ASSETS eutrophication assessment: method and application

Suzanne B. Bricker[1] and Joao G. Ferreira[2]
[1]*National Oceanic and Atmospheric Administration, Silver Spring, MD 20910, USA,* *suzanne.bricker@noaa.gov*
[2]*Institute of Marine Research, Monte de Caparica, Portugal,* *joao@hoomi.com*

The Assessement of Estuarine Trophic Status (ASSETS) assessment method is a Pressure-State-Response model that has been used most recently to complete the update of the National Estuarine Eutrophication Assessment (NEEA), an examination of a decade of change in nutrient related impacts in 141 U.S. estuaries. It has also been applied to systems from Europe and Asia and shows that similar eutrophic symptoms occur in coastal waterbodies around the globe. The model includes three components: *Influencing Factors* which are a combination of natural system susceptibility and human-related nutrient loads, *Overall Eutrophic Condition* based on the combined staus of five indicators (chlorophyll a, macroalgae, dissolved oxygen, seagrass distribution, and nuisance/toxic blooms), and *Future Outlook* which examines how conditions will change in the future. The three components are then combined into a single rating for a system.

The NEEA results show that eutrophication is a widespread problem in U.S. systems with 65% of assessed systems showing moderate to high level problems (Figure 1).

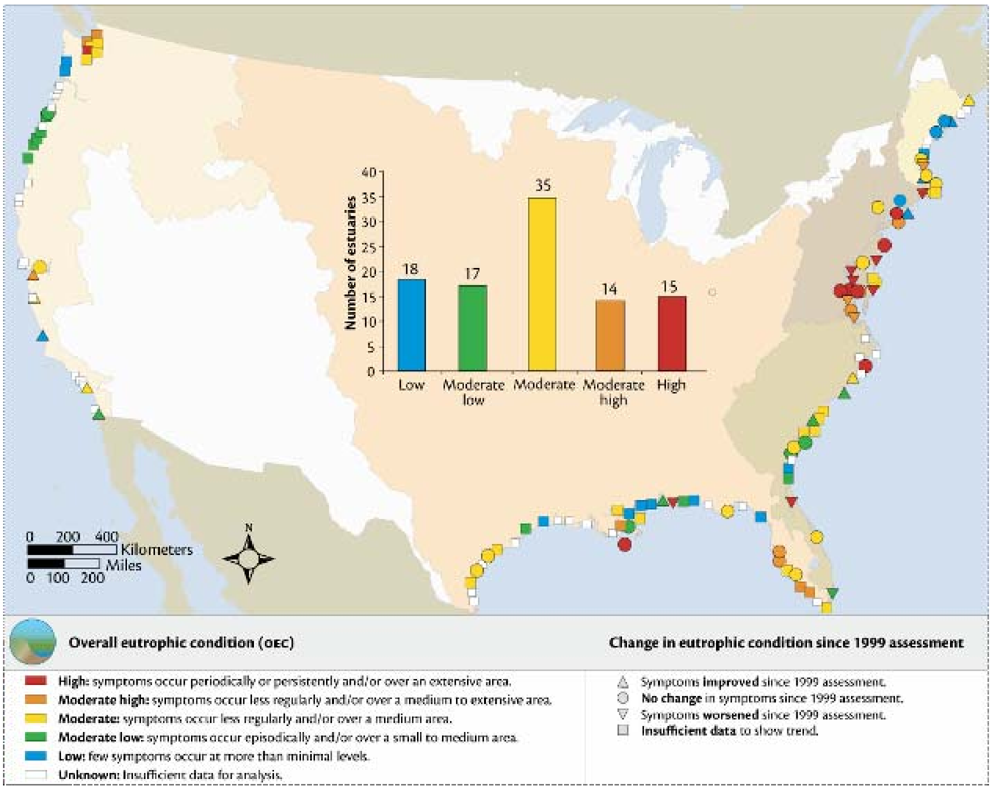

Figure 1: Overall eutrophic condition in US estuaries.

The most impacted region was the mid-Atlantic which is also the most densely populated region.

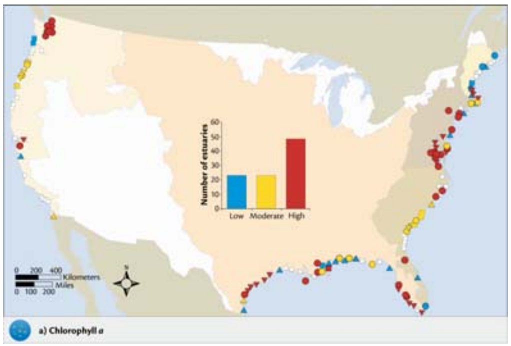

Figure 2a: Chlorophyll a symptom expression in US estuaries.

