INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
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COASTAL EUTROPHICATION: LINKING NUTRIENT SOURCES TO COASTAL ECOSYSTEM EFFECTS AND MANAGEMENT: NEWS2USE

Summary. The IOC Executive Council (41st Session, 24 June–1 July 2008), requested the IOC Secretariat to develop a work plan and funding strategy for integrated coastal research through a dialogue between the Secretariat, GlobalNEWS, the GEOHAB SSC and interested Member States and agencies. This document is such a plan and is the result of an organizational workshop held 2–4 February 2009 at UNESCO.

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Executive Summary

The IOC Executive Council (41st Session, 24 June–1 July 2008), requested the IOC Secretariat to develop a work plan and funding strategy for integrated coastal research through a dialogue between the Secretariat, GlobalNEWS, the GEOHAB SSC and interested Member States and agencies. This document is such a plan and is the result of an organizational workshop held 2-4 February 2009 at UNESCO. The workshop was co-chaired by John Harrison (Washington State University, Vancouver, USA) and Lex Bouwman (Netherlands Environmental Assessment Agency, Bilthoven, The Netherlands). Nutrient over-enrichment of coastal ecosystems is a major environmental problem globally, contributing to problems such as harmful algal blooms, dead zone formation, and fishery decline. Yet, quantitative relationships between nutrient loading and ecosystem effects are not well defined. The development of such relationships, concurrent with an improved understanding of the complexity of these relationships is critical to effective management of coastal resources; without such understanding degradation of aquatic systems will almost certainly continue, resulting in increased social, economic, and environmental hardship. The proposed activity, which has provisionally been named **Global Nutrient Export from Watersheds 2, User Scenario Evaluation (Global NEWS2USE)**, aims to address the need for more quantitative analysis of impacts of nutrient loading and changing nutrient stoichiometry in coastal ecosystems. It will explore relationships between nutrient inputs, coastal chlorophyll, the occurrence of harmful algal blooms (HABs) and hypoxia, and related effects on coastal fish and fisheries, with the ultimate goal of developing novel datasets and innovative, predictive models, which will be shared with stakeholders. This proposed activity directly addresses a critical gap in scientific understanding and an important coastal management need while establishing a necessary, but currently missing, link between several IOC of UNESCO-programs and projects. A workplan was developed for Global NEWS2USE for a period of 4-5 years. The coastal zone ecosystem stresses on organisms that will be considered by NEWS2USE are HAB, hypoxia and impacts on fish and fisheries (abundance, composition, landings). The scope of NEWS2USE is global; the aim is to investigate relationships between nutrient loading and nutrient transformations in coastal marine ecosystems, develop models that quantitatively describe such relationships, and to identify regions where conditions are prone to the development of HABs and hypoxia and where further in-depth research is needed. The proposed approach comprises short term (Phase I), medium (Phase II) and long term (Phase III) activities. Phase I concentrates on data collection and the establishment of statistical relationships between nutrient loading and harmful algal blooms and hypoxia based on the data that is available at the start of the project. For fisheries the short term activity is the collection of data. Phase II will focus on the development and use of deterministic models to describe nutrient impacts in coastal marine ecosystems. Phase III will include the integration of insights gained in Phases I and II as well as the development of a tool for evaluation and implementation of management options and policies to improve coastal water quality, integrating the results of Phases I and II. We anticipate that scientists will use this tool in close collaboration and with feedback from managers and policy makers at various levels (national, international) to assess the effects of management and policy alternatives on coastal marine ecosystems. This will allow visualizing the potential impacts of alternative development and mitigation strategies, a process that has proven effective in promoting conservation of resources in a number of cases worldwide. To be an effective aid to managers and policy makers, this model must be as useful and accessible as possible. The activity includes training workshops for scientists and policy makers in developing countries. A web facility will initially be a forum for data exchange of the NEWS2USE activity, and later on a facility for disseminating the data, results and tool developed in NEWS2USE.

1. Why a new integrative activity?

1.   The IOC Executive Council (41st Session, 24 June – 1 July 2008), requested the IOC Secretariat to develop a work plan and funding strategy for integrated coastal research through a dialogue between the Secretariat, GlobalNEWS, the GEOHAB SSC and interested Member States and agencies. This document is such a plan and is the result of an organizational workshop held 2-4, February, 2009 at UNESCO. The workshop was co-chaired by John Harrison (Washington State University, Vancouver, USA) and Lex Bouwman (Netherlands Environmental Assessment Agency, Bilthoven, The Netherlands). Objectives and participants of this workshop are in Annex 2 and 3.

2.   Nutrient inputs (nitrogen N; and phosphorus P) to watersheds associated with agriculture, sewage and fossil fuel combustion are projected to more than double by 2050 unless technological advances and policy changes are implemented (Tilman et al. 2001; Millennium Ecosystem Assessment 2006). Therefore, understanding the quantitative relationships between nutrient sources throughout watersheds, nutrient transport by rivers to coastal systems, and the effects of that nutrient loading on receiving coastal ecosystems is critical to effective and integrated management of water resources and coastal zones. Without a quantitative and whole watershed perspective, and without an effective and efficient means of implementing programs that respond to current understanding of watershed-coastal ecosystem linkages, aquatic systems are likely to continue to be degraded by both nutrient over-enrichment and by changes in nutrient ratios due to human activities.

3.   This activity, which has provisionally been named **Global Nutrient Export from Watersheds 2**, **User Scenario Evaluation** (Global NEWS2USE), will address the need for more quantitative analysis of impacts of nutrient loading and changing nutrient stoichiometry in coastal ecosystems. It will explore relationships between nutrient inputs, coastal chlorophyll, the occurrence of harmful algal blooms (HABs) and hypoxia, and related effects on coastal fish and fisheries, with the ultimate goal of developing novel datasets and innovative, predictive models, which will be shared with scientists, managers, and policy-makers from regions experiencing (or likely to experience) negative impacts due to changes in coastal nutrient loading. In so doing, this program will establish a necessary, but currently missing, link between several IOC of UNESCO programs and projects, including: the Integrated Coastal Area Management (ICAM) program, ,the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) program, and the Global Ocean Observing System (GOOS), as well as the activities of other organizations such as the IGBP Land-Ocean Interactions in the Coastal Zone (LOICZ) program (See section on collaborations and Figure 1). It will also build directly on work developed through the SCOR/LOICZ work group 132 called "Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems."

