contained in the body of the report to support the information in the table. This included a case study of a toxic marine dinoflagellate that may have been introduced by ballast water and more detailed background to the freshwater species list.

The group acknowledged that there is a lack of information for many species and that this limits the amount of detail that can be provided for some species. However, these lists are a good starting point and can be updated and adapted as more information and feedback from users is incorporated.

1 Opening of the meeting

The meeting was held from 14-15th October, 2010 at ICES Headquarters in Copenhagen and was attended by 11 participants from Denmark, Ireland, Sweden, the United Kingdom and the United States of America (Annex 1). Diane Lindemann and Claus Hagebro (ICES) gave an overview of the meeting arrangements at ICES. The meeting was co-chaired by Joe Silke (Ireland) and Tracy McCollin (United Kingdom) who opened the meeting and welcomed all the participants. Each of the participants introduced themselves and gave a brief background to their work.

Joe Silke gave an outline of the request from the Intergovernmental Oceanographic Commission (IOC) Intergovernmental Panel on Harmful Algal Blooms (IPHAB) (see Annex 4). This request had been sent to both the Working Group on Harmful Algal Bloom Dynamics (WGHABD Chair: Joe Silke) and the Working Group on Ballast and Other Ship Vectors (WGBOSV Chair: Tracy McCollin) and was discussed by each of these groups during their meetings in early 2010. Both groups agreed there was a need to provide the information requested by the IOC IPHAB and a decision was taken to hold the Workshop on harmful phytoplankton that could potentially be transported or introduced by ballast water (WKHABAL). The main Terms of Reference for this group were to (Annex 3):

a) Identify species of phytoplankton, especially HAB species (and their characteristics) which are more likely to be successful as invasive species, and have significant potential ecological or economic impact, is possible;

b) Determine if there are particular characteristics of coastal waters which favour the establishment of invasive phytoplankton.

Eileen Bresnan (United Kingdom) was appointed as rapporteur.

2 Adoption of the agenda

Joe Silke reviewed the agenda (Annex 2) and outlined the plan of work for the meeting. The agenda for the first day comprised of a series of short presentations by members of the group regarding ongoing work and research relevant to the meeting. This was followed by a detailed discussion of how each of the Terms of Reference should be dealt with and starting to draft the response to each. The agenda for the second day involved the group drafting tables and text for the report in order that a draft version was available by the end of the meeting.

The draft agenda was reviewed and adopted with some minor changes on the first day regarding which presentations were to be given by members of the group (Annex 3).

3 Presentations

Members of the group gave some brief presentations to outline work that was relevant to the workshop and to set the scene for the Terms of Reference.

3.1 Overview of the work of WGBOSV and WGITMO.

Tracy McCollin

The Working Group on Introductions and Transfers of Marine Organisms (WGITMO) was set up in 1980 and was initially concerned with the transfer of organisms for aquaculture and developing codes of practice to prevent the unintentional introduction of non target organisms along with the target species. The remit of the group gradually expanded to include the introduction and transfer of non native species more generally and the issue of ballast water and other ship vectors became an increasingly important issue. It was therefore decided that this issue would be better dealt with separately and a Study Group on Ballast and Other Ship Vectors was established in 1996 and this group gained Working Group status in 2004 (WGBOSV).

The WGTIMO has developed an ICES Code of Practice on the Introductions and Transfers of Marine Organisms and has also produced Alien Species Alert Reports on *Crassostrea gigas, Rapana venosa* and *Undaria pinnitafida,* reports of vectors for non native species and the intentional introduction of the Red King crab in the Barents Sea. Another output from the group is a series of reports that summarise the records of non native species that have been submitted to the Working Group and collate the information to provide and update of the status of introductions in the North Atlantic and adjacent waters. The recording of new species is an ongoing agenda item for the group and it is intended that these data be entered into a dedicated database at ICES.

The WGBOSV has a different remit to WGITMO in that the work of the group is very closely related to the development of the Ballast Water Management Convention and this is reflected in the fact that ICES, the Intergovernmental Oceanographic Commission (IOC) and the International Maritime Organization (IMO) are the umbrella organizations for the group. The WGBOSV responds to specific requests for information related to the development of the Ballast Water Management Convention (BWMC) and the associated guidelines and has submitted papers *via* ICES for discussion at IMO e.g. the paper submitted by ICES in relation to the D-2 standard was fundamental to the development of the standard contained within the BWMC. WGBOSV continues to work closely with the WGITMO and the groups continue to meet "back to back" and to have a joint meeting to discuss matters that are relevant to both groups.

3.2 Overview of the Ballast Water Management Convention

Tracy McCollin

The Ballast Water Management Convention (BWMC) was adopted in 2004 but is not yet ratified. The convention will enter into force one year after it has been ratified by 30 States representing 35% of gross tonnage of world's merchant shipping and to date (October 2010) it has been ratified by 27 States representing 25.32% of tonnage. The BWMC contains some sections that would be able to use the list that is to be produced by WKHABAL. For example, exemptions from managing ballast water can be granted under Regulation A-4 if a vessel is always travelling between specified ports but the exemptions would have to be based on a risk assessment as outlined in Guidelines G7. Such a risk assessment would require knowledge of any species that might be likely to cause problems. Regulation C-2 outlines when special requirements for ballast water management might be needed and a harmful algal bloom would be one of the occurrences that might require such an arrangement. Guidelines G7 on Risk Assessment, G13 on Additional Measures and G14 on Ballast Water Exchange Areas would also require information regarding which species might be likely to cause problems if transported by ballast water. The outcome of the WKHABAL is therefore likely to contribute to several aspects of the BWMC.

3.3 Overview of the work of WGHABD

Joe Silke

The Working Group on Harmful Algal Bloom Dynamics (WGHABD) was established in 1984 and has wide participation from all over the ICES area. It meets on an annual basis and covers a wide range of HAB topics and provides advice to ICES through the expert reports. The group has also regularly engaged with other expert groups and initiatives including the Strategic Initiative on Climate Change (SICC) and this present workshop on Harmful Phytoplankton that could be transported or introduced by Ballast Water (WKHABAL). It covers many diverse topics in the area of HAB dynamics including the following which were addressed at the 2010 working group meeting:

- Models of cysts in the Gulf of Maine to track blooms of *Alexandrium* sp.
- New projects such as the FP7 funded ASIMUTH
- Bloom dynamics of *Dinophysis acuta* in Western Iberia
- Information systems for aquatic microalgae and heterotrophic flagellates in Nordic Countries
- *Dinophysis* spp. bloom events in Scottish waters
- Influence of salinity, temperature and nutrients on the yessotoxin formation of different strains of *Protoceratium reticulatum*
- Microarrays for the detection of Toxic Algae (MIDTAL)
- Changes in the phytoplankton community in the North East of Scotland: observations since 1997
- Detailed study of the dinoflagellate genus *Alexandrium* (Halim) in Scottish waters demonstrated diversity and toxin production

An important task of WGHABD has been to collect up-to-date information about HAB occurrences in the ICES area. This information maintained as a HAB database by the IOC Communication Center on HAB in Vigo (HAE-DAT). This information is summarized as decadal maps at ICES and IFREMER. In the area of Ballast Water, the group have an important role in documenting on an annual basis the main harmful and toxic events that have occurred in the member countries, thus providing information which may be important in setting baselines.

3.4 Summary of activities in Sweden

Bengt Karlson

There is great concern regarding invasive marine species in Sweden. The cnidarians (comb jellyfish) *Mnemiopsis leidyii* and *Mertensia ovum* have recently been introduced to the Baltic Sea and the Skagerrak-Kattegat area. Research on their distribution and ecology are ongoing.

