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HYPOXIA AND NUTRIENT REDUCTION IN THE COASTAL ZONE

(Prepared by STAP)

Scientific and Technical Advisory Panel

The Scientific and Technical Advisory Panel, administered by UNEP, advises the Global Environment Facility

Hypoxia and Nutrient Reduction in the Coastal Zone

Advice on Prevention, Remediation and Research

Executive Summary

May 2011

Foreword

Reported cases of coastal hypoxia or low oxygen areas have doubled in each of the last four decades, threatening global environment benefits in most of the Large Marine Ecosystems (LMEs) in which GEF supports programs. GEF requested STAP to review the scientific evidence on coastal hypoxia and advise how to address the issue, beyond current actions. This STAP advisory document is based on a review of the scientific evidence, and scientific and management expert consultations. It has been reviewed by subject matter experts, the GEF Secretariat, the GEF International Waters Task Force and GEF agencies.

STAP concludes that the growing problem of coastal hypoxia requires accelerated GEF attention. Hypoxia is caused by eutrophication, i.e., the overloading of waters with nutrients, especially nitrogen, phosphorous and silicon and/or organic matter. Coastal areas are suffering from accelerating nutrient pollution from multiple sources including agriculture and livestock production, sewage and industrial waste, plus additional complex temperature and water exchange impacts from climate change. Nutrient effects on water oxygen levels are exacerbated when local water bodies become stratified and mixing, and thus oxygenation, of layers is prevented.

Hypoxia remediation is possible by reducing eutrophication through systematically reducing nutrient pollution from the most significant local sources. Nutrient reduction also brings multiple ecosystem benefits such as improved water quality, biodiversity, healthier fish stocks, aquaculture improvement and fewer algal blooms. The GEF and its development partners have already invested in substantial nutrient reduction efforts, with measurable success in the longer running European projects. To address accelerating coastal hypoxia, **GEF and its development partners should urgently increase their support to nutrient reduction projects, building on GEF's experience and leadership.** Coastal hypoxia and its causes are multi-focal area issues. GEF-International Waters is the lead focal area but hypoxia also concerns Biodiversity, Land Degradation and Climate Change and is an issue in which most GEF agencies have a role. This advisory document describes the need for integrated approaches and the specific roles for each GEF agency, and for international, national and local governments and industries.

Not all cases of coastal hypoxia are amenable to easy remediation. Where hypoxia originates primarily from the combined effects of larger scale ocean circulation events and climate change, local land based interventions will have limited impact. Intervention areas should be selected based on their expected potential for prevention or remediation and progress should be monitored. **GEF should establish principles for supporting priority systems in which to test management responses to permanent and seasonal hypoxic systems.** Priority should be given to east and south Asia where the largest increase in the number of hypoxic areas is expected.

Most of the GEF LME projects in advanced stages of implementation have reported coastal hypoxic areas matching those in the most comprehensive scientific database.[1] To assist GEF projects, **GEF guidance materials for International Waters Transboundary Diagnostic Analysis and Strategic Action Programs should include new tools on how to address hypoxia and nutrient reduction.** A**ll existing LME projects should examine the current knowledge on coastal hypoxia and establish monitoring, prevention and remediation programs if these are not already underway.** To assist new projects, **GEF should support the development of a Hypoxia Toolkit, similar to the Persistent Organic Pollutants Toolkit (www.popstoolkit.com), and integrate into the screening process for new projects a hypoxia screening tool that should be made available on the GEF IW:Learn project website.**

[1] Prof. R. Diaz, Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, VA, USA

Coastal hypoxia is a complex problem and, although research has made great strides in understanding its causes and remedies, more knowledge is needed to fill critical gaps that impede efficient and effective action. **Prevention and remediation of hypoxia must be based on realistic expectations for success.** We recommend that **GEF agencies develop proposals along with selected targeted research initiatives to fill critical coastal hypoxia action and knowledge gaps and to guide action in GEF LME projects, within the overarching framework of global nitrogen cycle disruption.**

Thomas E. Lovejoy
Chair, Scientific and Technical Advisory Panel

Meryl J Williams
Panel Member for International Waters

Brief for the GEF - Coastal Hypoxia and Nutrient Reduction in the Coastal Zone

Rapid economic development and population growth, much of it along the world's coasts, plus increasing agriculture and livestock production, have placed huge environmental pressures on coastal ecosystems from direct resource use and the rising influx of nutrients and other pollutants from the land and atmosphere. A major symptom of the environmental pressures is the exponential rise in the number of coastal areas suffering from low oxygen or hypoxia. In each of the last five decades, the number of hypoxic coastal and estuarine areas has doubled. More than 500 hypoxic zones now threaten critical ecological areas, including the majority of the world's large marine ecosystems supported by the Global Environment Facility (GEF). Recognizing the increasing threats from hypoxia, the GEF tasked its Scientific and Technical Advisory Panel (GEF-STAP) to review the current knowledge of coastal hypoxia, its causes, lessons learned from GEF investments and other cases, and develop recommendations on how to prevent and remediate the growing problem. The present STAP Advisory Document addresses GEF's request. It was developed from reviewing the latest scientific literature and opinion, along with input from two expert consultations, the first in October 2009, in Shanghai, China covering the scientific basis and the second in June 2010 in Washington DC, USA covering local to international management options.