4.   The proposed work builds on work performed by the IOC of UNESCO Global NEWS project, which has developed datasets and models of river nutrient export at the river mouth and information on land-based nutrient sources. The strengths of this Global NEWS system and the feasibility of using it to establish links between land-based nutrient loading and coastal impacts have been demonstrated in previous applications using global databases. For example, comparison between Global NEWS-predicted nutrient export and HAB occurrences suggests that high values of dissolved inorganic N river export correspond to locations of hypoxia and blooms of specific algal bloom species (Figure 2, Seitzinger et al., 2005, Harrison et al., 2005a and b, Dumont et al., 2005, Beusen et al., 2005, Glibert et al., 2008). This kind of qualitative comparison represents the extent to which the effects of nutrient loading in coastal marine ecosystems have been linked to coastal impacts at the global scale. To improve our capability to *quantify* coastal nutrient effects, considerable effort is needed. At the most recent Global NEWS2USE meeting, a strategy was developed to move forward with this work.
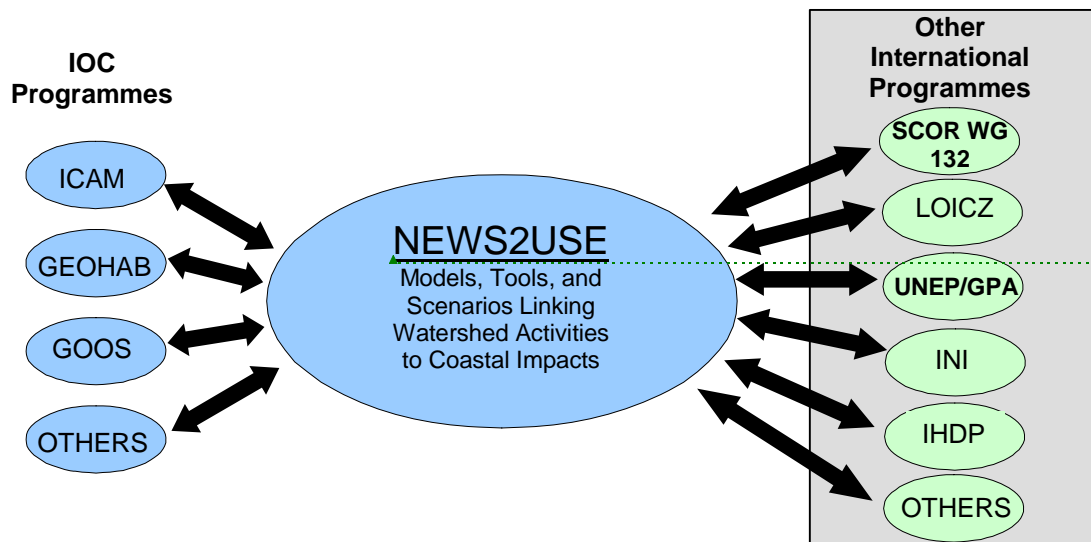
Figure 1. A conceptual framework demonstrating how NEWS2USE will interact in mutually beneficial ways with multiple IOC and non IOC programs. IOC programs with which NEWS2USE will help unify include Global Ocean Observing System (GOOS), the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) program, the Integrated Coastal Area Management (ICAM) program. Non-IOC programs with which NEWS2USE will interact directly or indirectly include Land-Ocean Interactions in the Coastal Zone (LOICZ), the SCOR/LOICZ Work Group 132, UN Environment Program Globlal Programme of Action for the Marine Environment (UNEP/GPA), the International Nitrogen Initiative (INI), and the International Human Dimensions Programme (IHDP). Depending on the group, interactions with other entities will include sharing personnel, sharing data, formal and informal scientific collaboration, co-hosting/co-funding workshops and open science meetings, outreach, identification of stakeholder groups, publication, peer review, dissemination of results in less formal venues. For additional details regarding anticipated interactions between NEWS2USE and other international entities, see section 4.
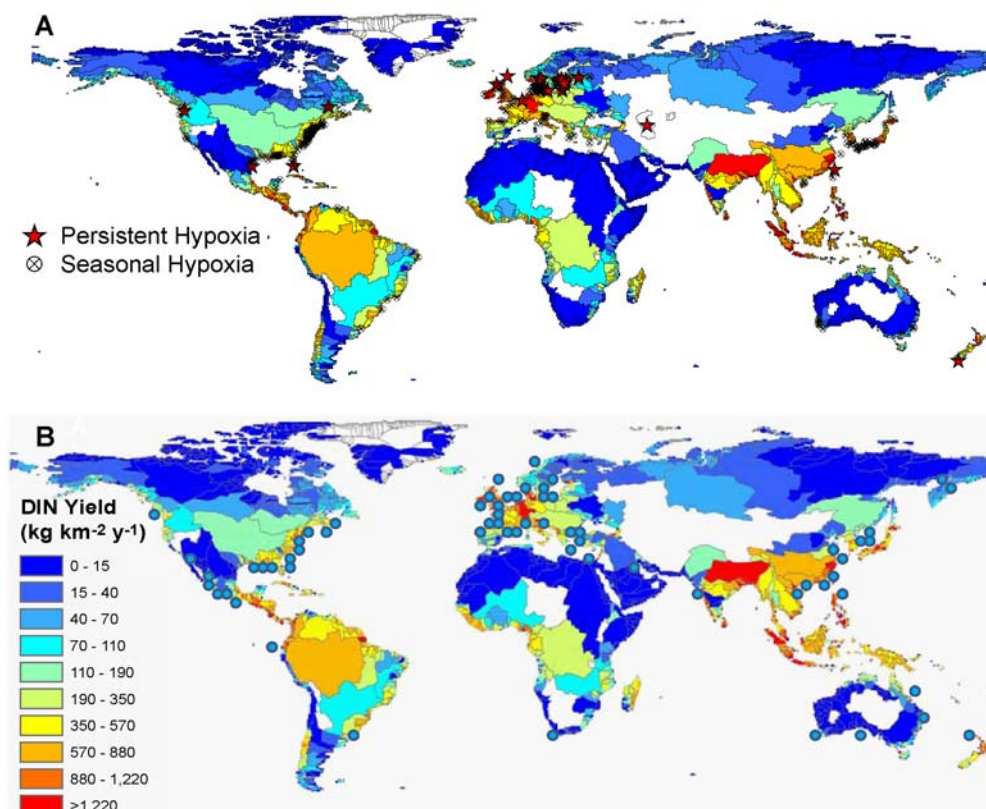
Figure 2. Spatial correspondence between NEWS-model-predicted DIN yield (kg N km^{-2} yr^{-1}) and A) reported hypoxia events (Diaz and Rosenberg, 2008) and, and B) reported HAB (*P. minimum*) blooms (From Glibert et al., 2008). NEWS2USE will provide a sophisticated quantitative approach to analyze spatial correlations between nutrient loading and HAB and hypoxia occurrences, and will employ a retrospective analysis using time series of hypoxia and HAB occurrences to study changes occurring over recent decades. NEWS2USE will also use Millennium Ecosystem Assessment scenarios for 2030 and 2050 to examine how coastal ecosystems are likely to respond to expected changes in coastal nutrient loading over the next several decades.

2. Background

5.   It is well-established that eutrophication, due to nutrient over-enrichment, is a major environmental problem in many coastal ecosystems around the world (e.g., National Research Council, 2000, Smil, 2001, Cloern, 2001, Howarth et al., 2002, Seitzinger et al., 2002, 2005; Bouwman et al., 2005a; Wassmann 2005; Conley et al., 2009). Nutrient sources driving coastal eutrophication are primarily associated with increasing human population, food, and energy production in watersheds and, in some cases, coastal aquaculture. The effects of eutrophication are many and include increased algal biomass, toxic and high-biomass HABs, hypoxia/anoxia, seagrass decline, increased water turbidity, and change in fisheries yields, among others. Yet, the relationships between nutrient loading and ecosystem effects, such as HABs or fisheries landings, are complex and variable and depend on the specific nutrient sources, ratios and forms, as well as the physical dynamics of the receiving waters, among many other factors (Glibert et al., 2005; Glibert and Burkholder, 2006; Heil et al., 2005). Predicting the effects of nutrient loadings on abundances of finfish and shellfish species targeted by fisheries are further complicated by the influence of fisheries removals and the complex interactions between nutrient enrichment, hypoxia and fishing practices in coastal waters (Caddy, 1993; Nixon and Buckley, 2002; Breitburg et al., 2009).

6.   Many coastal systems that exhibit eutrophication effects have been identified and in many cases the nutrient loading rates have also been quantified (Beman et al., 2005; National Research Council, 2000; Selman, 2007). To date, however, predictive (quantitative) relationships between nutrient loading rates (and changes in element ratios) and ecosystem effects (e.g., algal biomass, HABs, hypoxic/anoxic regions, seagrass decline, increases in turbidity, and changes in fisheries yields) applicable across a range of coastal systems have been lacking as outlined in a recent report (Seitzinger and Lee, 2008). A large amount of data, and increasingly sophisticated analytical approaches are now available to develop such relationships, including nutrient loading rates and quantitative measures of eutrophication, and physical properties (flushing rates, depth, etc.) for a wide range of coastal systems. Through improved global, spatially explicit models of nutrient loading from watersheds to coastal systems, better understanding of coastal dynamics, and the expansion of global databases on coastal algal biomass and production, including HAB occurrences and hypoxia, we are now in the position to begin linking patterns of eutrophication with coastal effects around the world in a more rigorous and quantitative way. Enhanced observing systems are also advancing our knowledge base of coastal effects.

7.   There is a need for integration of knowledge and data on the impacts of nutrient loading in coastal marine ecosystems, particularly in developing countries, for managers and policy makers of national governments and international organizations like IOC of UNESCO and UNEP. Often policies with respect to nutrient management are oriented towards local solutions, such as wastewater treatment. However, the impact of nutrient loading often spreads across boundaries, and particularly in the marine environment problems associated with eutrophication may have multiple and multinational sources. Examples of such regional integrative activities are the OSPAR Commission for the Northeast Atlantic, the Helsinki Commission (HELCOM) for the Baltic Sea and the different programmes established under the UNEP Regional Seas Programme. Global integration of data, models and knowledge with a focus on the developing countries is therefore a useful addition to these existing regional activities, and NEWS2USE will coordinate with these groups to minimize overlap and maximize scientific output and policy effectiveness.