Other examples include the pacific oyster *Crassostera gigas* and the brown sea weed *Sargassum muticum*. A list of introduces phytoplankton species that are likely to have been introduced is found at www.frammandearter.se. Additons to the listed phytoplankton include the diatoms *Chaetoceros convolutus*, *Pseudosolenia calcar-avis* and the dinoflagellate *Prorocentrum redfeldii*. The flagellate *Pseudo-chattonella farcimen* is likely to have been introduced to the Skagerrak_Kattegat area. This fish killer is now established in the Kattegat and is also observed in the southern Baltic Sea. A study using 3D-physical modelling aiming to investigate the feasibility of establishing Ballast Water Exchange Areas in Baltic Proper showed that this is not likely to be feasible

3.5 Overview of work in the Great Lakes

Euan Reavie

A brief seminar was presented on the Great Ships Initiative (www.greatshipsinitiative.org) and the strategies that are applied to test whether candidate treatment systems are able to eliminate microorganisms during ballasting simulations. Reavie's focus is on the "10-50 µm" size group of organisms as defined by IMO protocols, primarily composed of phytoplankton, some benthic algae and protozoans. The bulk of freshwater phytoplankton biomass tends to contain cells that fall below the 10µm criterion, so GSI testing includes assessments of these organisms that fall below the IMO range. GSI phytoplankton assessments employ sample staining and microscopic observation that incorporates fluorescent indicators of viability.

3.6 Effects of dredging on phytoplankton cyst redistribution

Lyndsay Brown, Eileen Bresnan and Barry O'Neil

Dredging the sea bed can impact the benthic communities in the marine environment. Demersal fishing gears which are used to keep the mouth of fishing nets open are one form of dredge used in Scottish waters. To date little work has been performed to examine how dredging influences the re- distribution of sediment or phytoplankton resting cysts present. To investigate this impact, dredging using a variety of different gear types was carried out at three different sites along the Moray Firth on the Scottish north east coast. The sediment plume from the dredge was quantified and examined for the presence of phytoplankton resting stages. Results showed the amount of sediment disturbed per unit dredged area varied with gear type, with more sediment resuspended using heavier door type gears than by light chain type gears. A variety of dinoflagellate cysts and diatom resting stages were identified in the sediment plumes including *Protoperidinium, Gonyaulax, Scrippsiella, Alexandrium, Protoceratium*, unidentified round brown cysts and diatom resting stages. At all sites the highest densities of resuspended cysts were found in the sediment plumes generated using the gear with small discs. This gear type did not dislodge the highest amount of sediment per unit swept area but disruption was focused on the surface layers where more phytoplankton resting stages may be present. This study suggests that the impacts from dredging on the resuspension of dinoflagellate cysts varies with the type of fishing gear used. Dredging activity in areas where ballast water or other vectors can introduce phytoplankton resting stages should be considered as an influence which can promote their resuspension from the sediment.

4 Terms of Reference

The group then moved on to discussing the Terms of Reference (Annex 3) in more detail. Each Term of Reference was dealt with separately with input by correspondence from Dan Minchin (Ireland) included in the discussion.

4.1 Term of Reference 1

To identify species of phytoplankton, especially HAB species (and their characteristics) that are more likely to be successful as invasive species, and have significant potential ecological impact.

The unintentional introduction of non-indigenous phytoplankton to new areas may result in populations of species being established outside their native ranges. Many of these species that may be transferred also have various deleterious effects on native species, the receiving habitats and their economies.

In considering this term of reference the group discussed various lists and databases of phytoplankton that could potentially be used as a starting point to address their suitability as a reference list of species that could have the potential to transfer via ballast water.

The IOC –UNESCO Taxonomic Reference List of Harmful Micro Algae (Moestrup et al. 2010) was selected as the most appropriate list to use as a starting point in generating a list of potential transferees via ballast. It was noted by the group that there are numerous other phytoplankton species that may not appear on this list that can have mechanical or physico-chemical impacts based on characteristics including high biomass or oxygen depletion. In some cases the more important species that have other (ie. non-toxic) deleterious impacts were added to the list to address this. It was decided that freshwater species should be dealt with separately and, as a starting point, the Great Lakes Invasive Species List (http://www.glerl.noaa.gov/res/Programs/ais/) was used to draw up a list of those freshwater species that have been transported by ballast water. The freshwater species are not necessarily toxic and may only cause harm in some high cell density situations but the group agreed that it was useful to consider freshwater species as well as marine species.

The marine species master list listed the correct name according to the international botanical code of nomenclature, followed by author(s) and year it was given its present name (Annex 5). This list was broken into three groups; the dinoflagellates, the diatoms and others. Each of these groups was considered and appropriate characteristics that are relevant to the transfer of these via ballast were listed. The characteristics were then considered for each species and a spreadsheet was developed to form a risk matrix. Comments received from Dan Minchin (Ireland) prior to the meeting were distributed to the group and informed this discussion.

The characteristics of the species that were addressed were:

- Phototrophic / Heterotrophic
  - If the species requires light or if it is one that obtains its nutrition from predation may have a bearing on its viability in dark ballast tanks.
- Resting Stage Production
  - Many species produce resting stages that can remain in sediments for long periods of time. This is relevant in both prolonging its viability in ballast tanks, and also if these resting stages are delivered into receiving waters.
- Salinity preference
  - The salinity range and preference of individual species is relevant to the viability on discharge.
- Temperature Range

  - Many species are very flexible in their range of temperatures that they will tolerate, others have narrow ranges and will not survive outside these.
- Benthic / Planktonic
  - The habitat of vegetative stages is relevant when it comes to taking on ballast and also the discharge.
- Previous ballast records
  - Whether there have been previous records of the species in ballast water.
- Known Impacts
  - Direct or indirect impacts associated with the species.
- Previous Invasion
  - If the species (or similar species) has been known to be invasive.
- Ease of Identification
  - Certain species are readily identifiable by light microscopy, while others require more complex methods including specific staining, electron microscopy and molecular techniques.
- Only known to cause problem at high cell concentrations
  - Some species require dense blooms before they cause problems.

4.2 Term of Reference 2

Identify particular characteristics of coastal waters which favour the establishment of invasive phytoplankters.

It is important to consider physical and ecological characteristics of receiving waters to estimate the potential impact of invasive phytoplankton. The group identified key elements that are relevant to this term of reference. The coastal water that receives large quantities of ballast originating from geographically distant areas, is only susceptible to the invasion of non-indigenous species if that water has biological and physical compatibility with the originating water. Conditions upon discharge must be suitable for survival, and the organism must then find sufficient food and resources, suitable habitat, and in some cases, other individuals with which it can reproduce before a population can become established (Gollasch 1996). The workshop discussed these conditions and came up with the following list of coastal water requirements:

Enclosed Areas vs Open Water

Enclosed areas are generally considered more susceptible to invasions of non-indigenous species. The factors specifically facilitating establishment of newcomers include among others:

  - Retention time
  - Sedimentation rate and resuspension
  - Stratification
  - Nutrient enrichment

In enclosed waters propagules will be retained for longer periods of time and thus will have better opportunity of reproducing and forming dense populations. Enclosed areas also often have high sedimentation rates, meaning that resting stages can survive for extended periods. High sedimentation rates also occur in estuaries. Whether resting stages in the sediment will successfully establish viable populations will depend on the risk of resuspension.

Many HABs develop in situations with elevated nutrient availability. This can occur seasonally following natural geobiochemical cycling patterns, but also be based on enrichment from terrestrial sources. Seasonal stratification of coastal waters influences nutrient availability. Natural undisturbed ecosystems will deplete nutrients in surface waters following seasonal phytoplankton blooms, but enrichment through terrestrial runoff (and/or atmospheric deposition) may make nutrients available during longer periods, thus increasing probability of successful establishment of introduced photoautotropic species. Stability of stratification will depend on latitude, precipitation, riverine outflow, etc.

