6-12-2017

# External Advisors to PREP Technical Advisory Committee Statement Regarding Eelgrass Stressors in the Great Bay Estuary

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Recommended Citation
Kenworthy, Jud; Gobler, Chris J.; and Moore, Moore, "External Advisors to PREP Technical Advisory Committee Statement Regarding Eelgrass Stressors in the Great Bay Estuary" (2017). *PREP Publications*. 377.
https://scholars.unh.edu/prep/377

# External Advisors to PREP Technical Advisory Committee Statement Regarding Eelgrass Stressors in the Great Bay Estuary

PREP
Piscataqua Region Estuaries Partnership

## External Advisors to PREP Technical Advisory Committee

## Statement Regarding Eelgrass Stressors in the Great Bay Estuary

### June 12, 2017

## Background for this Statement

Three external advisors were invited to participate in PREP's Technical Advisory Committee (TAC) process during the 2016-2017 meetings. Dr. Jud Kenworthy has been advising PREP since the spring of 2016 and he served on the 2014 Peer Review Panel for the Numeric Nutrient Criteria for the Great Bay Estuary. Dr. Ken Moore was one of the scientists approached to be on the the Peer Review Panel by NH Department of Environmental Services (DES) and the Great Bay Municipal Coalition. Dr. Moore joined the process in February 2017. Dr. Chris Gobler began offering advice on issues related to seaweeds, shellfish, and general water and sediment quality in December 2016. Dr. Gobler was chosen because of his unique combination and depth of background in issues pertaining to phytoplankton, seagrass and bivalves.

In early 2017, several conference calls involving the PREP coastal scientist and all three advisors were held. The primary task for the advisors was articulated as: "Provide feedback on what stressors should be considered and prioritized (relative to each other) when trying to manage for improved ecosystem condition, in particular, as measured by the distribution and abundance of eelgrass in the Great Bay estuarine ecosystem, but also considering health of shellfish habitats." The advisors were asked to focus on data collected specific to the Great Bay Estuary and to bring to bear knowledge gained from experience and studies in other coastal ecosystems. The advisors were given access to 44 different sources of environmental information on eelgrass, oysters and water quality in the Great Bay Estuary. These sources included data from PREP, EPA, NH DES, the Municipal Coalition and individual researchers. All three advisors attended the May 9th and 10th (2017) TAC meetings and continue to offer advice on the development of the State of Our Estuaries Report.

The charge for this statement was to offer overarching views on the question of eelgrass stressors, based on science, but in a way that builds a foundation for future management discussions. In addition, Dr. Kenworthy, who also served on the 2014 Peer Review of 2009 proposed numeric nutrient criteria, was asked to write a paragraph relating the Peer Review to the 2017 TAC Process.

In the statement below, the pronoun "we" refers to the three external advisors only.

**Statement Regarding Eelgrass Stressors in the Great Bay Estuary**

Many previous discussions have focused on very specific stressors (e.g., nitrogen, major storms) in an attempt to determine what are the main drivers of ecosystem changes in the Great Bay Estuary. We suggest that these narrowly focused debates do not reflect the complexity of estuarine ecosystems. Rather, management actions should be considered in the context of multiple stressors having both additive, cumulative, and potentially synergistic impacts on the resilience of the system. For example, rather than focus on what is stressing eelgrass and oysters, the charge is to focus on what is stressing these habitats' ability to respond to chronic and acute stressors (Unsworth et al 2015). This gets to the core of "resilience," which is defined as "the capacity of an ecosystem to absorb repeated disturbances or shocks and adapt to change without fundamentally switching to an alternative and sometimes undesirable stable state" (Holling 1973). It is believed that the preponderance of evidence indicates that multiple stressors have acted and interacted to weaken the resilience of the Great Bay ecosystem.

We agreed that there is evidence the Great Bay Estuary has become de-stabilized with regard to eelgrass and oyster abundance. We note that eelgrass continues to partially recover from stress but has not returned to levels of abundance previously recorded. Three things are important in acknowledging that the ecosystem has been de-stabilized. 1) It is possible to regain a previous state (Greening et al 2014); 2) It is challenging to regain the previous state because of new or modified conditions in the current state (Duarte et al 2009; Kenworthy et al 2013; Kuusemae et al 2016). For example, with 89% of oysters and 30% of eelgrass gone, the ability of the system to filter and stabilize sediments is greatly decreased. Also, eelgrass cannot recover through vegetative reproduction alone; it must rely on sexual reproduction (through seed production and dispersal). But given the plant's two-year life cycle, complex life history, sensitive life stages and decreasing number of plants, there are multiple pathways for stressors to affect eelgrass and inherent limits to how much eelgrass can respond unless conditions significantly improve (Kenworthy et al 2013); 3) regaining past levels of resilience may require environmental conditions to improve initially to levels better than before the declines were observed (Biber et al 2008; Jarvis and Moore 2010; Jarvis et al 2014). This follows on point #2; due to the current lack of resilience, improving conditions to previous levels may only allow habitats to remain at the current state or slow the decline and not regain the previous one (Bostrom et al 2014; Duarte et al 2015).

Regarding the suite of stressors affecting eelgrass, we believe it is important to not consider individual stressors separately, but rather consider their interactive and additive effects. Any one stressor—warming waters, major storms, excessive nutrient loading, the overgrowth of seaweeds, organically-enriched sediments, episodes of high phytoplankton concentrations, continually increasing suspended sediments—can make eelgrass less resilient to the other stressors (Orth et al 2006; Kenworthy et al 2013; del Barrio 2014).