8.   Estimating nutrient export to the coastal zone has been a challenge, but enormous advances have been made with respect to global models over the past several years. The first global model of N loading to coastal systems was published just over 10 years ago (Seitzinger and Kroeze 1998). Since then, several other global and regional nutrient export models have been developed, including six compared in Alexander et al. (2002). Models that describe total phosphorus export have also been developed (e.g. Johnes, 1995, Caraco 1995, Smith et al, 2003). However, these models have focused on a single nutrient (N or P) and a single nutrient form (most often total N or P, though some predict dissolved inorganic N or P). Also, because these models have been developed largely in isolation from each other, using inconsistent input datasets, it is often very difficult to apply these models in a common framework. For investigating the impact of nutrient loading on HABs, hypoxia and fisheries it is important to know both the total load of carbon, nitrogen, phosphorus and silica and also the different forms of each of these elements. For example, it has been suggested that some HAB species have a preference for specific nutrient forms such as ammonia or urea (Glibert and Burkholder, 2006).

9.   The IOC Global Nutrient Export from WaterSheds project (Global NEWS) has now developed models of nutrient export for dissolved inorganic, dissolved organic and particulate N, P and carbon (C), as well as for dissolved silica (DSi). Global NEWS is unique as a global nutrient export model because it provides an integrated, internally consistent approach to modeling river export of nitrogen, phosphorus, silica and carbon, and the different forms of these elements. The Global NEWS framework includes the Integrated Model for the Assessment of the Global Environment (IMAGE) to generate spatially explicit land use, greenhouse gas emissions, and climate fields (Bouwman et al., 2006), the Water Balance Model (WBM) for predicting river discharge (Fekete et al., 2002), and the Global NEWS river-basin scale nutrient export models (Figure 3). The Global NEWS framework can be used to evaluate effects of socio-economic developments, climate change, food consumption, agricultural nutrient management, dam construction and consumptive water use, and sewage treatment trends on river nutrient export. The Global NEWS models utilize relatively simple approaches to simulate in-stream retention of nutrients (e.g. denitrification and burial in rivers, lakes, reservoirs, etc.). The global NEWS system uses consistent input databases for predicting export of dissolved inorganic nitrogen and phosphorus (DIN, DIP), dissolved organic carbon, nitrogen and phosphorus (DOC, DON, DOP), total suspended solids (TSS), particulate organic carbon (POC), particulate nitrogen and phosphorus (PN and PP), and dissolved silica (DSi). These models account for nutrient sources (natural as well as anthropogenic, including fertilizer, atmospheric deposition, crops, manure and sewage), hydrology, land use, and physical factors in watersheds (see, for example, Figure 4). Results for estimates of the 1995 global condition were published in a special issue of *Global Biogeochemical Cycles* in 2005 (see especially Beusen et al., 2005; Bouwman et al., 2005a,b; Dumont et. al., 2005; Harrison et al., 2005a,b; Seitzinger et al., 2005). Since 2005, the Global NEWS project has advanced models of global nutrient stoichiometry, and developed a model for describing river dissolved silica export (Beusen et al., 2009).

10.   In addition, the Global NEWS work group has developed scenarios for river nutrient export for the years 2030 and 2050 based on the Millennium Ecosystem Assessment (Alcamo et al., 2006) assumptions (special issue of Global Biogeochemical Cycles, forthcoming) (Figure 3). The Millennium Ecosystem Assessment (MEA) (Alcamo et al., 2006) developed four scenarios: Global Orchestration (GO), Order from Strength (OS), Technogarden (TG) and Adapting Mosaic (AM). On the basis of these scenarios and their storylines, scenarios for nutrient management in agriculture and for wastewater management have been developed to assess possible future river nutrient export using the Global NEWS model framework (special issue of Global Biogeochemical Cycles, forthcoming).
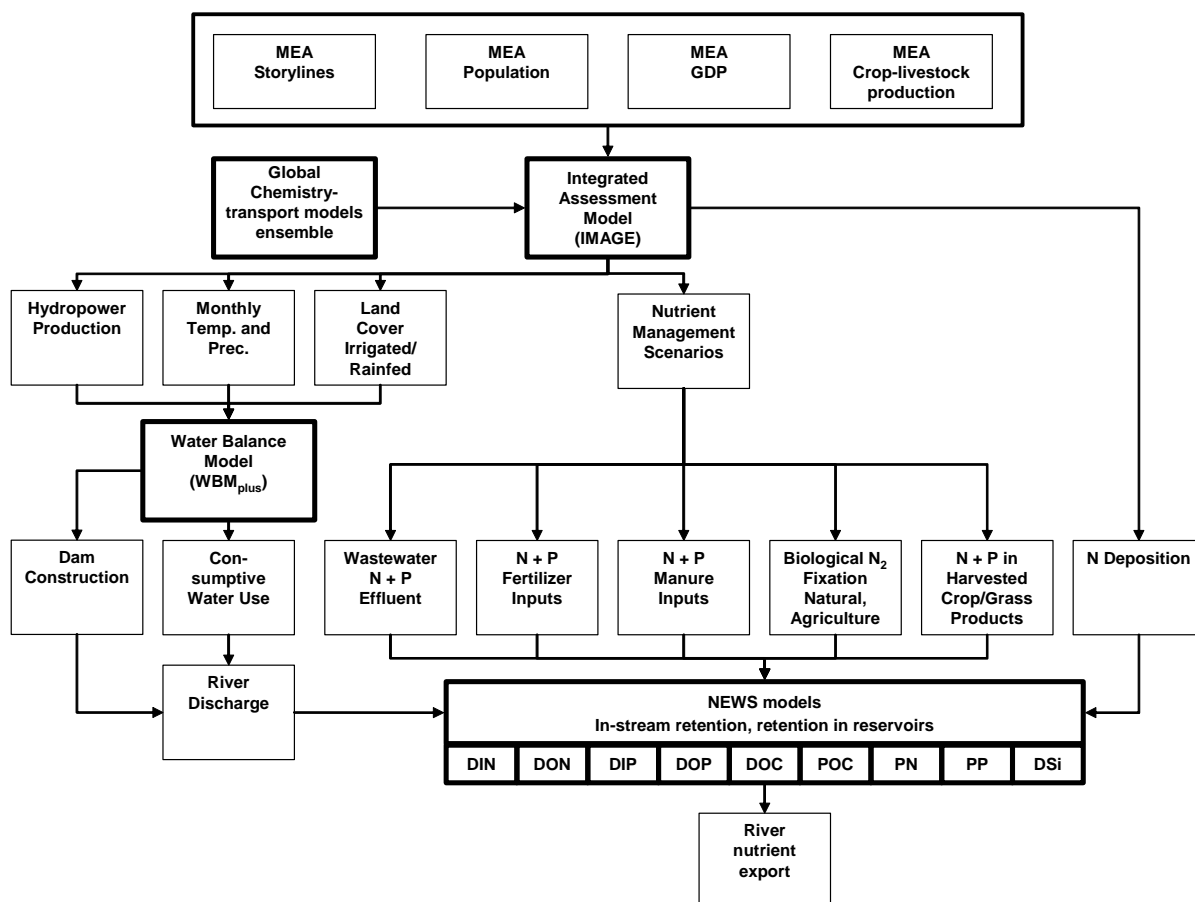
Figure 3. Scheme showing the input data and information flows into the NEWS models for the retrospective analysis 1970-2000 and assessment of scenarios for 2030 and 2050 based on the Millennium Ecosystem Assessment (MEA). All data are spatially explicit with 0.5 by 0.5 degree resolution. The NEWS2USE tool will include all the data generated in Global NEWS, as well as the Global NEWS models; the Integrated Assessment Model (IMAGE) and the Water Balance Model (WBM) were part of the Global NEWS project to supply input data for the NEWS models, and will not be included as such in the NEWS2USE tool.

11.   Hence, the development of the multi-element and multi-form Global NEWS models has positioned us to begin developing quantitative relationships between coastal nutrient loading and coastal impacts at the global scale, such as eutrophication, HAB development, hypoxia, and the attendant effects on fish and fisheries. Yet, apart from applying the concept of the Indicator for Coastal Eutrophication Potential (ICEP) (Billen and Garnier, 2007) and preliminary comparisons of correspondence of N loading and hypoxia occurrence and extent and HAB events for specific species (Figure 2), the Global NEWS project has not looked into the effects of nutrient loading in coastal marine ecosystems. Furthermore, we are not aware of any attempt to link nutrient loading and coastal effects at the global scale. Therefore, an exciting next step is to use the Global NEWS (and possibly other) models to develop approaches for assessing the impact of human activities on coastal eutrophication. At the most recent Global NEWS2USE meeting, a strategy was developed to move forward with this work.