Examples of enclosed areas with several invasive species:

- Duluth Superior Harbour
- Baltic
- San Francisco Bay

Stability of receiving ecosystem

Ecosystem effects appear to be scale-dependent. Natural, undisturbed ecosystems are generally thought to be less susceptible to impacts from introduced species (Elton, 1958; Stachowicz & Byrnes, 2006). Ecosystems that are stressed, either from natural variations in environmental factors, e.g. changing salinities in a tidal estuary, or from various human impacts, e.g. fisheries or agricultural runoff, are considered more susceptible to invasions (Occhipinti-Ambrogi & Savini, 2003; Zaiko et al., 2007). This is because undisturbed ecosystems contain good competitors (ecological specialists) and few or no unoccupied niches whereas disturbed ecosystems are comprised of species that are struggling against physically and/or chemically adverse conditions (Jewett et al., 2005). It is also assumed that species that are capable of surviving in ballast-tanks are those that are adapted to survive in adverse conditions. In undisturbed ecosystems introduced species may become established, but probably will not be able to outcompete native species and/or cause major disturbances of ecosystem function. Of course, if an introduced species has harmful effects even at low population densities, it may still be problematic.

A special situation is found in the Baltic Sea, which is a rather young ecosystem with generally low salinity, more or less permanent vertical stratification, and therefore low biodiversity. This means that presumably many ecological niches are unoccupied and thus available for introduced species (Paavola et al., 2005).

Phytoplankton species are grazed by zooplankton and benthic suspension feeders, and in undisturbed ecosystems timing of occurrence of predators is correlated with phytoplankton blooms. Introduced species may disturb this pattern and thus affect the entire food web structure and function. Again, this is more likely to occur in disturbed areas and in areas that have previously been invaded by non-indigenous zooplankton grazers and/or benthic suspension feeders.

Other environmental factors

It should also be considered that coastal waters may possess chemical and/or biological features that are conducive to the establishment of specific new HAB species. Areas that have not been known to harbour bloom-forming species may contain particular nutrients that are favourable to specific HAB species. Also, combination of several factors, e.g. turbulence, increased temperature, lack of grazers, may be particularly favourable to HAB species introduced through ballast water.

Examples of species specific environmental conditions

- *Pseudo-nitzschia australis* extension in Europe
- *Gymnodinium catenatum* limits (see case study in section 4.3)

Propagule Pressure

Areas of high shipping intensity, i.e. with many ports or designated ballast water exchange areas, receive a high number of viable propagules and thus will be more susceptible to successful establishment of invasive species. Probability of successful establishment will be higher if the discharged ballast water originates in waters of similar temperature/salinity conditions.

In general the risk of introduction of invasive species into a specific coastal area is dependent upon the type of vessel and ballast water management system. The risk of introducing new HAB species from ballast water of ships operating exclusively within one biogeographical region will be minimal. Also, NOBOB (No ballast on board) vessels will constitute minimal risk.

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4.3 Case study of a toxic marine dinoflagellate

As an example of the difficulty of ascertaining whether a species has been introduced *via* ballast water a case study of *Gymnodinium catenatum* is given below.

The toxic dinoflagellate *Gymnodinium catenatum* appears to have been imported to Tasmania, possibly via ballast water. In marine systems this is the most well studied case of introduction of a harmful phytoplankton species by ballast water. The studies on this possibly invasive species have included multiple markers and indicators of introduction and of the affinity of Australian strains to foreign strains. The factors studied include 1) Comparisons of strains with regard to toxin profile, iso-enzyme signature and DNA sequences, 2) Mating studies with Australian strains and foreign strains, 3) Finding viable cysts in ballast water tanks, 4) Documenting the extent of the transport on the route, 5) Studying sediment cores to determine the date of appearance in Tasmania of the resistant cysts of *Gymnodinium catenatum*, 6) Documenting the first registered toxic events in Tasmania. So far there is still not complete agreement about the origin of the Tasmanian *Gymnodinium catenatum,* but there is some evidence that it was introduced, possibly from East Asia (see 1 and references therein)

It is very difficult to unequivocally prove that a phytoplankton species has been introduced, particularly in the absence of historical records. Even in the presence of historical records it may be difficult to prove because of the possibility of "hidden" flora (species present in very low numbers) that may proliferate if conditions change. If it has been shown that a species is likely to have been introduced, it is difficult to prove that it happened via ballast water as other vectors could be involved. Finally, it may be difficult, as in the example of *Gymnodinium catenatum*, to show the origin of the introduced species.

Other examples of phytoplankton species that have been suggested to possibly be introduced via ballast water are:

Coscinodiscus wailesii to the southern North Sea (Edwards et al 2001.; Eno et al. 1997)

Alexandrium tamarensis complex in Australia (Bolch and de Salas, 2007)

Alexandrium catanella in France (Lilly et al., 2002)

Prorocentrum minimum (Helcom, see website address below)

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4.4 Freshwater perspective of the "species list" (by Euan Reavie)

Annex 6 contains a list of known invaders (National Oceanic and Atmospheric Administration, 2008, http://www.glerl.noaa.gov/res/Programs/ais/) in the Great Lakes that are likely to be relevant as 10-50 μm propagules in ballast tanks. Most of these are phytoplankton; also included are benthic algae, amoebae and a microsporidian. Most of these taxa are believed to have been introduced via ballast water, and most are not considered to create problems such as toxic blooms, aesthetic issues, etc. The "concern for ballast" column was added to note whether a taxon should be a concern as a future ballast-mediated invader. A response of "yes" or "maybe" is intended to reflect concern about that taxon or similar entity. For instance, *Cylindrospermopsis raciborskii* is known to produce toxins when in high abundance. Inclusion of this taxon as a concern in ballast water implies that it, and a large suite of similar cyanobacterial entities (e.g., *Aphanizomenon*, *Microcystis*), may be problematic invaders because they are known to produce detectable toxins under bloom conditions.

Several of the non-native phytoplankton in the Great Lakes are diatoms, many of which were confirmed as invaders using paleoecological records (e.g., Edlund et al. 2000). Although these taxa are generally not considered to cause problems, their probable vector for introduction is ballast water exchange. It also appears that the establishment of many of these taxa has been facilitated by high propagule pressure from repeated introductions. For instance *Thalassiosira baltica* is considered a brackish taxon, but has likely adapted to freshwater conditions in the Great Lakes due to periodic introductions of phenotypic varieties of the taxon with euryhalinity tolerance.

The benthic macroalgae in this list are not phytoplankton, but there is high likelihood that they have been introduced due to transport of phytoplanktonic zoospores (as speculated for marine systems; e.g., Forrest et al. 2000) or vegetative fragments that could have been suspended in the water column (e.g., Santelices, 1990).

The introduction of non-native arcellaceans (testate amoebae) in Lake Ontario may have been facilitated by the transport of the resilient resting cysts that are formed by these taxa (e.g., Hülsmann & Galil 2001).

Problematic taxa in the Great Lakes: Should they count as invaders of concern?

In addition to considering whether a taxon has potential to invade (i.e., those listed in Annex 6), there are many freshwater taxa that create significant problems, but may never have been confirmed (or suspected) as ever being introduced via shipping activities. The following are additional considerations for microplankton groups of potential concern in ballast water.

Blue-green algae. Several species of cyanobacteria can form massive blooms, often accompanied by severe aesthetic and/or toxicity issues (e.g., western Lake Erie; Vanderploeg et al. 2001). There is little evidence that ballast water has been a significant vector for the establishment of non-native cyanobacteria. It may be that these species are cosmopolitan, but given that they are known to cause problems, taxa like them may be considered as candidates for the list of species of concern. It may be that persistent propagule pressure from ballast water releases can favour the establishment of these taxa, as has been postulated for marine and estuarine algae (Ruiz et al. 2000).