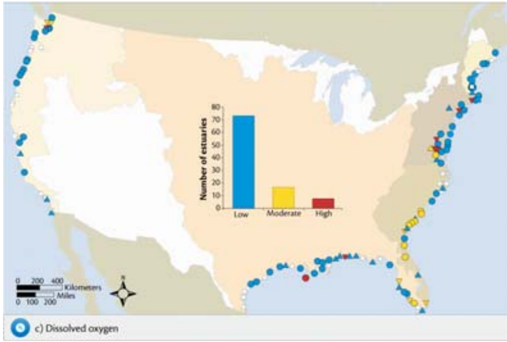

Figure 2b: Dissolved Oxygen symptom expression in US estuaries.

The least impacted area was the North Atlantic which has relatively low population density but these systems also have a high tidal range and thus good flushing capability.The most frequently reported symptom was chlorophyll *a* which was observed at high impact levels in many systems, particularly the mid-Atlantic but also in the Pacific northwest and the Gulf of Mexico region (Figure 2a).

In contrast, dissolved oxygen was reported in many systems but was at significant problem levels in only a handful of systems, mostly in the mid and South Atlantic regions (Figure 2b).

The majority of estuaries assessed are highly influenced by human related activities that contribute to land-based nutrient loads.

The mid-Atlantic region was the most influenced by human-related activities, while the North Atlantic region was the least influenced (Figure 3). The top reported sources of nutrients that contribute to eutrophic impairments were agriculture (both crops and animal operations), wastewater treatment plants, urban runoff and atmospheric deposition. Note that three of the top four are non-point sources which are much more difficult to control than point sources and thus

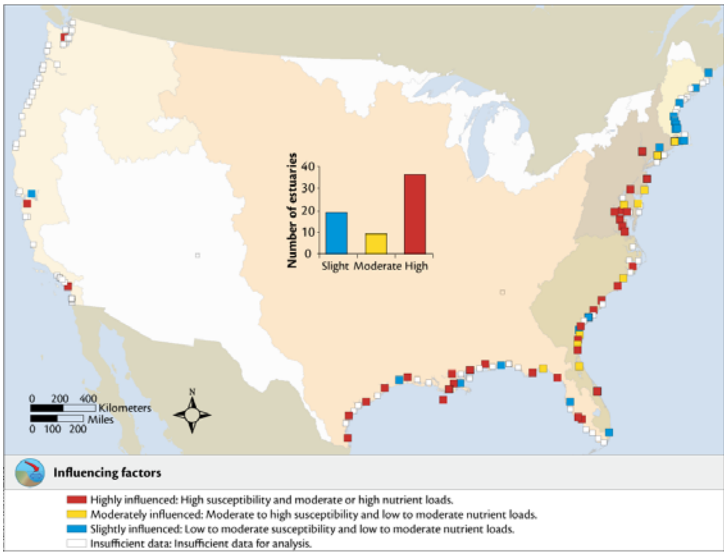

Figure 3: Influencing factors of eutrophic impairment for US estuaries.

present a formidable challenge for resource managers. Conditions were predicted to worsen in 65% of the systems due to expected increases in coastal watershed populations, and improve in 19% of assessed estuaries in the future.

This is a result of expected increases in human activities within coastal watersheds and particularly the rise in coastal population which is expected to increase 12% by the year 2020 (Figure 4). The ASSETS synthesis can only be made if all three components are complete and because of inadequate data for many systems, an ASSETS rating could be made for only 48 systems. For those systems for which the synthesis could be made, 88% were rated as moderate to bad and for 50% the rating was poor or bad. Change analysis (early 1990s to early 2000s) shows that in systems where the analysis could be made, conditions have mostly remained the same (32 systems) though changes were observed in several smaller systems; 13 systems improved due to management efforts (primarily point source) and 13 systems worsened as a result of coastal population increases.

