Theme session R

Causes and Consequences of Hypoxia

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Oxygen-depleted waters have become a worldwide problem for the management and conservation of marine ecosystems due to interacting forces of nutrient loading from continents, ocean circulation, and climate. This has led to declines in the suitable habitat for many fish populations, which can affect their distribution, survival and growth, and at the system level has led to an overall decline in fisheries production. However, in most cases effects on fish and fisheries have been difficult to observe, let alone quantify. It is only recently that we have begun to acquire the tools (such as physiological markers, otolith markers, and in-situ observation systems) to observe and describe the processes and consequences of hypoxia/anoxia on population and system production and subsequently on fisheries.

This theme session explored the effects and implications of hypoxia ("dead zones") for coastal and marine ecosystems. The session was roughly divided into four parts; each part began with two invited presentations by scientists widely recognized for their work in the field. Part 1 focused on drivers of hypoxia, and was led off by Nancy Rabalais and John Barth (both USA). Presentations showed that hypoxia was set up not only by the presence of high organic matter loads, often caused by anthropogenic fertilization, but also climate change effects that can exacerbate the intensity and duration of hypoxia. For example, in the Gulf of Mexico, warming waters intensify stratification that induces longer bouts of summer hypoxia but also affects the vertical depth and thus overall volume of hypoxic water; in Chesapeake Bay, Jeremy Testa (USA) noted a shift in the timing of seasonal hypoxia likely driven by climate change. However, forecasting hypoxia under the effect of climate change is difficult and uncertain given the multiple pathways (including some potential counteracting feedbacks) that link hypoxia to global warming

Part 2 focused on a severe problem close at hand: hypoxia in the Baltic Sea. Invited speakers Jacob Carstensen (Denmark) and Oleg Savchuk (Sweden) discussed the overall situation and changes through time. Carstensen discussed the diversity of hypoxia manifestations, showing how variable episodes can be in space and time. Savchuk used the modelling platforms developed at The Baltic Sea Centre to examine the causal feedback loops ("vicious circle") that reinforce the production of hypoxia and anoxia. Two other presentations discussed affects on Baltic Sea cod. Michele Casini (Sweden) presented the results of generalized additive models showing that hypoxia is the most important explanatory variable explaining body condition of Eastern Baltic cod; there is some suggestion that being crowded into increasingly smaller habitat volumes exacerbates the effect. Taking the long view, Bärbel Müller-Karulis (Sweden) used some of the modelling arsenal to examine whether cod recruitment is driven by eutrophication, by hydrography, or an interaction of the two. Her work suggests the

latter (i.e. climate change may jeopardize the effects of a reduction in nutrient loads), and has implications for what can be done and expected under the Baltic Sea Action Plan. Finally, co-conveners Walther and Limburg (both USA) presented paired speed talks on their discovery of proxies for tracking fish exposure to hypoxia through otolith microchemistry; the Baltic Sea is one of their study arenas.

