

Theme Session I – Effects of hazardous substances on ecosystem health in coastal and brackish-water ecosystems: present research, monitoring strategies and future requirements

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Marine ecosystems are still facing multiple uses and severe anthropogenic impacts even though inputs of various chemicals have been reduced in the past decades. Effects of contaminants can be recorded at different biological levels, their impacts has to be estimated when assessing the health status of ecosystems. To increase the power of risk assessments we need to bridge the gap between measured concentrations of chemicals and their biological effects at different ecosystem levels. Presently, suitable tools and monitoring strategies are under development. However, particularly in coastal and brackish-water systems, variability of natural environmental factors (oxygen availability, salinity, temperature, and hydrography) is known to have an influence on chemical pathways, exposure and thus biological responses. Moreover, projected changes in some of these environmental factors due to climate change have to be taken into account. The present session was initiated to gain an overview concerning on-going research activities, monitoring strategies, and the development and application of suitable indicators in respect to pollution impacts and the assessment of ecosystem health in these complex ecosystems.

In total 17 oral presentations were given and 11 posters were displayed at the poster session. One of them (I:28, Hellwig *et al.*) was awarded at the end of the conference as Best Poster of the ICES ASC 2007. The session was attended by 50–70 participants. The session was started with a keynote lecture given by Lúcia Guilhermino (I:17) on “The use of biomarkers to assess the effects of environmental contamination in coastal and estuarine ecosystems: what questions remain?” Giving examples from the Portuguese coast, she discussed the advantages and limitations in using biomarkers to assess the effects of contamination on organisms and populations. She clearly documented that biomarkers have diagnostic power and that it is possible to establish relationships between biomarker responses and ecologically relevant parameters such as reproduction, feeding and growth. In order to discriminate between the effects of contaminants and of natural factors (e.g. temperature) on the biomarker responses application of multi-variate statistical methods are useful (e.g. redundancy analysis). This was also shown in studies on yellow eels (Poster I:26).

The relationship between different kinds of contaminants and their biological effects was presented and discussed in a set of talks and posters. The increased occurrence of micronuclei (MN) as the result of an exposure to genotoxic contaminants was shown (I:05) and differences between species were pointed out. Flounder and dab develop higher frequencies of micronuclei compared to cod, thus, indicating that flatfish species could be used in the further monitoring of exposure to genotoxic chemicals (I:06). Flounders (*Platichthys flesus*) were also used to describe the response to polycyclic aromatic compounds (PAH) after an oil spill in the NW of Estonia (I:16). A clear relation between oil exposure and occurrence of PAH metabolites was visible. An interactive effect between diesel oil and the presence of toxic algae in the Baltic Sea was documented by Aalto *et al.* (Poster I:33). Their results suggest that algae toxins impair the immune system of blue mussels. Additional exposure to diesel oil disabled mussels to recover from pathological changes induced by the dinoflagellate *Prorocentrum minimum*. Contaminants accumulated in prey can also have an impact on biochemical parameters of predators as shown by Vuorinen *et al.* (Poster I:30). PCDD/Fs and PCBs accumulated in salmon (*Salmo salar* L.) exposed to a diet made of Baltic herring or sprat, at similar levels as in wild salmon caught from the Baltic Sea.

Although DDT and PCBs were banned all around the Baltic Sea three decades ago, there is evidence of current inputs associated with effects in contaminated bird eggs. Kellner and Schneider showed in their study a correlation between p,p'-DDE concentrations in eggs, and eggshell thinning in Baltic Sea cormorant (I:07). Trace metals are another group of contaminants still present in the Baltic Sea and accumulating in key species. Using macrophyte communities from the Gulf of Riga in a 10-year study, Boikova *et al.* (I:19) found clear differences among species (i.e. *Chara aspera*, *Fucus vesiculosus* and *Cladophora glomerata*) regarding the metal levels in the tissue likely related to differences in ecological features. This has to be taken into account when assessing biological effects on biota. Effects on snails from ports and marinas in the Basque Country (Spain) due to TBT were shown by Rodríguez *et al.* (I:12). A clear correlation was found between TBT concentration and degree of imposex which was generally higher in zones with high intensity of large vessel traffic or presence of shipyards. In the discussion afterwards it became clear that TBT is still a common problem in some countries whereas concentrations and prevalence of imposex have decreased in others, as expected in response to environmental regulations. However, TBT content in sediments is still high which may cause persistence of exposure and effects long after regulation.