A review of the evidence for coastal hypoxia

The incidence, intensity, size and duration of coastal hypoxic areas are increasing, threatening GEF investments in global environmental benefits in large marine ecosystems (LMEs). Coastal hypoxia reduces fisheries production, kills and impairs fish and other marine life populations (changing their diversity and health), threatens human health, and reduces coastal amenities. Hypoxic areas also emit the most potent greenhouse gases, especially nitrous oxide and methane. Scientific evidence conclusively shows that coastal hypoxia is caused by eutrophication - that is, the overloading of waters with nutrients, especially nitrogen, phosphorous and silicon and/or organic matter. The effects of added nutrients on oxygen levels are exacerbated by local water body conditions, particularly strong stratification that prevents mixing and oxygenation of water body layers. Coastal areas, particularly but not only in newly industrializing countries, are suffering from accelerating nutrient pollution from multiple sources, including agriculture and livestock production, sewage and industrial waste, plus additional complex temperature and water exchange impacts from climate change. Hypoxia is often accompanied by increased harmful and obstructive algal blooms that harm human health, and may cause or contribute to severe economic losses. In areas such as the Yellow Sea, the Oregon Coast and in the eastern Arabian Sea, naturally low oxygen water from oxygen minimum zones in the deep ocean intrudes on the coastal shelves and interacts with and exacerbates human-induced hypoxic events.

Experience, including through GEF interventions, shows that remediation of hypoxia is possible. Eutrophication must be reduced systematically by reducing nutrient pollution from the most significant local sources, such as municipal sewage, agricultural fertilizers, and livestock waste. Beyond reducing the areal extent and severity of hypoxia, nutrient reduction also will bring multiple ecosystem benefits, such as improved water quality, biodiversity, healthier fish stocks, aquaculture improvement for filter feeders such as oysters, fewer algal blooms, and reduced biochemical oxygen demand. However, not all cases of coastal hypoxia are amenable to easy remediation. In cases where hypoxia originates primarily from the combined effects of larger scale ocean circulation events, (upwellings of low oxygen water from the deep), and climate change, local land based interventions will have limited impact. Intervention areas should be selected based on their expected potential for prevention, or remediation, and progress should be monitored. To support sustained action, realistic expectations of the time needed for recovery should be established. Even for areas that can be remediated, 10-30 years may be needed to return to acceptable conditions, although improvements usually manifest after the first few years. Left unremediated, coastal hypoxia leads to serious and mounting social, economic and ecological costs as has been experienced by some OECD countries.

Indicators for coastal hypoxia and nutrient reduction

The most important indicator for stress reduction is the annual nutrient load entering the coastal areas through rivers and streams. In measuring progress towards reduced eutrophication, dissolved oxygen in the water column is a critical measure. Other indicators include turbidity, nutrients such as nitrogen, phosphorous and silicon and their compounds, temperature, salinity and depth. Totally anoxic (zero oxygen) conditions are marked by the accumulation of hydrogen sulphide which should also be measured as an indicator in severe cases. Harmful algal blooms (HABs) also serve as an example of a bioindicator of a potential hypoxic area, although HABS do not necessarily lead to hypoxia. Once diagnosed, hypoxic conditions should be drawn to the attention of policy makers and their management responses directed towards solving eutrophication problems. Biogeochemical indicators should be complemented by socio-economic indicators.

The initial step towards reducing nutrient emissions should be an inventory of point source discharges and agricultural activities. If no hypoxia problems are evident, this would be followed by a carefully designed monitoring program on point source and diffuse nutrient concentrations and run-off, adjusted to a "standard run-off situation" or baseline for each location. Atmospheric sources must also be assessed especially in heavily industrialized regions where they can be a significant source of nutrient inputs. Indicators of nutrient reduction should be measured on monthly to annual scales, according to the rates at which changes manifest. When hypoxia from land-based sources of pollution is documented, a careful program of pollution reduction from sources of nutrients and oxygen depleting substances is warranted, accompanied by a water quality and biological monitoring program to document future conditions in the area of hypoxia. Non-point sources of nutrient pollution are the most difficult to measure and reduce. To date, most successful reductions have been from point sources.