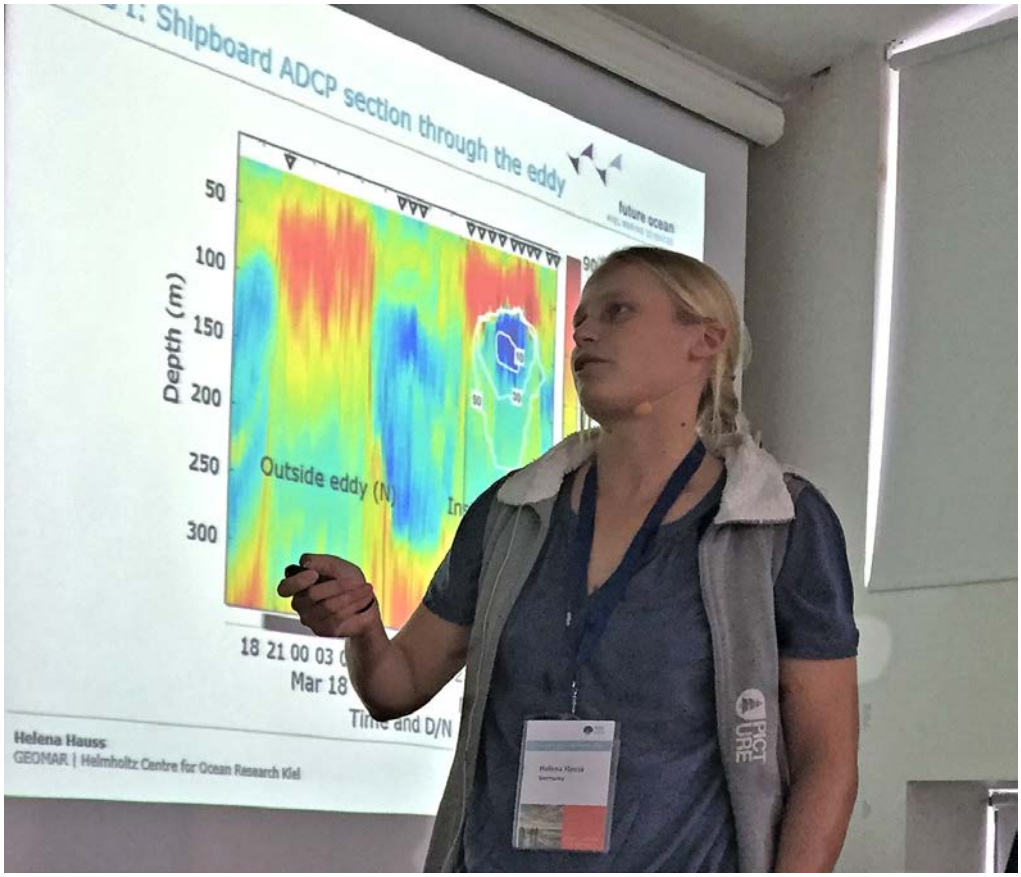
Physiological effects of hypoxia constituted Part 3 of this session, led off by Guy Claireaux (Belgium) and Jane Behrens (Denmark). This section focused on the affects of reduced oxygen on the metabolic scope for activity and growth, highlighting the potential sub lethal affects of hypoxia exposure on exposed organisms. Claireaux provided compelling data that small reductions in oxygen availability can produce large physiological changes, resulting in slower metabolizm and activity, largely because the fish is up against stressful limits. Behrens, standing in for lead co-author Denis Chabot (Canada) discussed new experiments on detailed studies of gastric evacuation rate, again in cod. Their work suggests that one large affect of hypoxia is a slow-down in this process. Finally, Bronwyn Gillanders (Australia) presented ongoing research in her lab, studying effects of hypoxia on metabolic rate and tolerance.

More complex biotic consequences of hypoxia rounded out the session as Part 4. Kenny Rose (USA) presented an ambitious model that combined present climate and future projections with spatially explicit, individual based models of Atlantic croaker in the Gulf of Mexico, asking how hypoxia and climate affect long term population dynamics over numerous generations. One of the many interesting results was that some of the scenarios of nutrient load reduction produced substantial reductions in croaker biomass and abundance, thus recognizing that hypoxia is associated with an "ecosystem fertilizer effect." This was also discussed in the following presentation by Denise Breitburg (USA), who has observed nonlinear effects of hypoxia and nutrient loading on marine biomass and fish catches. Breitburg also highlighted another important interaction factor, namely marine acidification, presenting experimental evidence that hypoxia exacerbates adverse effects of acidified waters on young oysters. Nuno Cosme (Denmark) presented an ambitious model to quantify exposure of organisms and ecological communities to eutrophication, and then used a life cycle assessment to quantify ecosystem responses. In the tropical region of the Atlantic, Helena Hauss (Germany) discussed observations of a different kind of ephemeral "dead zone," namely a warm-core eddy that became hypoxic. Her research team opportunistically surveyed the eddy with vertical samplers, and were able to describe not only the physics and chemistry, but also the zooplankton community response – a rare look at this in the open ocean. Niko Nikolioudakis (Greece) showed how foodweb structure was disrupted by hypoxia in shallow hypoxic areas near Athens. Lastly, Stephanie Czudaj (Germany) used tissue stable isotopes to detect shifts in foodweb functioning in mesopelagic communities. Together, these presentations emphasized the complex effects of hypoxia, alone and in combination with other environmental stressors, at the individual, population and community levels.

A final period (Casting a Hypoxinet) allowed participants to discuss the benefits and feasibility of forming an interdisciplinary research network on hypoxia. The general sense was of interest, with questions of process and institutional format. Some favoured the creation of an ICES Working Group, others suggested independent ways to finance a network and series of workshops; some thought developing graduate and post-doctoral programs could stimulate the research.

Casting a HypoxiNet.

Guy Claireaux makes a point



Helena Hauss discusses a hypoxic, open ocean eddy.