REPORT ON ICES - ASC 2014 THEME SESSION H
Harmful Algal Blooms in Aquaculture and Fisheries ecosystems: prediction and societal effects

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Harmful Algal Blooms (HABs) area major hazard for the exploitation of coastal resources in ICES countries. HABs include i) toxin producing microalgae, which contaminate shellfish with their toxins, cause human intoxications and lead to lengthy harvesting bans when toxins in commercial bivalves exceed regulatory levels; ii) high biomass fish killing HABs with devastating effects in areas of intensive caged-fish aquaculture; iii) emerging benthic HABs, traditionally reported from tropical areas, which cause Ciguatera Fish Poisoning or are associated with toxic sea-spray causing respiratory and skin irritations; iv) Cyanobacteria blooms, in brackish waters, associated with surface scums and mortalities of wild fauna. Improved monitoring and predictive capabilities constitute the main tools to prevent or mitigate the negative impacts of HABs for coastal ecosystem services. The main objective of this session was to review increased monitoring efforts, technological developments for in situ detection of harmful algae, and new analytical tools for toxin detection. Combined with international programmes and projects promoting species-specific research in the last two decades, these efforts have led to a considerable advance in our capabilities for early warning, detection, and for understanding of the mechanisms underlying initiation, maintenance and decay of these blooms. Additionally, the application of operational oceanography principles to forecast HAB events has improved the flow of information from research and monitoring agencies to the end-users (health and environmental authorities, shellfish growers, tourist industry). Scientists from ICES countries were invited to contribute with communications on the following topics: i) HABs and their impact on wild fisheries and shellfisheries; ii) Emerging benthic HABs and their toxins; iii) Advances in the ecology and oceanography of HABs in the ICES domain; iv) Improvements in HAB forecasting – coupled physical-biological, and toxin uptake-detoxification models; v) Advances in automated HAB observing systems, biosensors and toxin-detection methods; vi) Mitigation strategies; vii) Supporting information for the end-users.
The session, held on Thursday afternoon (15.00-19.00) and Friday (09-17.00), had a successful response and included 27 oral communications and 17 posters. The latter were allowed 5-min speed-talks to present their results. They were distributed in the sub-sessions described below.

HABs and their impact on wild fisheries and shellfisheries
The opening presentation (H:01) introduced the increasing number of HAB species and toxins that have been characterized since the early days (1980's) of ICES working groups, when paralytic shellfish poisoning (PSP) and some fish mortalities were practically the only known syndromes in the area. Long time series from pilot areas show that some events seem to be going through an intensification (DSP in western Europe and North America) whereas others are receding (PSP in western Europe). In addition to health impacts on humans (and the market impact), some toxic dinoflagellates, modulated by other factors, such as contaminants and parasites, affect bivalve biological processes (e.g. gametogenesis) (H:02). Diarrhetic Shellfish Poisoning (DSP) events arethe most damaging in terms of days of harvesting closures. They were dealt with from two different perspectives: practical aspects of their monitoring in Sweden (H:04) and how different food processing (steaming, canning) affect the estimates of toxicity when the official EU technique is used, thus showing the need to develope more robust ones (H:05). The latter addsfurther uncertainties to shellfish marketing.. The Curonian Lagoon, in the Baltic Sea, appeared as a hot spot of Cyanobacteria blooms causing multiple damages to the fauna and tourism (H:6, H:7). Transformation of cyanobacteria toxins in freshwater mussels were described (H:8)

Emerging benthic HABs and their toxins
Improved analytical methods (LC-MS) and the emergence of new toxins were discussed to highlight the need to improve monitoring programmes to minimize risks to human health. These included new Azaspiracid (AZP)

analogs (H:09), continuing observations of ciguatoxins in the Canary Islands (H:10), Tetrodotoxins (TTX) and Spirolides (SPX) in Portugal and BMAA in Morocco (H:12), and 7 new Ovatoxins from benthic HABs (*Ostreopsis* cf. *ovata* strains collected from the Gulf of Naples) (H:13). Azaspiracids are now known to originate from several *Azadinium* and *Amphidoma* biogenic sources(10 species of *Azadinium* described). So far the toxin has been found globally in four species (*A. spinosum*, *A. poporum*, *A. dexteroporum* and *Amphidoma languida)*. There are 42 variations of the molecule described, from three structural groups, some included in legislation and others so far not regulated in the EU. Many of these analogues are very closely related, and misidentification is possible. The first cases of Ciguatera fish poisoning in the EU were detected in the Canary Islands in 2008, and 100 people have been affected between 2008 and 2013. Most cases were associated with amberjack and grouper (*Seriola* spp.). In the Islands, three species of *Gambierdiscus* (*G. excentricus*, *G. silvae*, *G. australes*) have been identified. Another emerging marine poison, tetrodotoxin, was reported in warm water gastropod species in Portugal (*Monodonta lineata*, *Gibbula umbilicalis* , and *Charonia lampas*). Spirolides were found in a range of species (Gastropods and Bivalve molluscs) in Portugal and BMAA in *Patella intermedia* and *Monodonta lineata* in Morocco. The low levels detected are felt to pose little impact to humans, but nevertheless indicate the need to be vigilant. In recent years, seven new ovatoxins have been found in *Ostreopsis* cf. *ovata* from the Mediterranean Sea using QTOF LCMS for their identification. The complementary use of positive and negative ion mode enabled the elucidation of the structural characteristics of some of these ovatoxins. The role of ICES in HAB science is recognised by the longstanding Working Group on Harmful Algal Bloom Dynamics (WGHABD). The group is a forum for ICES and UNESCO-IOC to review and discuss HAB events and to provide advice and updates on the state of HABs in the region. It also facilitates interaction between scientists working in diverse areas of HAB science and monitoring (H:14).