Hypoxia in GEF LME projects

Large Marine Ecosystems (LMEs) are the GEF organizing units for transboundary coastal projects. GEF supports projects in 17 of the 64 LMEs. Using the GEF project IW:Science [2] document database, GEF LME project references to hypoxia were compared with those in the global scientific hypoxia database of Prof. R. Diaz.[3] For six LMEs (Gulf of Mexico, Mediterranean Sea, Black Sea, Guinea Current, Red Sea and Yellow Sea), GEF project reports closely matched information in the global database; six LME projects are still in early stages of development and have not yet provided relevant information (Agulhas and Somali Current, Canary Current, Baltic Sea, Gulf of Thailand and Indonesian Sea). Project documents from the remaining five LME projects (Bay of Bengal, Benguela Current, Caribbean Sea, Caspian Sea, Humboldt Current and South China Sea) reported hypoxia information that was not able to be matched directly with those in the global database. In some cases, the GEF LME reports were more precise and in others less. Overall, GEF LME projects are aware of hypoxia. To improve further how GEF projects address hypoxia, hypoxia management and nutrient reduction measures need to be explicitly embedded in GEF Transboundary Diagnostic Analyses (TDAs), and Strategic Action Programs(SAPs). Since new hypoxic areas are expected to emerge, all LME projects should monitor for hypoxia. To illustrate successes and challenges, five selected GEF case studies of hypoxia in LMEs are reviewed; Danube River/Black Sea, Baltic Sea, Yellow Sea, Gulf of Mexico and Guinea Current, plus two non-GEF case studies; Chesapeake Bay (United States of America) and the Mersey River (United Kingdom).

Preventing and remediating coastal hypoxia requires integrated actions

Experience with successful remediation efforts shows that management actions will need to be coordinated across sectors and scales as needed, and that fully integrated efforts can be built sequentially. The GEF-IW approach offers essential elements for integration. For example, the LMEs and freshwater transboundary surface water

[2] Enhancing the Use of Science in International Waters Projects to Improve Project Results, UNU-INWEH, see: http://www.inweh.unu.edu/River/IWScience.htm

[3] Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, VA, USA

projects support collaborative platforms for joint cross-country and cross-sector identification of issues (TDAs), and commitments to action (SAPs). Ultimately, integrated coastal management (ICM) and basin-scale integrated water resources management (IWRM) usually will need to be combined and emphasize nutrient pollution reduction to deal effectively with coastal eutrophication, and hypoxia. Coastal managers will need to work with land-based agencies to make the case for and stimulate behavioral and practice changes.

Comprehensive nutrient reduction models are valuable for integrated and single sector management such as in coordinating and ranking the sectoral and spatial priorities for interventions and comparing the cost effectiveness of different pollution reduction options. Since coastal hypoxia typically involves large geographical areas and a variety of sources of nutrients whose rates change over time, stress reduction requires an iterative, long-term approach, shared long term vision, and coordinated and agreed intermediate steps. To overcome financial barriers for interventions such as waste water treatment plants, local governments and coastal area managers will need support from national and regional authorities.

Existing integrated management and nutrient reductions tools from PEMSEA, FAO, UNEP-GPA and others and models from the Danube (MONERIS) and IOC can be adapted, used and further developed. This Advisory Document provides a guide to key tools and materials.

Implications for the GEF

For GEF, coastal hypoxia and its causes are multi-focal area issues. Most GEF agencies have a stake and capacity to contribute. GEF-International Waters (IW) is the lead focal area but hypoxia also impacts global environment benefits in Biodiversity (BD), Land Degradation (LD) and Climate Change (CC). For example, near marine protected areas it can impact (referring to GEF-5 Focal Area Strategies) BD Objective 1 (to improve sustainability of protected area systems). Similarly when linked to fisheries, forestry and tourism, hypoxia affects Objective 2 (mainstreaming protection in production landscapes). CC Objective 5 (conserve and enhance carbon stocks through sustainable management of land use, land-use change) is affected because hypoxia changes coastal carbon sequestration and leads to increased emissions. In LD all objectives are affected, or alternatively can play a remediation role. The GEF cross-focal area objective of contributing to sustainable forest management also would positively contribute to preventing and remediating hypoxia because good forest management improves water quality and nutrient retention.

The GEF, along with development partners, has already invested in substantial nutrient reduction efforts, having supported the UNEP-Global Plan of Action on Land Based Sources of Pollution and the Global Nutrient Management Programme, and invested more than USD120 million in projects over 15 years in Southeastern Europe and Asia, with measurable success in the longer running European projects. Asian nutrient reduction projects are still underway and results are not yet expected. However, the compelling scientific and technical evidence is that GEF and investment partners should urgently escalate support to nutrient reduction.