Benthic diatoms. Although not considered to be a ballast-mediated taxon, the diatom *Didymosphenia geminata* ("rock snot") has been introduced worldwide with substantial consequences. Several benthic diatom taxa are known to occur in ballast water tanks, particularly those that carry sediments that may have been suspended during ballasting operations in nearshore areas, so it is reasonable to suggest that similar benthic taxa could be introduced during ballast discharge.

Cyst-forming taxa (e.g., dinoflagellates and amoebae). As for the marine system, resting stages are a particular concern because they can be carried in the sediments that accumulate in ballast tanks. However, note that none of the taxa in Annex 6 are dinoflagellates, in contrast to the taxa that are considered to be problems in marine and brackish-estuarine systems. Clearly the considerations that will dictate problematic species in ballast water will vary between freshwater and marine systems. Given the potential for toxic effects resulting from establishment of dinoflagellates, these taxa may be important to include on the species list.

All tiny organisms. It seems likely that the composition of future invasions will be difficult to predict. For this reason it may be necessary to evaluate species in ballast water using blunt-force techniques (i.e., the whole assemblage). Supplementing these investigations with addition of known resilient taxa (e.g., those that form resting stages) would be worthwhile.

Etc. It is worth noting that the Great Lakes system is unique in that it is a large freshwater system that is subject to worldwide shipping activity. For that reason, extension of ballast water considerations to other freshwater systems may be limited.

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4.5 Outcome of discussion

The outcome of the discussion was a list of phytoplankton species that could potentially be transported in ballast water and information regarding the characteristics of the species that may mean they are able to survive transport in, and subsequent discharge from, ballast tanks. These lists are split into marine (Annex 5) and freshwater species (Annex 6) and where possible have consistent column headings. The marine list is based on the IOC –UNESCO Taxonomic Reference List of Harmful Micro Algae but has some other “nuisance” species added. The freshwater list is based on the Great Lakes list of introduced species and includes phytoplankton that are likely to have been introduced by shipping. The freshwater species list is not based on toxicity but provides clear examples of where phytoplankton have been introduced and which of these species is likely to cause problems when occurring at high densities.

5 Conclusions

The group concluded that there was not much information available regarding which species of phytoplankton are capable of surviving in ballast tanks and the associated sediments. Although there have been several ballast water sampling studies that have resulted in lists of species in many cases it has not been possible to identify the species reliably beyond genera. Also, in many cases it is assumed that a species has some form of resting stage or cyst but this is not known for sure so it is difficult to know whether the species is capable of surviving for any length of time in a dark ballast tank. For many species there is no detailed information on the temperature and salinity tolerances and in many cases this is not known for certain, particularly for species that are difficult to identify. This report is therefore very much a first attempt at collating some of this information and the group has included both marine and freshwater species in the resulting lists. Currently there is more focussed data for the freshwater species particularly for the work that has been carried out in the Great Lakes and there is more confidence in assuming that shipping was the vector of introduction.

This type of list is also problematic as many of the species included are very difficult to identify and in many cases it would be difficult to say whether a species is new or whether it has been missed previously. Paleoecological records and long term monitoring data sets are often required to try and piece together whether a species is new or has been overlooked and these are not always available. However, the lists included in Annexes 5 and 6 provide a good starting point and could be used as the basis for information for e.g. risk assessments.

The group would like feedback on the usefulness of the lists and has provided a list of potential users in the Recommendations (Annex 7).

Annex 1: List of participants

ICES Workshop on harmful phytoplankton that could potentially be transported or introduced by ballast water (WKHABAL)

14 – 15 October 2010

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Annex 2: Agenda

AGENDA FOR WKHABAL

14 – 15TH OCTOBER, 2010.

ICES HEADQUARTERS, COPENHAGEN.

CO-CHAIRS: Tracy McCollin and Joe Silke.

THURSDAY 14TH OCTOBER, 2010.

08.30	Arrival and set up computers onto ICES network
09.00	Logistical arrangements at ICES (Claus Hagebro/ Diane Lindemann) e.g. computers, photocopying
09.10	Welcome comments by co-chairs (Tracy McCollin and Joe Silke)
09.20	Introduction of participants.
09.30	Review of agenda, appointment of rappourteurs, plan of work etc.
09.45	Overview of work of WGBOSV and WGITMO and relevance of WKHABL to the Ballast Water Management Convention (Tracy McCollin)
10.05	Overview of WGHABD and relevant work already carried out (Joe Silke)
10.25	Opportunity to ask questions re. morning session.
10.30	Break
11.00	Presentations from other members of the group
	Bengt Karlson
	Euan Reavie
	Eileen Bresnan
12.00	**ToR 1**. Identify species of phytoplankton, especially HAB species (and their characteristics) which are more likely to be successful as invasive species, and have significant potential ecological or economic impact.
13.00	Lunch
14.00	**ToR 2**. Determine if there are particular characteristics of coastal waters which favour the establishment of invasive phytoplankton.
15.00	Break
15.30	Continue discussing and drafting relevant text and tables.
17.00	Review of day's work
17.15	Close of first day's meeting.

FRIDAY 15TH OCTOBER, 2010.

09.00 Logistical arrangements for the day, review of work for the day, any other business (Co-chairs and ICES).

09.10 Continuation of discussion and drafting of initial list of phytoplankton.

10.30 Break

11.00 Review of draft and development of associated text for the report.

12.30 Lunch

13.30 Finalise draft for report and start pulling together sections of the report.

15.00 Break

15.30 Collate different sections of the report (aim to get most of the report written at the meeting while everyone is there)

16.45 Final remarks (Co-chairs and ICES)

17.00 Close of meeting.

Annex 3: WKHABAL Terms of Reference

The **ICES Workshop on harmful phytoplankton that could potentially be transported or introduced by ballast water** (WKHABAL), Co-Chaired by Tracy McCollin (UK) and Joe Silke (Ireland), will meet in ICES HQ 14–15 October 2010 to:

a) Identify species of phytoplankton, especially HAB species (and their characteristics) which are more likely to be successful as invasive species, and have significant potential ecological or economic impact, if possible;

b) Determine if there are particular characteristics of coastal waters which favour the establishment of invasive phytoplankton.

WKHABAL will report by 15 November for the attention of the Advisory Committee (ACOM).

Background:

There is a need to develop advice on the phytoplankton most likely to be successful as invasive species, the size of inoculums and conditions that would result in an invasive species. The risk of an invasive species having a negative impact on ecosystem health or the human uses of the ecosystem is determined by the combination of the probability of a species being introduced, its survival and spread, and impact.

Therefore, priority should be given to those phytoplankton species that are known to be or have a high probability of transport by ballast water, high survival (cysts/spore formation) and high ecological or economic impact. The intention is to be able to assess risk associated with incoming ballast water that has not been exchanged/treated.

A top-ten or twenty list of high risk phytoplankton species that would not necessarily be world-wide, but region or climate-zone specific could be prepared. The list would be a watch list or an indication of high risk waters where specific (HAB) species are known to occur and cause problems.