Agriculture is the dominant source of N exported

from many watersheds to coastal systems
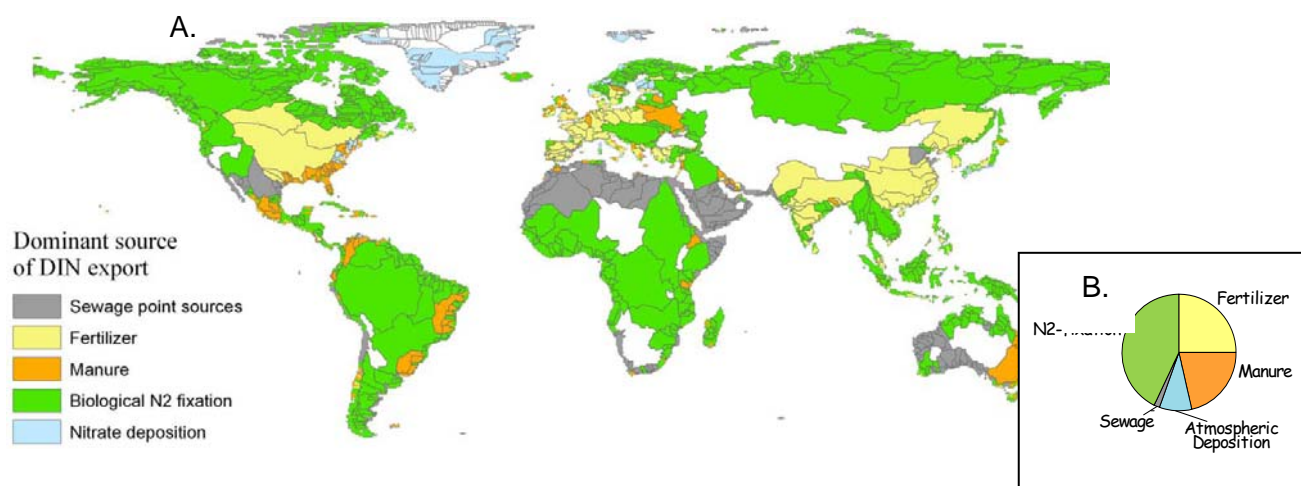
Figure 4. A) Single largest source of DIN in watersheds exported by rivers to coastal systems by large river basin; and B) Global perspective on the relative contribution of different N sources in global watersheds. Output from global watershed NEWS-DIN model (from Dumont et al., 2005; Seitzinger et al., 2005).

3. Key research questions

12.   The key research question for NEWS2USE is:

Can we predict how natural and anthropogenic factors interact to modulate coastal zone ecosystems and stresses on organisms ranging from phytoplankton to fish?

13.   This question can be broken down into the following sub-questions:

a.   Have anthropogenic increases in coastal N and P delivery resulted in elevated chlorophyll concentrations, greater coastal primary productivity, increased frequency and severity of coastal hypoxia, HAB development, and/or negative impacts on fish and fisheries?

b.   Is there a relationship between anthropogenic changes in element ratios (N:P:Si) and forms (inorganic/organic, dissolved/particulate) of land-based nutrients delivered to coastal ecosystems and observed changes in abundance and species composition of coastal primary producers, often favoring the development of HABs. Do specific nutrient ratios or forms favor different functional groups or species of HABs?

c.   How are effects of anthropogenic alteration of coastal nutrient inputs modulated by natural factors, such as the type of coastal system, rates of upwelling, conditions favoring stratification, inputs from the open ocean and inter-annual climate variability?

d.   Is the occurrence of some specific HAB species related to nutrient inputs from finfish aquaculture in coastal marine ecosystems, and nutrient transformations in shellfish and aquatic plant production systems?

4. NEWS2USE Goals and Integration with Existing Programs

14.   One central goal of the NEWS2USE program is to act as a link between several IOC programs with interest in aspects of coastal zone biology, chemistry or management (Fig. 1). The

Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) program has as its scientific goal the improved prediction of HABs by determining the ecological and oceanographic mechanisms underlying their population dynamics, integrating biological, chemical and physical studies supported by improved observation and modelling approaches, and specifically has one of its five Core Research Projects on HABs in Eutrophic Systems. The goal of the IGBP Land-Ocean Interactions in the Coastal Zone Program (LOICZ) is to provide the knowledge, understanding and prediction needed to allow coastal communities to assess, anticipate and respond to the interaction of global change and local pressures which determine coastal change. The Integrated Coastal Area Management (ICAM) programme brings natural and social scientists, coastal managers and policy makers together to understand how to manage the diverse problems of coastal areas. GOOS (Global Ocean Observing System) is a permanent global system for marine observation, modeling and analysis to support operational ocean services worldwide. GOOS provides accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible, and a basis for forecasts of climate change. These programmes all share an interest in understanding and managing the coastal zone, and nutrient loading constitutes a crucial link between human activities and coastal ecosystem function. By developing quantitative relationships between natural and anthropogenic factors (as observed in part by GOOS), eutrophication, coastal effects such as hypoxia and HAB development (as studied by GEOHAB), and potential management responses (ICAM, LOICZ), NEWS2USE will link the activities of these heretofore largely independent programs.

15.   Thought has been given to the role that NEWS2USE will play in relation to other existing programs outside of IOC as well. In general, NEWS2USE will coordinate with other existing programs to develop quantitative models relating land-based activities and resulting nutrient inputs to coastal impacts, now and into the future.

16.   Special consideration has been given to the nature of the interaction between SCOR/LOICZ Work Group 132 on "Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems." An important aspect is that the NEWS2USE group includes the two co-chairs of the SCOR/LOICZ work group (Pat Glibert and Lex Bouwman). This will ensure that the collaborative synergies are maximized and duplication of effort avoided. In 2008 the SCOR/LOICZ work group 132 started its work with the collection of spatially explicit information on HAB occurrences. This group has focused, at least initially, on bringing together information on the occurrence of HABs, with the goal of mapping the distribution of such events. The first map to be produced is for distribution of Noctiluca, and a number of other species will be added in the coming years. Another near-term goal of the SCOR/LOICZ workgroup is to develop models that describe direct effects of aquaculture, including coastal nutrient loading from finfish aquaculture, as well as nutrient transformation by shellfish and nutrient uptake/transformation by aquatic plant production in coastal marine ecosystems. A longer-term goal of SCOR/LOICZ workgroup is to determine simple, empirical relationships between types of coasts, nutrient loading, and HAB occurrences for a few species, as well as frequency and duration of those species. The timing for support of NEWS2USE is ideal as the SCOR/LOICZ workgroup will be half way through its effort (or more) by the time NEWS2USE gets underway, meaning that NEWS2USE will be able to build meaningfully on work already accomplished by the SCOR/LOICZ work group. Much like NEWS2USE builds on Global NEWS, so too it will build on the SCOR/LOICZ effort.

17.   All of the goals of SCOR/LOICZ are entirely consistent with the goals of the NEWS2USE program, which aims to both extend and deepen analyses begun by the SCOR/LOICZ workgroup by (i) based on the statistical relationships found in SCOR/LOICZ develop more sophisticated statistical approaches that account for the physical conditions in coastal marine ecosystems; (ii) using process-based marine ecosystem models, (iii) link HAB occurrences with hypoxia and impacts on fisheries; and (iv) develop a tool that integrates (i) to (iii).

18.   The SCOR/LOICZ workgroup will provide a number of essential databases, statistical relationships and experiences for NEWS2USE to build on, and NEWS2USE will greatly extend the depth and impact of the SCOR/LOICZ analysis by enabling participants to delve into the simple

relationships developed by the SCOR/LOICZ work group even further by examining multiple indices of nutrient loading and eutrophication, as well as additional HAB species not included in the original SCOR/LOICZ effort. Important contributions from the SCOR/LOICZ work group that extend the capacity of NEWS2USE will include the development of a global dataset of coastal type, the collection and pre-processing of satellite images, the collection of additional information on nutrient loading and transformations by aquacultural production systems, and, of course, global occurrences, frequency, location, extent and duration of a number of HAB species. The SCOR/LOICZ work group will also support the generation of seasonal river nutrient export estimates using the original Global NEWS models. Depending on the progress in the SCOR/LOICZ work group, the number of HAB species will be extended in NEWS2USE to 5-6. NEWS2USE will proceed by including physical conditions in coastal marine systems (see preliminary list in 5.1), use of process-based models for simulating river nutrient export, deterministic models for describing impact of nutrient quantity and quality on the development of different "functional groups" of HAB species, hypoxia and conditions for fisheries in coastal marine systems.

19. The primary IOC product resulting from NEWS2USE will be an assessment tool for use by scientists as an aid to, and in close collaboration with, managers and policy makers from developed and developing regions to use in the evaluation and implementation of policies to improve coastal water quality. The capacity building aspect of NEWS2USE will be a critically important component.