Advances in the ecology and oceanography of HABs in the ICES domain/ Improvements in HAB forecasting – coupled physical-biological, and toxin uptake-detoxification models
These 2 sub-sessions described advances (some developed within the EU 7FP project ASIMUTH) from the combination of field monitoring data and other observations with modelling to improve prediction of HAB events. Contributions included a very good study that combined laboratory experiments and numerical simulations to understand *Gymnodinium catenatum* cyst dynamics off Portugal (H.20). Although the idea had earlier been dismissed, resuspended cysts might seed planktonic *G. catenatum* blooms under certain environmental conditions and the cyst inoculum should not be discarded yet. This was proposed as **best oral communication**. A time series study using monitoring data from France, found strong relationships between temperature-irradiance and *Alexandrium minutum* bloom initiation (H:21). However, no correlation between abiotic factors and bloom decline was detected. H:22, H:23 and H:25 were centered on *Dinophysis acuta* and *Dinophysis acuminata* distributions and DSP events on Iberian Atlantic shores. H:22 presented Lagragian simulations to understand *Dinophysis* transport between Aveiro lagoon and the Galician Rías. H:23 used INTECMAR (monitoring) *Dinophysis* time series and concluded that abiotic factors such as upwelling and flushingtimes in the Rías were not always good predictors for *Dinophysis* blooms in the area. The inadequacy of *"Dinophysis* concentration threshold" to predict DSP toxin detection in mussels was also stressed. H:25 suggested that longshore advection (Portugal to Galicia) of *D. acuta* and *G. catenatum* populations come from different source areas. The relationship between cyanobacterial blooms in the Curonian lagoon and physical processes related to climate change was discussed (H:24).
H:28 showed how a HAB forecasting system, based on monitoring observations and operational oceanography, developed into a successful logistic product for aquaculture farming, policy makers and stakeholders in western Ireland. This resulted in an alert system, based on tools for nowcast and forecast HABs and toxins, disseminated through a weekly bulletin including the situation in each aquaculture zone (successful in predicting 50% of *Karenia mikimotoi* and *Pseudo-nitzschia* blooms). H:29 focused on a reanalysis of a HAB event during a downwelling episode off the Galician Rias Bajas in 2005. It modelled the advection and development of toxic algae and oceanographic conditions during spring (*D. acuminata*) and autumn (*D. acuta* transport from Portugal) in 2013: A weekly HAB bulletin for the area was developed. It was highlighted that models can now simulate conditions inside the rias and are adapted to tides. An artificial neural networks (ANN) was built with monitoring data (phytoplankton and environmental conditions) collected since 1990 in the Ebro River Delta region, NE Spain (H:30). After training (misclassification, error characteristics, presence-absence events) of the ANN, these were able to explain 60% of *Pseudo-nitzschia* (ASP) and 62.5% of *Karlodinium* (fish-killer)

abundance in the area. Phenological changes in the bloom season and intensification of *Pseudo-nitzschia* blooms were observed.

An Individual-based model (IBM) was used to understand biological interactions in *Alexandrium* (host) blooms infected by *Amoebophrya* (parasite) (H:31). The model balanced inputs versus outputs, focusing on *Alexandrium* mortality. It was validated with parameterization (data from literature and experiments) and emphasized the importance of the timing of gametogenesis and cyst infection. Results support the hypothesis of parasite-host simultaneous dormancy and the role of excystment to propagate both species. This was proposed for the **best young-scientist oral presentation.**