Sediments are also good indicators concerning the present level of contaminants such as PCBs and DDT as shown by Schneider and Leipe (I:08). They found in sediment cores from the central and western Baltic Sea remarkably similar patterns, all reaching a maximum in PCB and DDT levels around the 1960s and 1970s. However, DDT values were higher in the more coastal and shallower south-western basins in comparison to the central and deeper basins of the Baltic Sea. The found recent contaminant contents in the sediments are likely to be still high enough to cause effects in biota particularly in the coastal shallow waters. An example for the interaction between sediment contaminants and biota from the east coast of the US was given by Wieczorek *et al.* (Poster I:20). Flounders (*Pseudopleuronectes americanus*) held on highly contaminated sediment suffered significantly higher mortality and higher predation than fish held on (relatively) uncontaminated sediment. A way to use sediments for an integrated assessment was described by Franco *et al.* (Poster I:29) based on studies in a coastal area in the Basque Country (Spain) affected by wastewater discharges. They combined chemical measurements with the application of bioassays and a benthic index (AMBI) to link the measured pollution and toxicity with effects at the community level.

An approach for continuous real-time monitoring of effluents to detect peaks of contamination was shown by Kholodkevich *et al.* (I:15) in using fiber-optic remote biosensor systems recording changes in heart rate or pulsometry characteristics in crustaceans. Another novel approach to monitor pollution impact and the health status of marine mammals in coastal areas was presented by Hellwig *et al.* (Poster I:28) in using an *in vitro* cell culture approach to develop species-specific proteomic biomarkers that will be eventually applicable to harbour seal blood samples. Some pollutants are able to induce genetic alterations in organisms by several mechanisms, including fixation and spreading of favourable mutations, differential selection and gene expression. In studying the effects of PAHs on different estuarine and coastal organisms Gravato *et al.* (I:18) found significant alterations in oxidative parameters, behaviour and growth in exposed animals but also differentially expressed genes.

Another promising approach to link chemical pollution and its effects under field conditions is the use of caged mussels as shown by Lehtonen *et al.* (I:14). In a case study performed in the Archipelago Sea (SW Finland, Baltic Sea) they found marked site-specific differences in regard to accumulation of contaminants (PCBs, DDTs, organotins, PAHs, trace metals) and biological effects (biomarkers, growth and condition), and clear correlations between contaminant levels and selected biological parameters. Temporal changes in accumulation and effects were also observed, partly related to changes in abiotic factors (e.g. temperature). The interaction between biomarker responses, pollution level and environmental variables was also

studied by Mulkiewicz *et al.* (Poster I:31, I:32) in the Polish coastal area. Different biomarkers were tested on flounders (*Platichthys flesus*) and Baltic clams (*Macoma balthica*) and correlated with pollution levels and environmental variables such as temperature using Generalized Linear Models (GLM).

The contributions presented in the first part of the session mainly dealt with the application of various biomarkers to study sub-organismal responses, or the role of sediments. The last part of the session, however, aimed at giving a more integrated view concerning the presence and effects of hazardous substances and suitable assessment tools. All studies presented, covering different regional areas (e.g. Atlantic coast, Mediterranean, St. Lawrence Estuary, Canada or the Baltic Sea) underlined the importance of biological markers when monitoring chemical pollution. Furthermore, different approaches were suggested for the assessment of environmental or ecosystem health.

A toolbox of biomarkers (including molecular, cellular, physiological and behavioural endpoints) has been developed for a range of invertebrate species inhabiting different estuaries around the UK coastline. Based on this, Jones *et al.* (I:01) proposed a pragmatic, weight-of-evidence, holistic approach, called the “Biomarker Response Index” (BRI) as a measure of the general health status of organisms based on a ‘traffic-light system’. This index offers a potential measure of organism health that can be used in monitoring under the WFD to reduce uncertainty in defining risk classification and to provide evidence of impact.

In a study presented by Bebianno *et al.* (I:03) mussels (*Mytilus galloprovincialis*) were collected from several hot spots along the South Coast of Portugal. Six biomarkers were used in an integrated manner to classify the health status of the mussels and consequently of this coastal ecosystem. In order to compare and classify the different locations, several integrated indices were applied including an Expert System developed in the frame of MEDPOL. It was shown that these indices provide a useful assessment tool since they integrate a suite of biomarkers of exposure and/or effect, facilitating the definition of risk and, ultimately, offering an easier way for decision makers to assess the quality of the aquatic environment.