20. This NEWS2USE tool will provide:

   a. Estimation of present-day contributions of different watershed-based nutrient sources to coastal nutrient loading and effects of nutrient loading on receiving waters;

   b. Models to estimate the magnitude of expected effects of further changes (reductions or increases, changing stoichiometry) in nutrient loading on coastal systems under a range of scenarios and to assess the effect of management and policy options on nutrient impacts in coastal marine ecosystems.

   c. Capability to apply models and visualize the results for any selected coastal sea, LME, region, country or river basin(s) with coastal marine area of influence.

5. Approaches and data needs

21. The activities required to satisfy the needs of NEWS2USE have been identified and delineated into 3 phases (short-term, months; medium term, 1-2 years; and longer-term, 2-4 years). Six subgroups were charged with specifying the approaches:

   5.1 River nutrient export and aquaculture;

   5.2 Chlorophyll

   5.3 Hypoxia

   5.4 HABs

   5.5 Fisheries

   5.6 Tool development.

22. One major activity essential to all subgroups concerns the development of a common database. A preliminary list of data that will be collected and integrated includes:

   a. **River nutrient loading data:** Global NEWS models and data (seasonal scale for dissolved, particulate, inorganic and organic) from SCOR/LOICZ work group.

b. **Aquaculture:** Spatially explicit models for nutrient inputs from finfish aquaculture, nutrient transformation by filter-feeding shellfish and uptake by aquatic plant production systems evolving from the SCOR-LOICZ work group on "Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems".

c. **Data on environmental conditions**: A common database which includes information about physical and biological conditions in coastal marine systems, such as:

o Physical conditions
  ▪ Stratification regime
  ▪ Water residence time
  ▪ Tidal excursion/height
  ▪ Sea-surface temperature
  ▪ Type of coastal system
  ▪ Extent of river plumes (seasonal and annual)
  ▪ Other controlling variables
  ▪ Upwelling

o Nutrient (N-P-C-Si) loading data
  ▪ Upwelling and inputs from the open ocean and other downstream water bodies
  ▪ Burial of nutrients (C, N, P, Si)
o Data (where available time series) on nutrient effects
  ▪ Chlorophyll and primary production
  ▪ Hypoxia
  ▪ HAB occurrences and types, partly from SCOR/LOICZ work group
  ▪ Fish and invertebrate abundances and fisheries landings

5.1 River nutrient export and aquaculture

23. The first subgroup of NEWS2USE is charged with modeling nutrient loading from rivers, finfish aquaculture, and nutrient transformations by shellfish and aquatic plant production. A first task of this subgroup is to make an inventory of available river export models outside Global NEWS and to compare and test their suitability for inclusion in this effort. Where relevant, these models or model elements or approaches will be incorporated in the Global NEWS framework. A prerequisite to inclusion is that the models can be run with input data from the Global NEWS framework. Global NEWS currently uses a lumped river-basin approach, but it is anticipated that the next generation of Global NEWS models will be grid-based, allowing for the use of within-basin variability of environmental conditions and human economic activities (Harrison et al., forthcoming). Incorporating within-basin spatial variation into NEWS models will allow users to assess differences in cost effectiveness of policy alternatives that result in, for example, placement of agriculture or implementation of specific management strategies in different parts of the river basin. Such detailed approaches may be more feasible for regional applications, but possible global application will be investigated in the course of NEWS2USE. A second task is to collect measured river nutrient discharge from various sources not included in the original Global NEWS set of data, and to use this additional data to further test, refine and improve the NEWS models and any other models that are included in the NEWS2USE effort.

24. In addition to improving and the NEWS models, the global and or regional application of the mechanistic Riverstrahler model (Billen and Garnier, 2000) will also be undertaken as part of NEWS2USE. Where the Global NEWS models have relatively simple approaches for simulating in-stream retention of nutrients (e.g. denitrification and burial in rivers, lakes, reservoirs, etc.), the Riverstrahler model uses a process-based approach. Riverstrahler has been applied in various river basins in Europe, and the use of the Global NEWS data has been tested (Sferratore et al.,

2005). With this approach the seasonality of river nutrient export, and the variability of the element ratios can be used to assess impacts in the coastal marine system.

25.   In addition to these efforts to improve existing models or develop new ones, an effort will be made to quantify the effect of aquaculture on coastal nutrient loading and coastal nutrient transformations. In the SCOR/LOICZ work group spatially explicit models will be developed that describe the nutrient flows in aquaculture for the current situation and for the four Millennium Ecosystem Scenarios, consistent with the Global NEWS scenarios. This includes finfish, shellfish and aquatic plant (seaweed) production. Finshish production includes freshwater and marine production systems, and herbivore and carnivore species. The marine finfish systems directly add to nutrient loading, and the carnivore production systems have an important link to fishery because of the large input of fish, fish meal and fish oil. Freshwater systems are an important component of food production systems, particularly in Asia, and play an important role in nutrient cycling on the land. These freshwater systems therefore need to be linked to the Global NEWS models for predicting river nutrient export. Shellfish includes crustaceans and molluscs, and some of these systems also use imported nutrient or feed inputs. A special case is the filter-feeding molluscs which consume algae and excrete particulate organic and dissolved inorganic nutrients. As has been noted before, ammonia and urea excreted by shellfish may be a cause of the development of HABs of specific species. The SCOR/LOICZ workgroup will analyze such relationships between aquaculture production and HABs. The NEWS2USE will take this further by (i) establishing the relationship between aquaculture and fisheries through feed requirements (fish, fish meal and fish oil); (ii) analyzing relationships between aquaculture and hypoxia; (iii) using the nutrient cycling in inland aquaculture production as an additional input to the Global NEWS models for predicting river nutrient export; (iv) improving the spatial allocation of the aquaculture production regions; (v) integrating marine aquaculture in the coastal typology and marine ecosystem models for modeling of the development of HABs, hypoxia and impacts on fisheries.

5.2 Chlorophyll

26.   An understanding of the relationship between coastal nutrient loading, coastal chlorophyll concentration, and primary production is relevant to an understanding of coastal hypoxia, the occurrence of high biomass HABs, and fisheries. Hence, a subgroup of NEWS2USE will focus on developing relationships between coastal nutrient loading, coastal chlorophyll concentrations, and coastal primary production. The first step in developing these relationships will be to compile a global database that includes both in situ and satellite-based (MODIS, SeaWiFS, and others) chlorophyll measurements from a range of coastal typologies and latitudes. Algorithms for determining chlorophyll concentrations from space in coastal waters will be evaluated. Chlorophyll concentrations will be compared with both field-based and model–based estimates of nutrient loading by element and form.

27.   Past analyses (e.g. Nixon 1992) and a preliminary analysis of large rivers (Harrison, unpublished) suggests that there is a fairly strong and positive relationship between river N loading and coastal chlorophyll concentrations, though this relationship requires further testing and evaluation. In the process of developing an empirical model relating nutrient loading to coastal chlorophyll concentrations, the NEWS2USE group will develop and refine approaches that will be useful for other sub-groups. For example, since nutrient sources (rivers, aquaculture, upwelling, deposition, open ocean) may be spatially separated from observed effects, GIS and sophisticated mathematical and statistical approaches will be used to link the data on seasonal nutrient loading, nutrient ratios and forms to observed coastal effects. Potential approaches range from simple (e.g. determining zones of influence for rivers as half-circles with areas proportional to river discharge using Warrick and Fong, 2004 relationships) to relatively complex (e.g. using seasonal river plume extent determined by analysis of satellite imagery).

28.   In addition to using data to develop empirical relationships between nutrient loading, coastal characteristics, and coastal chlorophyll, an effort will also be made to develop a deterministic model linking nutrient loading to primary production. The strategy for the development of such a

model will include surveying the scientific literature for existing deterministic or mechanistic models that describe the biogeochemistry of coastal ecosystems, that may be used for predicting chlorophyll. Models will be developed to predict chlorophyll concentrations are likely to be high and hence have the potential to support the onset of hypoxic events or HABs. In general, as chlorophyll is likely to be related in some fashion to the onset of hypoxia and potentially to the formation of high biomass HABs as well, this effort will support further investigations into relationships between nutrient loading and HAB formation and hypoxia.

5.3 Hypoxia

29. A subgroup of NEWS2USE will focus on developing relationships between coastal nutrient loading and hypoxic events. The first step in developing these relationships is to compile a global database that includes both systems with observed hypoxia and systems without observed hypoxia from a range of coastal typologies (e.g. fjords, coastal embayments, drowned river valley estuaries, and large rivers discharging directly to the coast) and geographic locations. At present the hypoxia data for the Continental United States is near to complete. The compilation of a global database will take 1-6 months. In the database the precise boundaries of hypoxic conditions will be included (where possible) as well as a list of hypoxic system characteristics that would be considered in the analysis. Furthermore, the database will include the temporal dimensions (duration, frequency), spatial extent of hypoxia and the severity (dissolved oxygen concentrations). The database will include upwelling dominated systems and inland seas.