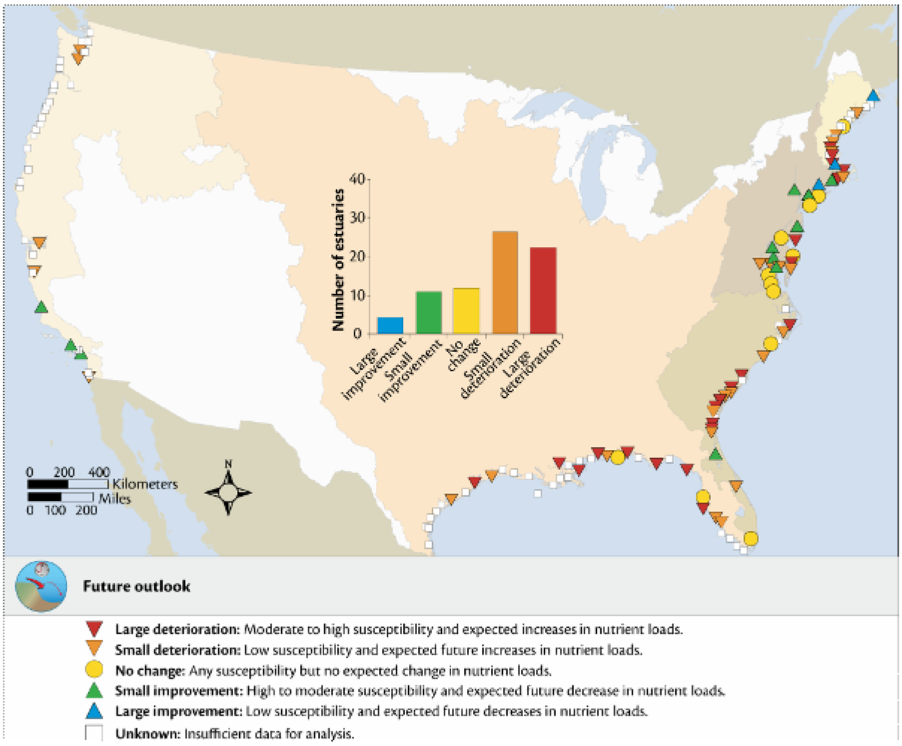

Figure 4: Future outlook for eutrophic conditions in US estuaries.

Case studies for systems from Europe (e.g. Venice lagoon) and Asia (e.g. Yangtze estuary) show that eutrophication is not restricted to U.S. waters and that management measures have worked to improve conditions in some systems (Figure 5).

The intent of the ASSETS approach is to provide information for management (i.e. status, causes of observed problems and probable future changes in condition) and in large scale studies may also be used to prioritize mangement and research to maximize use of limited resources.

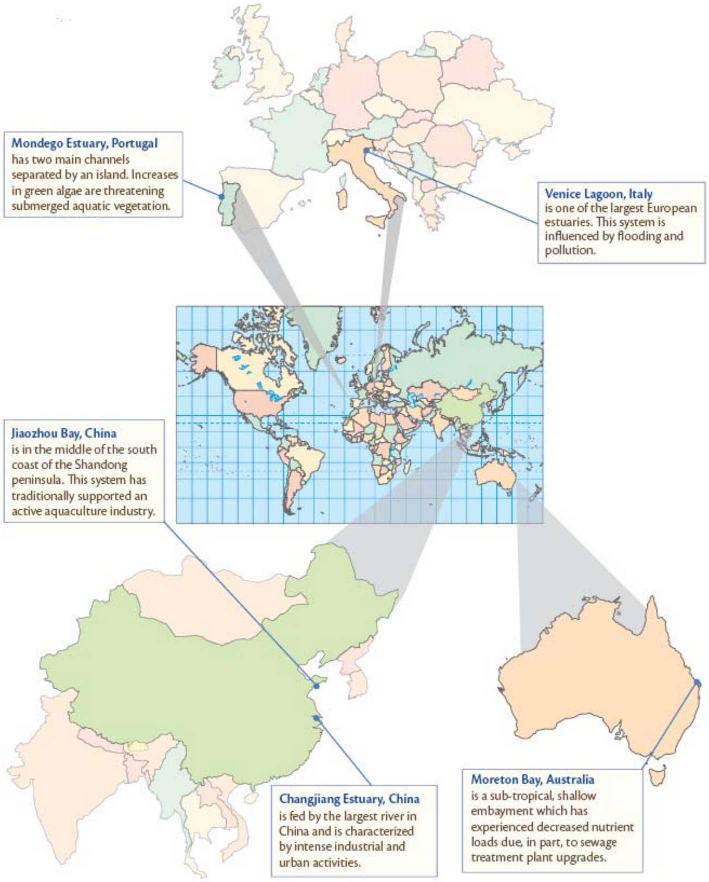

Figure 5: International case studies: Rapid large scale increase in eutrophic symptoms (nuisance/ toxic blooms, chlorophyll a, and dissolved oxygen) have occurred (Changjiang Estuary, China); Threats from eutrophication to large scale aquaculture stimulate nutrient management (Jiaozhou Bay, China); Seasonal macroalgae blooms lead to seagrass loss (Mondego River, Portugal); Sewage plume mapping tracks nutrient reductions (Moreton Bay, Australia); Flood protection measure can accentuate eutrophic symptoms (e.g., dissolved oxygen, macroalgae, and loss of submerged aquatic vegetation) (Venice Lagoon, Italy).