GEF should establish principles for supporting priority systems in which to test management responses to permanent and seasonal hypoxic systems, considering the following factors:

- Priority should be given to east and south Asia where the largest increase in the number of hypoxic coastal areas is expected.
- Smaller systems with existing hypoxic conditions are more amenable to hypoxia remediation than larger systems and serve as a good entry point to larger scale efforts. Larger systems more open to ocean circulatory patterns are more likely to be strongly influenced by global climate and climate change impacts, which may not be “controllable” in the short- to medium term.

STAP advice is given for seven different groups of stakeholders.

- Intergovernmental bodies – must facilitate multi-national, regional agreements on strategic action, normative instruments and create partnerships to bring nutrient reduction and hypoxia remediation to the fore of national pollution reduction agendas.
- National governments and agencies – should establish, implement and maintain sound scientific monitoring strategies, management strategies and supporting regulatory and legislative framework for pollution reduction, including especially for farm fertilizer use, livestock waste and sewage discharges as key sources of nutrients and oxygen demanding pollutants. Unless international bodies and national government sector ministries act, countries will not achieve the Millennium Development Goals in the coastal zone, such as reversing the loss of environmental resources.
- Industrial sectors – need to actively engage as stakeholders in policy-decision making and change their practices to reduce nutrient pollution.
- Scientific research community – must emphasize sound scientific input, which is crucial in every step of hypoxia management and communication of science to decision makers.
- Coastal zone managers, local governments – are central to hypoxia prevention and remediation through reforming municipal utilities for water and sewage pollution reduction and engaging local stakeholders. Complex institutional arrangements and infrastructure will be too much of a burden for most local governments and coastal managers. National governments need to assist local governments to overcome financial barriers and coordinate projects that cross political boundaries and involve multiple public and private sector stakeholders.
- NGOs – should be involved actively in integrated hypoxia management advocacy and actions.
- Communities and civil society – play an important role as environmental stewards and should show a vested interest in the health of their coastal marine and watershed environments and in continued flows of economic and social benefits of the goods and services they provide.

Specific roles are outlined for GEF partners, the GEF Secretariat, GEF Agencies (Multilateral development banks, UNEP, UNDP, UNIDO, FAO), three tiers of government in countries and key industrial sectors. Key roles and responsibilities are described for coordination, long term monitoring, new technological efficiencies, reforms and investments in reducing human sewage pollution and agricultural pollution, shared responsibilities, community involvement and integration in terms of management, scale, discipline and stakeholders. Based on critical knowledge gaps currently slowing progress, four research needs are proposed:

- Move towards an ecosystem-based management approach that includes the larger issue of global nitrogen cycle disruption.
- Synthesize the large body of knowledge on hypoxia and eutrophication across sectors and alternative remediation options to provide practical guidance on avoiding future areas of coastal pollution leading to hypoxia;
- Identify locations for focused research projects; and
- Look at future scenarios and contextual issues relating to hypoxia;

Although scientific understanding of the conditions that cause and remediate coastal hypoxia have become much better understood in the last decade, only a few long-term studies have yet been done to show how coastal ecosystems respond to decreases in nutrient loading and recover from hypoxia. While this is a critical knowledge gap, the STAP workshops clearly illustrated that the science community supports pollution reduction actions and that those actions are associated with improvements in coastal hypoxia where action has already been taken.

Recommendations to GEF to prevent and remediate coastal hypoxia

The growing problem of coastal hypoxia now requires heightened GEF attention. The following actions are recommended:

- GEF and development partners should urgently increase their support to nutrient reduction projects, building on GEF's experience and leadership.
- Establish principles for supporting priority systems in which to test management responses to permanent and seasonal hypoxic systems.
- Develop a Hypoxia Toolkit similar to the Persistent Organic Pollutants Toolkit (www.popstoolkit.com), integrating into the screening process for new projects a hypoxia screening tool that should be made available on the GEF IW:Learn project website.
- GEF guidance materials for International Waters Transboundary Diagnostic Analysis and Strategic Action Programs should incorporate the tools developed for LME projects to address hypoxia and nutrient reduction.
- All existing LME projects should examine the current knowledge on coastal hypoxia and establish monitoring, prevention and remediation programs if these are not already in place.
- Prevention and remediation of hypoxia should be based on realistic expectations for success.
- GEF agencies should develop hypoxia research proposal(s) to fill critical coastal hypoxia knowledge gaps to guide action in GEF LME projects while at the same time addressing the associated concern of global nitrogen cycle disruption.