30. The statistical approach used should account for possible spatial discontinuities and time lags between nutrient loading and seasonal hypoxia (nearly always hypoxia events are in summer/autumn). The approach will identify relationships between occurrence, temporal patterns and extent of hypoxia and how those relationships vary with system characteristics.

31. In addition to exploring the data for empirical relationships between nutrient loading, coastal characteristics, and coastal hypoxia, an effort will also be made to develop a deterministic model linking nutrient loading to primary production and the onset of hypoxia. As with the effort to model chlorophyll and primary production, the strategy for the development of such a model will include surveying the scientific literature for existing deterministic or mechanistic models that describe the biogeochemistry of coastal ecosystems, that may be used for predicting hypoxia. It is likely that a box model approach will be used to predict dissolved oxygen as a function of carbon fluxes and burial, and uptake rates of dissolved oxygen. Models will be developed to predict where hypoxia is likely to occur, as well as the extent and severity of hypoxic events and their potential impact on sessile species and biomass production.

5.4 Harmful algal blooms

32. The HAB subgroup of Global NEWS2USE will initially use the concepts developed by Smayda and Reynolds (2001) for testing relationships between nutrient loading and HAB occurrence globally. This conceptual model (Smayda and Reynolds, 2001) describes 11 life forms of HABs (dinoflagellates) relative to physical and chemical habitat. Global distributions of many of the species and life forms in this conceptual model are available and will be compared with global distributions of coastal types, N loading, P loading, N/P ratio, and N and P retention, Indicator for Coastal Eutrophication Potential (ICEP) maps from Global NEWS, and other indices of nutrient loading and retention to address the following question: do species of different so-called "life forms" have a different tendency to proliferate in different coastal typologies or regions of differential nutrient retention? The Smayda and Reynolds life forms include only dinoflagellates, and testing need to be extended to other species. For at least 2 HAB species, hindcasts (1970 conditions) will be developed. It is recognized that one limitation of this approach is that most globally available data are simply "events," with no information regarding intensity, extent, or duration. Also, global maps, while currently available for several species, need to be verified with original literature in some cases. This approach will draw on maps, data bases and relationships developed from the SCOR/LOICZ Work Group on "Land-based Nutrient Pollution and the Relationship to Harmful Algal

Blooms in Coastal Marine Systems". Depending on the progress in the SCOR/LOICZ work group, the number of HAB species will be extended in NEWS2USE to 5-6.

33.   Deterministic models will also be developed. These models will use a "functional group" approach to determine/predict if and when different functional groups develop in relation to nutrient quantity and quality. These deterministic models might draw on the "classic" concept that diatoms tend to proliferate when "new" nitrogen in the form of nitrate dominates, but flagellates tend to proliferate when "regenerated" nitrogen in the form of ammonium/urea/etc. dominates. These models will use loads of different nutrients (N, P, and Si), different nutrient forms (dissolved/particulate, inorganic/organic), and other parameters as inputs. Models will most likely need to include global predictions of new and regenerated production and some representation of seasonal effects.

34.   The use of the DARWIN models (Follows et al., 2007), now being developed for oceanic (not coastal systems) will be explored. In these models, algae are parameterized physiologically and allowed to "compete". For the scientific steering committee a new member is needed who is versed in these models. Specific regional case studies would allow better evaluation of regions where extent and duration of blooms are more accurately known. The GEOHAB approach includes comparison of case studies, so NEWS2USE will coordinate with GEOHAB regarding specific case studies to maximize the research potential of the two groups.

35.   Specific regional case studies may also be developed in consultation with GEOHAB and SCOR/LOICZ to further explore and test relationships suggested by the global analysis. There are numerous regions where excellent data bases exist with regard to species and/or toxins, and where excellent long-term data are available to characterize nutrient loading and coastal physical parameters likely to interact with nutrient loading to control HAB development. For this activity the detailed, spatially and temporally explicit river export models discussed in 5.1. will be used.

5.5 Fish and Fisheries

36.   The fifth sub-group of NEWS2USE will focus on the effects of land-based nutrient additions on fisheries and the species upon which they depend. The overall goals of the proposed Fish/Fisheries element are to improve the understanding and ability to predict effects of nutrient enrichment and hypoxia, and the interaction of nutrient enrichment, hypoxia and fisheries removals (including aquaculture and fisheries dependent on wild populations) on the abundance and composition of (1) fisheries landings, (2) abundances of finfish and mobile macroinvertebrates that are targets of fisheries (referred to collectively as fish or fishes below), and (3) benthic invertebrates that are important prey for fishes and are an ecologically important component of coastal ecosystems. The Fish/Fisheries element thus provides an examination of ecologically and economically important effects of nutrient enrichment (including enhancement of production by nutrient enrichment), and considers both food web and habitat consequences of nutrient enrichment.

37.   The first phase of this effort will focus on database development. The data to be collected include calibration databases and model output of foodweb models that predict biomasses of fishes under current and historical levels of primary production and fisheries exploitation at relevant spatial scales. Because it has been applied so widely, we anticipate that a rich database can be developed from Ecopath and Ecosim models (Pauly et al., 2000). We will also explore the compatibility of predictions of a variety of other statistical and food web models and use their results where possible. Currently available databases on fisheries landings (e.g., Breitburg et al. 2009) will be expanded to include data from additional systems and years.

38.   In the later stages of NEWS2USE, the Fish/Fisheries element will concentrate on the establishment of relationships between N, fish, fisheries and hypoxia using the nutrient loading data from rivers and other sources (e.g. aquaculture, atmospheric deposition, or groundwater) where needed. Factors such as of nutrient sources, system type, climate, population density and

local economic condition will be also be considered as drivers. In addition, Phase II will consider nutrient effects on fish abundances and fisheries landings at a variety of spatial scales.

5.6 Tool development

39.   The sixth subgroup of NEWS2USE will focus on the development of a tool that integrates results of the above studies on nutrient impacts on harmful algal blooms, hypoxia and effects on fisheries. This model-based tool will use a combination of empirical and deterministic approaches to estimate the magnitude of current and anticipated effects of anthropogenic alteration of coastal nutrient loading as a function of watershed characteristics (e.g. climate, lithology), human activities within watersheds (e.g. agriculture, urbanization), human activities within coastal waters (e.g. aquaculture, fishing), and coastal ecosystem characteristics (e.g. geomorphology, hydrodynamics). The tool will incorporate all global data and models brought together and developed in NEWS2USE, and will include the capability to visualize any selection of regions, seas, LMEs, country or river basin with the area of influence. The Integrated Assessment Model (IMAGE) and the Water Balance Model (WBM) were part of the Global NEWS project (Figure 2), and will not be included as such in the NEWS2USE tool.

40.   This tool will indicate where and when problem areas are likely to occur and will provide estimates of the relative importance of different nutrient sources within watersheds. The tool will, in a user-friendly environment, include geographic information at the global scale and all the relationships, models and scenarios developed in the NEWS2USE programme. It will allow stakeholders to use this information to generate maps for visualization of coastal effects in selected regions of interest. It will also allow users to assess the likely impact of various policy options in agriculture, wastewater, aquaculture, water engineering on the basis of retrospective analysis and future conditions for the Millennium Assessment scenarios. As such this tool will enhance the capacity of resources managers and policy makers to anticipate and avoid, social, economic, and environmental strife associated with degradation of coastal resources.

41.   We anticipate that this tool will be applied by scientists in close collaboration and with feedback from environmental managers and policy makers to assess the effects of management and policy alternatives on coastal marine ecosystems. The tool will integrate land-based diffuse and point sources of nutrients, and will also include impact modules for assessing the effects on primary production, hypoxia, harmful algal blooms and fisheries. This will allow scientists, managers, policy makers, and the general public to visualize the potential impacts of alternative development and mitigation strategies, a process that has proven effective in promoting conservation of resources in a number of cases worldwide. To be an effective aid to management, this model must be as useful and accessible as possible. Efforts to enhance the model's utility and accessibility will include: 1) the incorporation of stakeholders and potential model users (primarily policy-literate scientists) in model development, 2) easy distribution of the model via the internet, 3) the use, where possible, of non-proprietary software (e.g. Python) in building and running the model, and 4) the explicit development of model-related training and supporting materials and infrastructure.