However, the method can also be used in combination with other models and at smaller scales for more practical application, and the assessment of specific indicators in combination with hydrologic considerations can be used to forecast the types of problems that may occur, such as algal blooms. In the first case, the ASSETS model has been used in combination with models simulating shellfish growth to predict the water quality impacts of different shellfish growing scenarios in an aquaculture application. The combined models provide a tool for screening water quality impacts. In one application, examination of the mass balance of nutrients within an oyster farm and analysis of related revenue sources indicated that about 100% extra income could be obtained by emissions trading, since shellfish farms are nutrient sinks. In the second case, the ASSETS indicators for chlorophyll and nuisance/toxic blooms are combined with hydrologic considerations to predict occurrence of algal bloom occurrences. Since toxic algal species are typically slower growing, they are likely to be more prevalent in systems with longer residence times, such as lagoons. A preliminary analysis shows that the longer residence time systems have high levels of chlorophyll and and higher occurrences of nuisance/toxic bloom occurrences. In these types of systems, it is suggested that shellfish aquaculture could be used as an in-system management measure to complement traditional measures that limit nutrient inputs from the watershed. There is encouraging evidence in high use sytems where aquaculture is prevalent such as Jiaozhou Bay, China, that the pratice reduces the occurrence of algal related problems.

The ASSETS eutrophication assessment method at the larger scale application provides a basis for prioritization of management. In combination with other models, the method can be used to maximize yield from aquaculture while minimizing water quality impacts. And analysis of specific indicators and hydrologic considerations provides information about the probability of nuisance/toxic bloom occurrences. Taken together, these results give important information for management of systems that are impacted as well as those which are not impacted now but are at risk due to long water residence times and expected population increases (and thus nutrient loads) in the future.

Acknowledgements

This work would not have been possible without the collaboration of U.S. and international eutrophication experts including NEEA participants and members of the TAICHI Chinese eutrophication and UISCE Irish carrying capacity projects.

References

Bricker, S., B. Longstaff, W. Dennison, A. Jones, K. Boicourt, C. Wicks and J. Woerner. 2007. Effects of Nutrient Enrichment in the Nation's Estuaries: A Decade of Change, National Estuarine Eutrophication Assessment Update. NOAA Coastal Ocean Program Decision Analysis Series No. 26. National Centers for Coastal Ocean Science, Silver Spring, MD. 322 pp.

Bricker, S.B., J.G. Ferreira, T. Sima. 2003. An Integrated Methodology for Assessment of Estuarine Trophic Status. Ecological Modelling, 169(1), 39-60.

Ferreira, J. G., A.J.S. Hawkins, S.B. Bricker. 2007. Management of productivity, environmental effects and profitability of shellfish aquaculture – the Farm Aquaculture Resource Management (FARM) model. Aquaculture, 264, 160-174.

Ferreira, J. G., Hawkins, A. J. S., Monteiro, P., Service, M., Moore, H., Edwards, A., Gowen, R., Lourenço, P., Mellor, A., Nunes, J. P., Pascoe, P. L., Ramos, L., Sequeira, A., Simas, T. and Strong, J., 2007. SMILE – Sustainable Mariculture in northern Irish Lough Ecosystems – Assessment of Carrying Capacity for Environmentally Sustainable Shellfish Culture in Carlingford Lough, Strangford Lough, Belfast Lough, Larne Lough and Lough Foyle. Ed. IMAR – Institute of Marine Research. 97 pp.

Xiao, Y., J.G. Ferreira, S.B. Bricker, J.P. Nunes, Z. Mingyuan, Z. Xuelei. 2007. Trophic assessment in Chinese coastal systems - Review of methodologies and application to the Changjiang (Yangtze) Estuary and Jiaozhou Bay. Estuaries and Coasts 30(6): 901-918.

Websites:

http://www.eutro.org

http://ian.umces.edu/neea   or   http://www.eutro.us

http://ccma.nos.noaa.gov/news/feature/Eutroupdate.html