Supporting information:

Priority	The purpose of this Workshop is to identify "invasive" phytoplankton or eve providing lists of native phytoplankton so that future invasive species could be identified.
Scientific justification	The workshop will provide support to: - activities against unexpected or unacceptable effects of invasive phytoplankton - ICES Science Programme and Advisory Services - implementation of the EU MSFD and, - improve the ICES/IOC cooperation
Resource requirements	The research activities which provide the main input to this Workshop are ongoing.
Participants	The Workshop is expected to attract about 20 participants
Secretariat facilities	SharePoint
Financial	No financial implications.
Linkages to advisory committees	The Workshop will report to ACOM.
Linkages to other committees or groups	SCICOM
Linkages to other organizations	The report of the Workshop will be of interest to IOC Intergovernmental Pan on Harmful Algal Blooms

Annex 4 IPHAB Request

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

Reports of Governing and Major Subsidiary Bodies

IOC INTERGOVERNMENTAL PANEL ON HARMFUL ALGAL BLOOMS

NINTH SESSION

PARIS, FRANCE
22–24 APRIL 2009

EXTRACT

5.7 HARMFUL ALGAE AS INVASIVE SPECIES

1 C. McKenzie (Canada) introduced the topic and summarized the activities and achievements of the ICES-IOC-IMO Working Group on Ballast and Other Ship Vectors (WGBOSV). She noted with regret that the group had not submitted its reports from 2007 and 2008. She recalled that the Panel through Recommendation IPHAB-VII.4 had requested the WGBOSV to actively contribute to the process of developing the IMO guidelines for implementation of the IMO Ballast Water Convention.

2 **The Panel reviewed** the WGBOSV 2009 (Washington D.C, 9–11 March 2009) Terms of Reference and the resulting draft ballast water sampling manual. The terms of reference were to: (i) critical review and report on the status of shipping vector research with an emphasis on new developments in ballast water treatment technology, risk assessment, ballast water sampling devices, and selection of ballast water exchange zones; (ii) make a global review of shipping vectors through the participation of representatives from ICES, IMO, IOC, PICES; (iii) comment on the final draft of the ICES Code of Best Practice for handling Hull Fouling on Vessels; (iv) review draft ballast water sampling and port survey methodology Code of Practice; and (v) provide data on how climate change may alter distribution of alien introduced species and shipping operations.

3 To more accurately assess the achievements and focus of the Working Group on Ballast of Ships and other Vectors (WGBOSV) the panel requests that the reports from previous WGBOSV be submitted and also request that the WG Chairperson attend IPHAB-X to report on achievements, focus and future activities.

4 **The Panel decided** to review at IPHAB-X the achievement of the WG and advice on its future direction.

5 **The Panel endorsed** the co-sponsorship of the Working Group for 2010–2011 and urged IOC to ensure representation at the meetings of the WGBOSV.

6 **The Panel recognized** the difficulty of identifying an "invasive" phytoplankter or even providing lists of native phytoplankters so that future invasive species could be identified. **The Panel also recognized** that a list of harmful phytoplankton that could potentially be transported or introduced by ballast water is extensive and that it is complex or not possible to predict the likelihood of an introduced species becoming established in a new region.

7 **The Panel concluded by acknowledging** that there is a need to develop advice on the phytoplankters most likely to be successful as invasive species, the size of inoculums and conditions that would result in an invasive species. The risk of an invasive species having a negative impact on ecosystem health or the human uses of the ecosystem is determined by the combina-

tion of the probability of a species being introduced, its survival and spread, and impact. Therefore, priority should be given during the review to those phytoplankton species that are known to be or have a high probability of transport by ballast water, high survival (cysts/spore formation) and high ecological or economic impact. The intent is thus to be able to assess risk associated with incoming ballast water that has not been exchanged. The list would be a watch list or an indication of high risk waters where specific HAB species are known to occur and cause problems. A top ten or twenty of high risk phytoplankton species that would not be world-wide, but region or climate-zone specific.

8 **The Panel requested** IOC and ICES to request the WGHABD, in collaboration with WGBOSV, to consider this matter and in particular to determine whether: (i) it was possible to identify species of phytoplankton, especially HAB species (and their characteristics) which are more likely to be successful as invasive species, and have significant potential ecological or economic impact; (ii) there are particular characteristics of coastal waters which favour the establishment of invasive phytoplankters.

Annex 5 List of toxic or nuisance marine species that could be transported in ballast water

Species of toxic plankton from the IOC reference list of Harmful Algae version 2010-10-14	Phototrophic/Heterotrophic	Resting stage	Salinity preference	Temperature range	Benthic/Planktonic	Recorded in Ballast tanks	Known impact	Identification	Only known to cause problems at high cell concentrations
	Expert knowledge	Expert knowledge	Expert knowledge	Expert knowledge	Expert knowledge	See references at bottom of table	IOC taxonomic list	Expert knowledge	Expert knowledge
Haptophyceae									
Chrysochromulina leadbeateri Estep, Davis, Hargraves et Sieburth, 1984	Phototrophic	Unknown			Planktonic		Fish mortalities	EM required	Yes
Chrysochromulina polylepis Manton & Parke, 1962	Phototrophic	Unknown			Planktonic		Fish mortalities	EM required	Yes
Phaeocystis globosa Scherffel, 1899	Phototrophic	Unknown			Planktonic		Foam accumulations	Live colonies identifiable using LM	Yes
Phaeocystis pouchetii (M.P. Hariot, 1892) G. Lagerheim, 1896	Phototrophic	Unknown			Planktonic		Foam accumulations	Live colonies identifiable using LM	Yes
Prymnesium calathiferum Chang et Ryan, 1985	Phototrophic	Unknown			Planktonic		Fish mortalities	EM required	Yes
Prymnesium faveolatum Fresnel, 2001	Phototrophic	Unknown			Planktonic		Fish mortalities	EM required	Yes
Prymnesium parvum N. Carter, 1937	Phototrophic	Unknown	Wide salinity range		Planktonic		Fish mortalities	EM required	Yes
Prymnesium patelliferum Green, Hibberd et Pienaar, 1982	Phototrophic	Unknown			Planktonic		Fish mortalities	EM required	Yes
Prymnesium zebrinum Billard, 1983	Phototrophic	Unknown			Planktonic		Fish mortalities	EM required	Yes
Raphidophyceae									
Chattonella antiqua (Hada) Ono in Ono & Takano, 1980	Phototrophic	Yes			Planktonic		Fish mortalities	Only live material can be identified using LM	?
Chattonella globosa Y. Hara et Chihara, 1994	Phototrophic	Unknown			Planktonic		Fish mortalities	Only live material can be identified using LM	¡
Chattonella marina (Subrahmanyan, 1954) Hara & Chihara, 1982	Phototrophic	Yes			Planktonic		Fish mortalities	Only live material can be identified using LM	?
Chattonella subsalsa Biecheler, 1936	Phototrophic	Unknown			Planktonic		Fish mortalities	Only live material can be identified using LM	?
Fibrocapsa japonica Toriumi & Takano, 1973	Phototrophic	Unknown		Wide temperature range	Planktonic		Fish mortalities	Only live material can be identified using LM	¡
Heterosigma akashiwo (Y. Hada, 1967) Y. Hada ex Y. Hara & M. Chihara, 1987	Phototrophic	Unknown	Wide salinity range	Wide temperature range	Planktonic		Fish mortalities	Only live material can be identified using LM	¡
Dictyochophyceae									
Pseudochattonella farcimen (Eikrem, Edvardsen & Throndsen) Eikrem, 2009	Phototrophic	Unknown	Wide salinity range	Cold water	Planktonic		Fish mortalities	Only live material can be identified using LM	?
Pseudochattonella verruculosa (Hara & Chihara) Tanabe-Hosoi, Honda, Fukuya, Inagaki & Sako, 2007	Phototrophic	Unknown			Planktonic		Fish mortalities	Only live material can be identified using LM	?
Diatoms									
Amphora coffeaeformis (C. Agardh) Kützing, 1844	Phototrophic	Unknown			Benthic		Amnesic shellfish toxins	LM required	?
Nitzschia navis-varingica Lundholm et Moestrup, 2000	Phototrophic	Unknown	Wide salinity range	Warm water	Benthic/planktonic		Amnesic shellfish toxins	EM required	
Pseudo-nitzschia australis Frenguelli, 1939	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Genus found	Amnesic shellfish toxins-HAB	EM required	
Pseudo-nitzschia calliantha Lundholm, Moestrup & Hasle, 2003	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Genus found	Amnesic shellfish toxins-HAB	EM required	
Pseudo-nitzschia cuspidata (Hasle) Hasle emend. Lundholm, Moestrup & Hasle, 2003	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Genus found	Amnesic shellfish toxins-HAB	EM required	
Pseudo-nitzschia delicatissima (P.T. Cleve, 1897) Heiden, 1928	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Species found	Amnesic shellfish toxins	EM required	
Pseudo-nitzschia fraudulenta (P.T. Cleve, 1897) Hasle, 1993	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Species found	Amnesic shellfish toxins	EM required	
Pseudo-nitzschia galaxiae Lundholm et Moestrup, 2002	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Genus found	Amnesic shellfish toxins-HAB	EM required	
Pseudo-nitzschia multiseries (Hasle, 1974) Hasle, 1995	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Species found	Amnesic shellfish toxins-HAB	EM required	
Pseudo-nitzschia multistriata (Takano, 1993) Takano, 1995	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Genus found	Amnesic shellfish toxins	EM required	
Pseudo-nitzschia pungens (Grunow ex P.T. Cleve, 1897) Hasle, 1993	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Genus found	Amnesic shellfish toxins	EM required	
Pseudo-nitzschia seriata (P.T. Cleve, 1883) H. Peragallo in H. & M. Peragallo, 1900	Phototrophic	Unknown but likely	Wide salinity range	Cold water species	Planktonic	Species found	Amnesic shellfish toxins-HAB	EM required	
Pseudo-nitzschia turgidula (Hustedt, 1958) Hasle, 1993	Phototrophic	Unknown but likely	Marine	Wide temperature range	Planktonic	Species found	Amnesic shellfish toxins	EM required	
Pseudo-nitzschia pseudodelicatissima (Hasle) Hasle emend. Lundholm, Moestrup & Hasle, 2003	Phototrophic	Unknown but likely	Wide salinity range	Wide temperature range	Planktonic	Genus found	Amnesic shellfish toxins	EM required	