6. Develop collaborations

42.   For inventorying, organizing and structuring all the possible cooperations with ongoing and planned programmes and activities, a workshop will be planned in the initial stage of NEWS2USE. For example, the work proposed in NEWS2USE is a useful input to GEOHAB modeling work for specific HABs. In addition to linking IOC programs and projects, including GOOS, GEOHAB, LME, and ICAM, NEWS2USE will also collaborate directly with relevant ongoing projects not directly supported by IOC, including: the SCOR/LOICZ work group on "Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems" (see section 5), LOICZ, ESA, and NASA (MODIS, SeaWiFS), IGBP, and U.S. EPA.

7. Enhance national and regional capacity

43.   At the end of Phase III of NEWS2USE a key activity will be to reach out to the broader community. This will be achieved through training workshops for scientists and policy specialists from IOC Member States to enhance national capabilities to apply NEWS2USE deliverables in a national and or regional context. During these training workshops, stakeholders will be trained in the use and application of NEWS2USE models and datasets. The extent of the training activity will be adjusted to the demand by Member States and the mechanisms available to fund the activities. The present workplan includes what is seen as the minimum training effort.

8. NEWS2USE web facility

44.   A web facility will be developed as part of the IOC web site in parallel with these activities. Initially the web facility will serve as a source of documentation on model development and a forum for communication and data exchange among project members, as well as general information on project goals and progress for the broader scientific and management communities. As the NEWS2USE tool develops, the web facility could serve as a mechanism for beta testing by the broader community. Eventually the web facility will be the platform for open use by all IOC member states, and a forum for discussion among model user groups (primarily policy-literate scientists, but also policy makers, natural resource managers, and educators).

9 Deliverables of NEWS2USE

The **table** below summarizes the deliverables presented in section 5, indicating the main stakeholders and beneficiaries. Since an aim of NEWS2USE is to link IOC programmes, IOC has an interest in all deliverables and therefore not listed as a stakeholder.

NEWS2USE subgroup	Deliverable	Main stakeholder(s) [S] and beneficiaries [B] includes
1. River nutrient export	1.1. Inventory of available river nutrient export models.	[S] LOICZ, UNEP/GPA, INI, IHDP [B] researchers
	1.2. Regional application of spatially explicit river nutrient export models	[S]LOICZ, UNEP/GPA, INI, IHDP, [B] national governments and regulatory agencies, local governments and regulatory agencies, resource managers, coastal inhabitants, coastal fisheries and shellfisheries, the tourism industry, aquaculturists, and researchers
	1.3. Global/regional application of Riverstrahler for assessing temporal variability of processes and river export	
	1.4. Aquaculture: relationship with fisheries, effect on hypoxia, integration in coastal ecosystem models	[S]FAO, International Food Policy Research Institute (IFPRI), [B] National institutes
	1.5. Aquaculture: improving spatial allocation, incorporation of inland aquaculture in Global NEWS	
2. Clorophyll	2.1. GIS and statistical approaches for linking coastal marine nutrient loading to coastal chlorophyll concentrations	[S]LOICZ, IMBER, UNEP/GPA, [B] researchers
	2.2. Deterministic or mechanistic model for linking coastal marine nutrient loading to coastal chlorophyll concentrations	
3. Hypoxia	3.1. Global database and maps of observed hypoxia (spatial extent, temporal dimensions, frequency, severity)	[S]LOICZ, IMBER, UNEP/GPA, [B] researchers, coastal inhabitants, coastal fisheries

NEWS2USE subgroup	Deliverable	Main stakeholder(s) [S] and beneficiaries [B] includes
	3.2. Statistical analysis of relationship between nutrient load and hypoxia (spatially, temporal patterns); empirical model development	and shellfisheries
	3.3. Deterministic model describing development of hypoxia as a function of nutrient loading	
4. Harmful algal blooms	4.1. Analysis of relationships between nutrient loading and HAB occurrence with life form approach including hindcast for 2 HAB species; depending on progress in SCOR/LOICZ, list of species will be extended	[S]LOICZ, IMBER, UNEP/GPA, [B] researchers, Coastal inhabitants and shellfisheries
	4.2. Deterministic models describing relationships between nutrient loading and HAB occurrence using functional group approach	
	4.3. Assessment of feasibility to use DARWIN models	
	4.4. Analysis of time series with the above approaches for specific regions or sites, in combination with models developed in 1.2	
5. Fish and fisheries	5.1. Database of past and current fish biomass, fish exploitation and fish landings	[S]FAO, International Food Policy Research Institute (IFPRI), National institutes, LOICZ, IMBER, IHDP, [B] National institutes, researchers, commercial and recreational fishermen, coastal inhabitants, conservationists
	5.2. Establish relationships between nutrient loading, hypoxia and fish abundance and composition and landings at different spatial scales	
6. NEWS2USE tool	Integration of 1-5 in a user friendly, accessible tool for hindcasting and analysis of future changes and policy strategies; Coastal nutrient loading and response scenarios for 2030 and 2050	[S]All above stakeholders [B] policy makers, both national and international; national governments, local governments, resource managers, coastal inhabitants, coastal fisheries and shellfisheries, the tourism industry, tourists, coastal recreationists, aquaculturists, environmental educators, and researchers, students and general public
7. Databases and web facility	Databases from different subgroups, major outputs and maps of NEWS2USE, NEWS2USE tool with user manual and model documentation; scientific papers describing all deliverables and applications; synthesis of all results	[S] All above stakeholders [B] policy makers, both national and international; scientists, students, general public
8. Overall NEWS2USE	Enhanced national and regional research and management capacity through training workshops in the use of the modeling tool.	[B]Scientists, resource managers, and policy-makers from developing regions experiencing, or likely to experience, nutrient related changes in coastal zone function
9. Overall NEWS2USE	Peer-reviewed publications / Special issues of a journal	[B]Researchers and resource managers

10. Scientific Steering Committee

45.   The terms of reference for a Scientific Steering Committee of the NEWS2USE are proposed as:

1.   Act as the intersection of and collaborate with IOC of UNESCO Programs and activities related to nutrients (GEOHAB, ICAM, GOOS, LME,)

2.   Develop the NEWS2USE Science and Implementation Plans.

3.   Coordinate and implement research in accordance with the NEWS2USE Science and Implementation Plans.

4.   Foster framework activities to facilitate implementation of NEWS2USE, including dissemination and information tools.

5.   Establish appropriate data management activities to ensure access to, sharing of, and preservation of NEWS2USE data, taking into account the data policy of the IOC.

6.   Collaborate, as appropriate, with the concerned intergovernmental and non-governmental organizations (e.g., UNEP, SCOR), and their subgroups and related research projects (e.g., LOICZ, IMBER).

7.   Review NEWS2USE research progress over time and report regularly to the IOC and the global marine science research community on the state of planning and accomplishments of NEWS2USE, through annual reports, the NEWS2USE web site, an electronic NEW2USE Newsletter, special sessions at scientific meetings, and other venues.

8.   Interact with agency sponsors to stimulate the support of NEWS2USE implementation through various mechanisms (e.g., direct support of NEWS2USE initiatives and integration of the NEWS2USE approach in national programs).

   Approved {date} by the IOC Assembly.

46.   The following expertise is identified as essential to the SSC:

   Modeling coastal nutrient loading (i.e. NEWS models)

   Phytoplankton time series and remote sensing

   Upwelling-phytoplankton interactions

   Tropical fisheries and aquaculture

   Nutrient cycling in aquacultural production systems

   Applying Darwin models to coastal systems

   Coastal typology

   Coastal Hypoxia

   Coastal Harmful Algal Blooms

   Coastal Physical Oceanography

   Coastal Biogeochemistry

   Nutrients and estuarine primary productivity

   Nutrients, Hypoxia, Fish and Fisheries

   GIS and statistical approaches, database management

   Translation of science to management

47.   The SSC will build on the members of NEWS and the development workshop (see Annex II), with the addition of the required specific scientific and geographical expertise.

11. Workplan and required funding

48.   The coastal zone ecosystem stresses on organisms that will be considered by NEWS2USE are HAB, hypoxia and impacts on fish and fisheries (abundance, composition, landings). The proposed approach comprises short term (Phase I), medium (Phase II) and long term (Phase III) activities. Phase I concentrates on data collection and the establishment of statistical relationships between nutrient loading and harmful algal blooms and hypoxia based on the data that is available at the start of the project. For fisheries the short term activity is the collection of data. Phase II will focus on the development and use of deterministic models to describe nutrient impacts in coastal marine ecosystems. Phase III will include the integration of insights gained in Phases I and II as well as the development of a tool for evaluation and implementation of management options and policies to improve coastal water quality, based on the results of Phases I and II.