The following half subsession focused on the uptake and transformation of toxins within shellfish. Possible ways of uptake and elimination of toxins from the okadaic acid group (OA, DSP toxins) were discussed, in particular the cell export of toxins by passive diffusion and/or membrane transport (H:32). Mussels can accumulate free and esterified forms. Several dynamic models including different accumulation routes were used to simulate OA and DTX2 accumulation in mussels. Results suggest that esterification has an important role in reducing the accumulation of OA and DTX2 in bivalves and that the accumulation of DTX2 in mussels should be higher than that of OA. PSP toxin data from the Portuguese biotoxin monitoring programme (1996-2012) showed inter-annual and seasonal trends as well as connectivity between neighboring regions, in particular adjacent coastal and estuarine systems (H:34). Results showed absence of PSP during the period 1996-2004 in contrast with a bimodal distribution (autumn-early winter, and summer) during the period 2004-2012. The persistency of OA and spirolides in seawater is well known in Galicia. An innovative experiment was carried out on OA, spirolides and gymnodimine degradation in the water column and sediments to elucidate whetherobserved toxin levels are due to constant toxin production or to high toxin stability (H: 15),. Degradation of OA in the water is very slow; in contrast to that of gymnodimine and spirolides whose persistency (13-desmethyl SPX C) in sediments seems to be related to resistant forms of dinoflagellates (cysts). Sediment profiles of OA, spirolides and other toxins in the Galician rías were shown to be useful to study historical trends and show an increased impact of OA in recent years. This was proposed for **best young person poster presentation.**

Advances in automated HAB observing systems, biosensors and toxin-detection methods/Mitigation strategies

The notable irruption of molecular and genomic tools into HAB studies was evident in these two sub-sessions, which included twelve contributions on (i) molecular ecology, (ii) genetic and physiological basis of toxin accumulation, (iii) dinoflagellate toxin gene expression; and (iv) use of molecular tools for HABs and toxin identification in Atlantic areas.

Molecular qPCR technologies have been used for prevention and management of toxic dinoflagellate *Ostreopsis* events in Mediterranean tourist resorts (H:36), and of *Azadinium* (AZP) and *Pseudo-nitzschia* (ASP) in the eastern Atlantic (H:37). A novel study established that, using a developed parentage tool, the accumulation characteristics of mussels are inherited in a proportion that makes it possible to start selective breeding programmes to obtain low accumulating strains (H:39). *Ruditapes philippinarum* was also studied as a model for transcriptional response to exposure to microcystins (H:44). Microcystin -LR metabolism in *Ruditapes philippinarum* was investigated using this bivalve as a model for studies on biochemical degradation of microcystin (H:40). The biochemical response of mussels was investigated using the glutathione transferase proteomic response after exposure to toxic *Microcystis aeruginosa* (H:43). Meanwhile, the mussel *Mytilus galloprovincialis* was used as an animal model to investigate the *in vitro* genotoxic effects of OA in haemolymph and gill cells (H:41)., Gene expression variation of saxitoxin genes (*sxtA* and *sxtG*) in the toxic Mediterranean dinoflagellate *Alexandrium minutum* under different nutritional conditions was also investigated as a preliminary molecular approach for toxin monitoring (H:42). Detection of lipophilic toxins with passive (adsorbing resins) samplers was shown to be a valuable tool for research on toxin production and transformation kinetics, but its advantage as an early warning tool, in places where toxins are detected by LC-MS, was discarded.

Supporting information for end-users

Theme session H finished with successful examples of monitoring strategies and their efficient dissemination to end users: the Galician HAB monitoring programme (www.intecmar.org, H: 45) (1992 to date), devoted to HAB and toxin monitoring to safeguard shellfish production and consumer health, and the *Baltic Algae Watch System*,

monitoring cyanobacteria blooms in the Baltic Sea for the last 13 years. The recently established French network on Harmful Algal Blooms (PHYCOTOX) aims to optimize human and scientific resources devoted to HAB research and its impacts on the ecosystem through a well-coordinated national program (H:47).

Conclusions

It was shown that the number of HABs and affected areas in the ICES domain is high and that the number of harmful algal events is increasing. Also new toxins are observed. Consequently the harmful algal blooms have a large impact on fisheries and aquaculture. A new aspect of HABs is emerging – their effects on bivalves and their interaction with other processes that affect them, e.g. parasite infection. Many HAB ecological studies are currently using modeling, in many cases linked to oceanographic processes, which makes these studies more robust and prone to be of use for forecasting and therefore for mitigation of the effects of these events. The tools developed to study the past events in an area by using sediment cores are promising to evaluate the risks and to assess the impact of climate change and other environmental changes. Monitoring programs are starting to incorporate molecular tools to detect HAB events. This is a promising approach, especially for species that are difficult to identify or quantify using microscopy. In situ imaging flow cytometry is another promising approach. The methods of toxin quantification in bivalves are still not perfect. The toxins have a large impact on fisheries, aquaculture and food transforming activities. The methods should be improved to give reliable results in all situations. Some physiological and genetic studies relating to toxin accumulation in bivalves are being carried out showing good perspectives for the selection of organisms with reduced toxin accumulation. Finally, different strategies for supporting end users are being used. Most nowcasts are based on observations in situ or on analyses of collected water samples and in some cases on remote sensing. Forecasts based on observations and coupled models are being developed and are in use in a few countries.

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