Dinoflagellates									
Dinophysis acuminata Claparède & Lachmann, 1859	Mixotrophic	Unknown	Wide salinity range	Wide temperature range	Planktonic	Yes	Lipophillic shellfish toxins	Species poorly defined	
Dinophysis acuta Ehrenberg, 1841	Mixotrophic	Unknown	Wide salinity range	Temperate	Planktonic	Yes	Lipophillic shellfish toxins	LM required	
Dinophysis caudata Saville-Kent, 1881	Mixotrophic?	Unknown	Marine	Warm water	Planktonic	Yes	Lipophillic shellfish toxins	LM required	
Dinophysis fortii Pavillard, 1923	Mixotrophic?	Unknown	Marine	Warm water	Planktonic		Lipophillic shellfish toxins	LM required	
Dinophysis miles Cleve, 1900	Mixotrophic?	Unknown	Marine	Tropical	Planktonic		Lipophillic shellfish toxins	LM required	
Dinophysis norvegica Claparède & Lachmann, 1859	Mixotrophic?	Unknown	Wide salinity range	Temperate, Northern Hemisphere	Planktonic	Yes	Lipophillic shellfish toxins	LM required	
Phalacroma rotundata Claparède & Lachmann, 1859	Heterotrophic	Unknown	Wide salinity range	Wide temperature range	Planktonic	Yes	Lipophillic shellfish toxins	LM required	
Dinophysis sacculus Stein, 1883	Mixotrophic?	Unknown	Wide salinity range		Planktonic		Lipophillic shellfish toxins	LM required	
Dinophysis tripos Gourret, 1883	Mixotrophic?	Unknown	Marine	Warm water	Planktonic		Lipophillic shellfish toxins	LM required	
Phalacroma mitra Schütt, 1895	Phototrophic	Unknown	Marine	Warm water	Planktonic		Lipophillic shellfish toxins	LM required	
Azadinium spinosum Elbrächter & Tillmann, 2009	Phototrophic	Unknown	Marine	Temperate	Planktonic		Azaspiracids	EM/FM required	
Heterocapsa circularisquama Horiguchi, 1995	Phototrophic	Unknown	Wide salinity range	Temperate	Planktonic		Oyster mortalities	EM/FM required	
Prorocentrum arabianum Morton et Faust, 2002	Phototrophic	Unknown	Marine	Warm water	Benthic		Ichthyotoxin	EM/FM required	
Prorocentrum arenarium Faust, 1994	Phototrophic	Unknown	Marine	Warm water	Benthic		Lipophillic shellfish toxins	EM/FM required	
Prorocentrum belizeanum Faust, 1993	Phototrophic	Unknown	Marine	Warm water	Benthic		Lipophillic shellfish toxins	EM/FM required	
Prorocentrum borbonicum Ten-Hage, Turquet, Quod, Puiseux-Dao et Couté, 2000	Phototrophic	Unknown	Marine	Warm water	Benthic		Neurotoxins?	EM/FM required	
Prorocentrum cassubicum (Woloszynska, 1928) Dodge, 1975	Phototrophic	Unknown	Marine	Warm water	Benthic		Lipophillic shellfish toxins?	EM/FM required	
Prorocentrum concavum Fukuyo, 1981	Phototrophic	Unknown	Marine	Warm water	Benthic		?	EM/FM required	
Prorocentrum emarginatum Fukuyo, 1981	Phototrophic	Unknown	Marine	Warm water	Benthic		Low haemolytic activity	EM/FM required	
Prorocentrum faustiae Morton, 1998	Phototrophic	Unknown	Marine	Warm water	Benthic		Lipophillic shellfish toxins	EM/FM required	
Prorocentrum hoffmannianum Faust, 1990	Phototrophic	Unknown	Marine	Warm water	Benthic		Lipophillic shellfish toxins?	EM/FM required	
Prorocentrum lima (Ehrenberg, 1860) Stein, 1878	Phototrophic	Unknown	Wide salinity range	Wide temperature range	Benthic		Lipophillic shellfish toxins	LM required	
Prorocentrum maculosum Faust, 1993	Phototrophic	Unknown	Marine	Warm water	Benthic		Lipophillic shellfish toxins	EM/FM required	
Prorocentrum minimum (Pavillard, 1916) Schiller, 1931	Phototrophic	Unknown	Wide salinity range	Wide temperature range	Planktonic	Yes	?	LM required	
Prorocentrum rhathymum Loeblich III, Sherley et R.J. Schmidt, 1979	Phototrophic	Unknown	Marine	Warm water			?	EM/FM required	
Amphidinium carterae Hulburt, 1957	Phototrophic	Unknown	Wide salinity range	Temperate	Benthic		Ichthyotoxin	EM/FM required	
Amphidinium operculatum Claparède & Lachmann, 1859	Phototrophic	Unknown	Wide salinity range	Temperate	Benthic		Ichthyotoxin	EM/FM required	
Cochlodinium polykrikoides Margalef, 1961	Phototrophic	Yes	Marine	Warm water	Planktonic		Fish mortalities	EM/FM required	
Gymnodinium catenatum Graham, 1943	Phototrophic	Yes	Marine	Warm water	Planktonic	Yes	Paralytic shellfish toxins	LM required	Yes
Karenia bicuneiformis Botes, Sym et Pitcher, 2003	Phototrophic	Unknown		Temperate	Planktonic		Brevetoxins	Only live material can be identified using LM	Yes
Karenia brevis (Davis, 1948) G. Hansen et Moestrup, 2000	Phototrophic	Unknown	Wide salinity range	Tropical	Planktonic		Marine mammal mortalities, NSP, r	Only live material can be identified using LM	Yes
Karenia brevisulcata (F.H. Chang, 1999) G. Hansen et Moestrup, 2000	Phototrophic	Unknown	Wide salinity range	Temperate	Planktonic		Marine mammal and plants mortali	Only live material can be identified using LM	Yes
Karenia concordia Chang & Ryan, 2004	Phototrophic	Unknown		Temperate	Planktonic		Brevetoxins	Only live material can be identified using LM	Yes
Karenia cristata Botes, Sym et Pitcher, 2003	Phototrophic	Unknown		Temperate	Planktonic		Eye, skin irriation, sub - intertidal m	Only live material can be identified using LM	Yes
Karenia digitata Yang, Takayama, Matsuoka et Hodgkiss, 2000	Phototrophic	Unknown		Temperate	Planktonic		Fish mortalities	Only live material can be identified using LM	Yes
Karenia mikimotoi (Miyake et Kominami ex Oda, 1935) G. Hansen et Moestrup, 2000	Phototrophic	Temporary known	Wide salinity range	Wide temperature range	Planktonic	Yes	Fish mortalities	Only live material can be identified using LM	Yes
Karenia papilionacea Haywood & Steidinger, 2004	Phototrophic	Unknown		Temperate	Planktonic		Brevetoxin	Only live material can be identified using LM	Yes
Karenia selliformis Haywood, Steidinger & MacKenzie, 2004	Phototrophic	Unknown		Wide temperature range	Planktonic		Gymnodimine	Only live material can be identified using LM	Yes
Karenia umbella de Salas, Bolch et Hallegraeff, 2004	Phototrophic	Unknown		Temperate	Planktonic		Fish mortalities	Only live material can be identified using LM	Yes