49.   The various tasks and estimated work load in each phase are listed in the tables on the next pages. For the NEWS2USE programme, funding is required for Ph.D. or postdoctoral positions. Participating institutes and organizations will provide approximately 92 man-months needed for supervision and support of the PhDs and postdocs. Apart from the funding requested for the Ph.D. or postdoctoral positions for the full period of the program, funding is requested for one meeting to organize and structure the linking with other programmes and activities, annual steering committee meetings with project members, and two open science meetings (in 2012 and 2015), for publication of the results, and for 2 training workshops aimed at coastal zone scientists and managers from developing regions.

50.   Estimated budget items thus include:

	Years	Cost/Yr.	Total
5 Postdoctoral Scholars	5	$350,000.00	$1,750,000.00
Database Manager	5	$60,000.00	$300,000.00
Travel/workshops	5	$40,200.00	$210,000.00
Open Science Meetings	2	$40,000.00	$80,000.00
Publication Costs	2	$40,000.00	$80,000.00
Training Workshops	2	$40,000.00	$80,000.00
Total overall			**$2,500,000.00**

Workplan for NEWS2USE activities					
	River nutrient export	**Chlorophyll**	**Hypoxia**	**HABs**	**Fisheries**
Phase 1					
Workshop	Workshop with key-persons from relevant programmes, projects and activities to inventory potential collaborations, data and information exchange and to elaborate a detailed workplan				
Databases	Collect common data on physical and environmental conditions. For a preliminary list see section 5.1.				
	Use seasonal river export based on hydrology from Global NEWS data as prepared by SCOR/LOICZ work group; estimate nutrients from aquaculture; calibration/validation data in addition to model output; enhanced temporal and spatial applications; Inventory of available and relevant models; selection of models or model elements for inclusion in Global NEWS	Satellite images, data (partly from SCOR work group)	Compile geo-referenced data on global occurrences, frequency, location and extent of hypoxia	Global occurrences, frequency, location, extent, and duration of HABs for 5-6 species, SCOR/LOICZ working on developing some of these; check georeferencing, HAEDAT	Compile data of global landings, abundance and composition
Geographical linking	Linking river loads, aquaculture nutrient output, and transformations to hypoxia, HAB and fisheries impacts, for example using coastal typologies, chl as precursor (Can be initiated as soon as hypoxia, HAB and fish data are available; from then will require 6 months)				
Statistical Models	Develop statistical approaches to establish relationships between nutrient loads and coastal effects at the global scale; initially on annual basis, then seasonal (Can be initiated as soon as hypoxia, HAB and fish data are available)				
Hindcasting/Forecasting	Use statistical models to generate estimates of hypoxia and HAB formation for past decades (1970-2000) and future years, based on Global NEWS simulations of river nutrient export for the four Millennium Ecosystem Assessment scenarios (2030; 2050)				
IOC web site	Key research questions, project plan, members, steering committee and terms of reference, databases, first results, ppts and pdfs of relevant papers (already underway)				
Publications	Consider special issue				
Phase II					
Statistical Models					More elaborate

Workplan for NEWS2USE activities					
	River nutrient export	**Chlorophyll**	**Hypoxia**	**HABs**	**Fisheries**
					statistical modeling, scenarios
Deterministic Models	Global applicaton of Riverstrahler model and comparison with NEWS models	Develop simple deterministic/conceptual models for global application; should deal with development of HABs (by functional group) and hypoxia (starting at beginning of project)			Model development and sensitivity analyis to examine how drivers such as fishing pressure, food-web interactions, etc., affect abundance and food-web structure (done by the end of yr 4)
Decisions that will have to be made in order to develop all coastal impact models	How to deal with marine-derived nutrients, coastal typologies, chlorophyll as precursor, residence time, tidal prism, salinity gradient, etc. (Will start addressing these issues at the project outset)				
Phase III					
Integration	Integration of individual sub-projects to examine how interactions between effects control coastal ecosystems and human health and well-being. Examine whether there are synergistic effects between stresses, feedbacks between stresses (e.g. hypoxia and fishing). Perform a sensitivity analysis where multiple stressors change simultaneously				
Tool development	Develop and implement a tool that integrates all the above in a form that is appropriate for assessing management and policy options and developing nutrient criteria, including a user manual, documentation, and a mechanism for dissemination				
Additional training workshops	Workshops for training scientists and policy makers from developing countries in using the tool				
Open Science Meeting	2012 (with SCOR and GEOHAB) and 2015				
Publications	Consider special issue				
Training workshops	2015				

Estimated person-months required for the NEWS2USE activities					
	NEWS models/deterministic models	**Chlorophyll**	**Hypoxia**	**HABs**	**Fisheries**
From requested funding					
Research positions for Phase I-III	60 months PhD/postdoc	60 months PhD/postdoc	60 months PhD/postdoc	60 months PhD/postdoc	60 months PhD/postdoc
Database management	12 months database manager				
Contributions from institutes/universities					
Phase I	2 months	6 months	12 months	12 months	12 months
Phase II	12 months		6 months	6 months	12 months
Phase 1II			12 months		
Total	14	6	21	21	30

Annex 1. Objectives of this organizational workshop

The organizational workshop, which included key persons from related IOC programs and associated projects and additional participants with specific expertise (See Annex 1 for participants), had the following objectives:

1. Define the key research and policy questions that need to be answered with the NEWS2USE (Nutrient Export from Watersheds- User Scenario Evaluation) toolbox.

2. Define goals for this activity

3. Assess suitable approaches and define specific activities and tasks for answering the key questions and assess data and information needs, expertise required

4. Develop a work plan covering 4-5 years and estimate the support needed

5. Develop collaborations and explore synergisms that this group could bring to bear

6. Draft the terms of reference for the Steering Committee (for approval by the IOC) and propose a Steering Committee for the Project (for approval by the IOC Secretariat)

7. Training workshops at IOC for scientists and policy specialists from IOC member countries and regional workshops to use, evaluate and refine models/tools

8. Establish a web facility as a source of documentation on model implementation, a clearinghouse for modeling results, and a forum for discussion among model user groups.

Annex 2. Participants of the organizational workshop

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Annex 3. Workshop programme

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Organizational workshop of the NEWS2USE programme
Coastal Eutrophication: Linking Nutrient Sources
to Coastal Ecosystem Effects and Management
The intersection of several UNESCO-IOC Programmes Related to Nutrients
UNESCO, Paris, 2-4 February 2009

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2 February

Morning	-Welcome, introduction by Luis Valdez (Ocean Science Section of IOC) -Practical details by Henrik Enevoldsen, IOC Programme Specialist -Introduction, workshop goals (Lex Bouwman & John Harrison) -Introduction to Integrated Coastal Area Management Programme of IOC (Julian Barbière) -Introduction to GEF proposal "Providing the tools for reducing nutrient enrichment and oxygen depletion from land-based pollution of coastal waters in Large Marine Ecosystems (LMEs) (Sybil Seitzinger) -Introduction to GEOHAB and SCOR work group on "Land-based Nutrient Pollution and the Relationship to Harmful Algal Blooms in Coastal Marine Systems"(Pat Glibert) -Presentations of participants clarifying their ideas for this project from their field of work (10 min. each + 5 min. discussion)
Afternoon	-Presentations of participants clarifying their ideas for this project from their field of work (10 min. each + 5 min. discussion) -Discuss/make programme for the workshop days, see the list of topics below.

3 February

Morning	-Discussion of NEWS2USE central research questions -Introduction by Patricio Bernal, IOC Executive Secretary
Afternoon	-Break-out groups harmful algal blooms, hypoxia and fisheries to discuss research strategy, data requirements

4 February

Morning	-Discussion of terms of reference for the scientific steering committee -Discussion of potential members of the scientific steering committee -Drafting of workplan
Afternoon	-Drafting of workplan, continued -Discussion on funding requirements -Various issues, wrapping up.

Annex 4. Literature

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Annex 5. Acronyms

GEOHAB= Global Ecology and Oceanography of Harmful Algal Blooms Programme

GOOS= Global Ocean Observing System

ICAM= Integrated Coastal Area Management programme

ICES = International Council for the Exploration of the Seas

IMBER = Integrated Marine Biogeochemistry and Ecosystem Research project

IOC = Intergovernmental Oceanographic Commission

LOICZ = Land-Ocean Interactions in the Coastal Zone project

LME= Large Marine Ecosystems

NEWS2USE = Nutrient Export from WaterSheds (2), User Scenario Evaluation project

PICES = North Pacific Marine Sciences Organization

SCOR = Scientific Committee on Oceanic Research