Another comprehensive methodology for the assessment of the health status of estuarine ecosystems was presented by Amiard-Triquet *et al.* (I:09) based on data obtained in a multidisciplinary study where contaminant levels were measured in water, sediments and the infaunal worm *Nereis diversicolor*. It was proposed to link sub-individual effects with effects seen on the population or community level to improve the ecological value of biomarkers. Furthermore, impairments due to contaminants in different types of biota (from bacteria to macrofauna) should be taken into account when investigating biogeochemical cycles of contaminants.

Environmental changes and variation could increase the risk of impacts of persistent toxic compounds in higher trophic levels (e.g. beluga whale) as pointed by Couillard and Lebeuf (I:04). Despite decreased levels since the 1970s, organisms in the St. Lawrence Estuary and Saguenay Fjord (Quebec, Canada) are still exposed to complex mixtures of contaminants including (PCBs, Hg, Organochlorine pesticides) remaining in the ecosystem and novel compounds (e.g. Polybrominated diphenyl ethers) which also have the potential of causing deleterious effects. Several fish populations historically used as prey by beluga whales are declining as a consequence of multiple anthropogenic factors. Hypoxic area in the bottom is increasing and could act as an additional stressor. An ecosystem-based approach is being developed to pursue the protection of these ecosystems facing multiple stressors and variable environmental conditions. Even without further inputs of chemicals, climate change may increase risk of toxic impacts due to changing chemical pathways or by increasing vulnerability of organisms. Possible consequences for future ecosystem health and its assessment could be to greatly underestimate the risk caused by contaminant on aquatic species if chemical-environment interactions are ignored.

In the last talk of the session by Lehtonen and Schiedek (I:13) requirements and outline of an integrated monitoring were presented as contribution to the assessment of ecosystem health in the Baltic Sea. It was proposed that the main goal should be an operative and effective integrated chemical and biological monitoring programme, with inclusion of the so far absent biomarker approach both as screening tool to provide information to perform targeted chemical analyses, and to document the impact of chemical pollutants on biota. Such a revised programme should be based on already existing practices (e.g. OSPAR, MEDPOL or AMAP) and initiatives (WKIMON). However, due to the specific biotic (decreased biodiversity) and abiotic characteristics (salinity and temperature gradients) of the Baltic a direct transfer of methodology is not possible and more research and validation of methods is needed. The discussion after this talk resulted in some more general considerations regarding the effects of hazardous substances and some general suggestions how to assess their impacts on organisms and also on the ecosystem level.

Final considerations and conclusions

Within the general framework of management concepts such as the Water Framework Directive (WFD), the EU Marine Strategy, the HELCOM Baltic Sea Action Plan, or the International Great Lakes Water Quality Agreements (IGLWQA) the main goals are “good ecological status” and “healthy wildlife” based on the Ecosystem Approach. The session has shown that a large set of methodologies and a variety of target species is already available to monitor and assess pollution effects and ecosystem health in coastal areas and brackish water systems (e.g. Baltic Sea). The application of a set of biomarkers representing different biological processes was underlined and it was demonstrated:

Biomarkers are useful as diagnostic tools to identify the nature of the most important environmental impacts affecting the ecosystem, and links can be established between organismal responses and effects at population levels (e.g. growth, feeding, reproduction),

Applications of new molecular endpoints (gene expression, “omics” approach) contribute to better understand pollution effects and their possible ecological consequences.

A number of integrated indices and similar approaches (e.g. Expert Systems) based on the measurement of a set of biomarkers have recently been developed and tested in the field. Their application allows comparing the “health status” of different regions or ecosystems. These indices have proven to be very useful to communicate the results of complex interactions to managers or the public.

In the general discussion the application of biomarkers in combination with bioassays and passive samplers was recommended to support the biological measurements. Moreover, an integrated biomarker approach should be linked with other health indicators (e.g. externally visible diseases or parasites in fish, histopathology). When developing an integrated monitoring strategy another step towards the Ecosystem Health Assessment would be to include Biodiversity Indices which describe effects on the population and community level. A better understanding of the complex interactions between chemicals and physical/biological ecosystem processes, e.g. in view of climate change, is also needed to better manage the risks of toxic impact in this variable environment.