Karlodinium armiger Bergholtz, Daugbjerg & Moestrup, 2005	Mixotrophic	Unknown	Wide salinity range	Temperate	Planktonic			Only live material can be identified using LM	Yes
Karlodinium corsicum (Paulmier et al.) Siano & Zingone 2009	Mixotrophic	Unknown	Wide salinity range	Temperate	Planktonic			Only live material can be identified using LM	Yes
Karlodinium veneficum (Ballantine, 1956) J. Larsen, 2000	Mixotrophic	Unknown	Wide salinity range	Temperate	Planktonic	Yes	Fish & marine invertebrate mortalit	Only live material can be identified using LM	Yes
Takayama cladochroma (J. Larsen, 1996) de Salas, Bolch et Hallegraeff, 2003	Phototrophic	Unknown		Temperate	Planktonic			Only live material can be identified using LM	Yes
Alexandrium acatenella (Whedon et Kofoid, 1936) Balech, 1985	Mixotrophic	Yes		Temperate	Planktonic		Paralytic shellfish toxins	EM/FM required	
Alexandrium andersonii Balech, 1990	Mixotrophic	Yes		Temperate	Planktonic		Paralytic shellfish toxins	EM/FM required	
Alexandrium balechii (Steidinger, 1971) Balech, 1985	Mixotrophic	Yes		Temperate	Planktonic		Paralytic shellfish toxins	EM/FM required	
Alexandrium catenella (Whedon et Kofoid, 1936) Balech, 1985	Mixotrophic	Yes	Wide salinity range	Temperate	Planktonic	Yes	Paralytic shellfish toxins	EM/FM required	
Alexandrium fundyense Balech, 1985	Mixotrophic	Yes	Wide salinity range	Temperate	Planktonic		Paralytic shellfish toxins	EM/FM required	
Alexandrium hiranoi Kita et Fukuyo, 1988	Mixotrophic	Yes		Temperate	Planktonic		Paralytic shellfish toxins	EM/FM required	
Alexandrium minutum Halim, 1960	Mixotrophic	Yes	Wide salinity range	Temperate	Planktonic	Yes	Paralytic shellfish toxins	EM/FM required	
Alexandrium monilatum (Howell, 1953) Balech, 1985	Mixotrophic	Yes	Wide salinity range	Temperate	Planktonic		Paralytic shellfish toxins	EM/FM required	
Alexandrium ostenfeldii (Paulsen, 1904) Balech & Tangen, 1985	Mixotrophic	Yes	Wide salinity range	Temperate	Planktonic		Paralytic shellfish toxins & spirolide	EM/FM required	
Alexandrium peruvianum (Balech et Mendiola, 1977) Balech et Tangen, 1985	Mixotrophic	Yes		Wide temperature range	Planktonic		Paralytic shellfish toxins & spirolide	EM/FM required	
Alexandrium tamarense (Lebour, 1925) Balech, 1985	Mixotrophic	Yes	Wide salinity range	Temperate	Planktonic	Yes	Paralytic shellfish toxins	EM/FM required	
Alexandrium tamiyavanichii Balech, 1994	Mixotrophic	Yes		Tropical	Planktonic		Paralytic shellfish toxins	EM/FM required	
Coolia tropicalis Faust, 1995	Phototrophic	Unknown		Wide temperature range	Benthic		Cooliatoxin	LM required	
Gambierdiscus australes Faust et Chinain, 1999	Phototrophic	Unknown		Warm water	Benthic		Ciguatoxin - Maitotoxin	LM required	
Gambierdiscus pacificus Chinain et Faust, 1999	Phototrophic	Unknown		Warm water	Benthic		Ciguatoxin - Maitotoxin	LM required	
Gambierdiscus polynesiensis Chinain et Faust, 1999	Phototrophic	Unknown		Warm water	Benthic		Ciguatoxin - Maitotoxin	LM required	
Gambierdiscus toxicus Adachi et Fukuyo, 1979	Phototrophic	Unknown		Warm water	Benthic	Yes	Ciguatoxin - Maitotoxin	LM required	
Gambierdiscus yasumotoi M.J. Holmes, 1998	Phototrophic	Unknown		Warm water	Benthic		Ciguatoxin - Maitotoxin	LM required	
Gonyaulax spinifera (Claparède & Lachmann, 1859) Diesing, 1866	Phototrophic	Yes	Wide salinity range	Wide temperature range	Planktonic	Yes	Yessotoxin	LM required	
Lingulodinium polyedra (F. Stein) J.D. Dodge, 1989	Mixotrophic	Yes	Wide salinity range	Wide temperature range	Planktonic	Yes	Yessotoxin	LM required	
Ostreopsis lenticularis Fukuyo, 1981	Phototrophic	Unknown		Warm water	Benthic		Ostreotoxins, Palytoxin?	LM required	
Ostreopsis mascarenensis Quod, 1994	Phototrophic	Unknown		Warm water	Benthic		Ostreotoxins, Palytoxin?	LM required	
Ostreopsis ovata Fukuyo, 1981	Phototrophic	Unknown	Marine	Warm water	Benthic		Ostreotoxins, Palytoxin?	LM required	
Ostreopsis siamensis Schmidt, 1901	Phototrophic	Unknown		Warm water	Benthic		Ostreotoxins, Palytoxin?	LM required	
Protoceratium reticulatum (Claparède et Lachmann, 1859) Bütschli, 1885	Phototrophic	Yes	Wide salinity range	Wide temperature range	Planktonic	Yes	Yessotoxin	LM required	
Pyrodinium bahamense Plate, 1906	Phototrophic	Yes	Marine	Warm water	Planktonic		Paralytic shellfish toxins	LM required	
Species not on the IOC HAB list									
Cyanophyceae									
Nodularia spumigena Mertens in Jürgens 1822	Phototrophic	Unknown	Brackish		Planktonic		Mammal mortalities	Characteristic morphology	Yes
Pelagophyceae									
Aureococcus anophagefferens Hargraves & Sieburth, 1988	Phototrophic	Unknown			Planktonic		Inhibits filtration by grazing	EM or molecular methods required	Yes

Diatoms									
Coscinodiscus concinnus	Phototrophic	Unknown		Wide temperature range	Planktonic		Oil production - harm to marine org	LM required	Yes
Coscinodiscus wailesii	Phototrophic	Unknown but likely		Wide temperature range	Planktonic	Survive long dark periods	Mucus production - clogging fishing	LM required	Yes
Cerataulina pelagica	Phototrophic	Unknown		Wide temperature range	Planktonic	Alive in ballast water	Mucus production	LM required	Yes
Chaetoceros concavicornis	Phototrophic	Unknown		Wide temperature range	Planktonic	Species found	Physical irritation to fish	LM required	Yes
Chaetoceros convolutus	Phototrophic	Unknown		Wide temperature range	Planktonic		Physical irritation to fish	LM required	Yes
Grammonema striatula	Phototrophic	Unknown			Planktonic		Allergenic	LM / EM required	Yes

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Annex 6 List of nuisance freshwater species that could be transported in ballast water

Year sighted	Species	Common Name	Type	Endemic Region	Location of First Sighting	Vector	Resting stage	Salinity preference	Temperature range	Benthic / planktonic	Recorded in Ballast tanks	Known impact	Identification	Only known to cause problems at high cell concentrations
1938	*Actinocyclus normanii fo. subsalsa*	Diatom	Phytoplankton	Eurasia	Lake Ontario	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
1938	*Diatoma ehrenbergii*	Diatom	Phytoplankton	Widespread	Lake Michigan	Shipping, Ballast Water	Likely	Low		Planktonic		No	LM	Unknown**
1938	*Stephanodiscus binderanus*	Diatom	Phytoplankton	Eurasia	Lake Michigan	Shipping, Ballast Water	Likely	Low		Planktonic		No	LM	Unknown**
1946	*Cyclotella pseudostelligera*	Diatom	Phytoplankton	Widespread	Lake Michigan	Shipping, Ballast Water	Likely	Low		Planktonic		No	LM	Unknown**
1946	*Stephanodiscus subtilis*	Diatom	Phytoplankton	Eurasia	Lake Michigan	Shipping, Ballast Water	Likely	Low		Planktonic		No	LM	Unknown**
1962	*Thalassiosira weissflogii*	Diatom	Phytoplankton	Widespread	Detroit River	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
1963	*Skeletonema potamos*	Diatom	Phytoplankton	Widespread	Lake Erie drainage	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
1964	*Cyclotella atomus*	Diatom	Phytoplankton	Widespread	Lake Michigan	Shipping, Ballast Water	Likely	Low		Planktonic		No	LM	Unknown**
1964	*Cyclotella cryptica*	Diatom	Phytoplankton	Widespread	Lake Michigan	Shipping, Ballast Water	Likely	Low		Planktonic		No	LM	Unknown**
1964	*Cyclotella woltereki*	Diatom	Phytoplankton	Widespread	Lake Michigan	Shipping, Ballast Water	Likely	Low		Planktonic		No	LM	Unknown**
1973	*Skeletonema subsalsum*	Diatom	Phytoplankton	Eurasia	Lake Erie	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
1973	*Thalassiosira guillardii*	Diatom	Phytoplankton	Widespread	Lake Erie	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
1973	*Thalassiosira pseudonana*	Diatom	Phytoplankton	Widespread	Lake Erie drainage	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
1975	*Hymenomonas roseola*	Coccolithophorid alga	Phytoplankton	Eurasia	Lake Huron	Shipping, Ballast Water	Likely	Low-high		Planktonic		No	LM	Unknown**
1978	*Biddulphia laevis*	Diatom	Phytoplankton	Widespread	Lake Michigan	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
1978	*Chaetoceros hohnii*	Diatom	Phytoplankton	Unknown	Lake Huron	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
1978	*Thalassiosira lacustris*	Diatom	Phytoplankton	Eurasia	Lake Erie	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
1983	*Nitellopsis obtusa*	Green alga	Phytoplankton	Eurasia	Lake St. Clair	Shipping, Ballast Water	Likely	Low		Planktonic & benthic*		No	LM	Yes
1988	*Thalassiosira baltica*	Diatom	Phytoplankton	Europe	Lake Ontario	Shipping, Ballast Water	Likely	Low-medium		Planktonic		No	LM	Unknown**
2002	*Cylindrospermopsis raciborskii*	Cyanobacterium	Phytoplankton	South America?	Lake Michigan drainage	Unknown	Yes	Low		Planktonic		Yes	LM	Yes
1975	*Sphacelaria fluviatilis*	Brown alga	Benthic Alga	Asia	Lake Michigan drainage	Aquarium release	Likely	Low		Planktonic & benthic*			Macro/LM	
1926	*Enteromorpha intestinalis*	Green alga	Benthic Alga	Atlantic NA	Lake Ontario	Release, unintentional	Likely	Low		Planktonic & benthic*		Yes	Macro/LM	Yes
2003	*Enteromorpha flexuosa*	Green alga	Benthic Alga	Widespread	Lake Michigan drainage	Shipping	Likely	Low		Planktonic & benthic*		Yes	Macro/LM	Yes
1964	*Bangia atropurpurea*	Red alga	Benthic Alga	Atlantic NA	Lake Erie	Shipping	Likely	Low		Planktonic & benthic*		Yes	Macro/LM	Yes
1964	*Chroodactylon ramosum*	Red alga	Benthic Alga	Atlantic Ocean	Lake Erie	Shipping, Ballast Water	Likely	Low		Planktonic & benthic*			Macro/LM	
1975	*Sphacelaria lacustris*	Brown alga	Benthic Alga	Unknown	Lake Michigan	Shipping, Ballast Water	Likely	Low		Planktonic & benthic*			Macro/LM	
1979	*Enteromorpha prolifera*	Green alga	Benthic Alga	Atlantic NA	Lake St. Clair drainage	Unknown	Likely	Low		Planktonic & benthic*		Yes	Macro/LM	Yes
2001	*Psammonobiotus communis*	Testate amoeba	Other Invertebrate	Ponto-Caspian	Lake Ontario	Shipping, Ballast Water	Yes	Low		Benthic			LM	Unknown
2002	*Psammonobiotus linearis*	Testate amoeba	Other Invertebrate	Ponto-Caspian	Lake Ontario	Shipping, Ballast Water	Yes	Low		Benthic			LM	Unknown
2002	*Psammonobiotus dziwnowi*	Testate amoeba	Other Invertebrate	Ponto-Caspian?	Lake Ontario	Shipping, Ballast Water	Yes	Low		Benthic			LM	Unknown
2000	*Heterosporis sp.* (fish parasite)	Microsporidian	Other Invertebrate	Unknown	Lake Ontario	Unknown	Yes	Low		Planktonic		Yes	LM	Yes

Derived from the National Oceanic and Atmospheric Administration species list (http://www.glu.org/sites/default/files/great-lakes-list.xls), published 18 March 2008, available online as of 1 November 2010.

Empty cells indicate that a rapid determination was not possible; additional literature review or research required.

* Benthic taxa that are likely to have phytoplanktonic zoospores and/or vegetative fragmentation.

** Not typically considered to be bloom organisms.

Annex 7: Recommendations

Recommendation	For follow up by:
1. Bring report to the attention of WGBOSV, WGITMO, WGHABD, WGPME and IOC IPHAB	ICES
2. Request feedback from IOC IPHAB	IOC
3. Review the lists as information becomes available	ICES/WGBOSV/WGHABD
4. Collate feedback from users via ICES	ICES
5.	
6.	