Some might argue that the decrease in eelgrass is related to a "pulse" stressor like major storms, but it is equally plausible that a slow "press" stressor chronically applied, such as decreased water quality in response to increases in population and impervious cover, created conditions limiting eelgrass recovery from a pulse disturbance (Orth et al 2006; Bostrom et al 2014). Further, the interactions of stressors can create feedback loops that can promote rapid ecosystem degradation. For example, the overgrowth of seaweeds may lead to the progressive organic enrichment of sediments that have high levels of sulfide and low levels of oxygen, depressing both the abundance of benthic animals and the growth of eelgrass. Since eelgrass and benthic animals promote oxygen levels in sediments and since high oxygen in sediments degrade organic matter, the loss of eelgrass and benthos could lead to continually declining sediment oxygen and sulfide levels that in turn will further decrease the abundance of eelgrass and the benthos. This feedback loop has been documented in several coastal ecosystems where eelgrass and shellfish were considered foundation species (Burkholder et al 2007; Viaroli et al 2008).

We appreciate that there are many stressors affecting eelgrass, such as ice scour, bioturbation and consumption by geese and green crabs as well as the light attenuating components of phytoplankton, CDOM, total suspended solids, epiphytes and drift seaweed. More spatially and temporally comprehensive data needs to be collected to better understand the interactive effects of these stressors, especially so that the community can track the response of the ecosystem to the many interventions that are already taking place and determine if they are sufficient or others need to be implemented. We strongly recommend that: 1) the Great Bay Estuary system develops a comprehensive, frequent and coordinated environmental quality monitoring program; 2) the monitoring program should be designed to capture the fundamental conditions in the different geographic zones of the Great Bay Estuary, and 3) seek a means of funding and cooperation between the scientific community, the resource managers and the municipalities to integrate the existing data to develop a set of verifiable conclusions about the state of the system as can be known from the existing data. This will help remove quite a bit of the present uncertainty and will also help inform the design and interpretation of a long-term monitoring program.

Despite encouraging reductions in nitrogen from wastewater treatment plants, loading levels are still high enough that nitrogen cannot be dismissed as an important stressor (Latimer and Rego 2010). The most recent physiological measurements of Ulva (a green seaweed) that is abundant in the estuary indicate complete nitrogen saturation (Nettleton et al 2011). Episodic phytoplankton blooms reach levels that both NOAA and EPA consider high and potentially damaging to eelgrass (Bricker et al 2003; US EPA 2012; NH DES 2017). Low nitrogen levels will reduce the number and impact of phytoplankton and seaweed blooms. In fact, if nitrogen isn't low enough, reducing sediment loadings will allow more light to phytoplankton and seaweed which could cause a further decrease in eelgrass abundance. Both stressors need to be addressed.

Parts of Great Bay Estuary are well flushed, but this characteristic comes with stress. Much of the estuary is extremely shallow, especially at low tide, so any nitrogen in the system is more concentrated and sediments are more easily resuspended. A large tidal range may allow more light to temporarily reach eelgrass in the intertidal zone during ebb, but associated shifts in light levels are stressful to eelgrass as well. It is energetically costlier and less efficient for the plants to have to continually shift their photosynthetic apparatus to deal with highly varying light conditions associated with high tidal ranges in areas with relatively shallow water depths. Additionally, much of the hydrodynamic flushing comes from substantial riverine inputs, but these inputs also bring in light-attenuating substances (like CDOM) as well as other contaminants.

How much nitrogen reduction is enough or too much? The data to answer this question do not currently exist. To help answer that question, a thorough quantitative ecosystem based model as recommended by the 2014 Peer Review (Bierman et al 2014) would be required. And this model would need to be specific to different assessment zones within the estuary. It is not likely that one model would work for the entire system.

The fact that municipalities have significantly reduced nitrogen from wastewater treatment facilities is an excellent foundation to build upon. Based on the reports given to the advisors, it is evident that a large fraction of the nitrogen entering the system comes from non-point sources (NH DES 2014). Given that only 2.6% of the estuarine watershed area is occupied by the mitigating effects of wetlands, the Great Bay estuary is extremely vulnerable to non-point source loadings. This is typical of northeastern estuaries, which have much less wetland buffering capacity compared to estuaries in the southeast and Gulf of Mexico (Bricker et al 1999; Bricker et al 2003). Addressing these non-point source loads is a natural next source for managers to consider, especially as non-point source reduction can also mitigate other run-off related pollutants, such as toxic contaminants, including herbicides and petrochemicals, both of which have been linked with eelgrass stress.

In summary, the opinions expressed here with respect to the status of eelgrass in the Great Bay Estuary are consistent with the general conclusions of the 2014 Peer Review Panel Joint Report (Bierman et al 2014), which reviewed the NHDES proposed Numeric Nutrient Criteria for the Great Bay Estuary. Empirically derived evidence from experimental studies and monitoring programs indicate that eelgrass distribution and abundance in an estuary results from the complex interaction of several physical, biological and process based factors and no two estuaries or sub-embayments of an estuary are identical in all of these factors. To determine if one or more factors are the primary controlling factor it is necessary to either consider all the factors and their interactions or be able to definitively rule out factors as insignificant. The multivariate factors, the linkages between factors and the processes by which they can be evaluated that was identified in the Panel's report provide a basis for developing a comprehensive monitoring and modelling program that could be used to improve our understanding of which physical and biological variables in the system are having the greatest effect on eelgrass distribution and abundance.

We are grateful for the opportunity to offer our perspectives on estuarine ecosystem issues as they pertain to the Great Bay Estuary. Readers should know that all three advisors agreed without question on the above statement.

With regards and best hopes for the Great Bay and Hampton-Seabrook Estuaries,

*Chris Gobler*

*Jud Kenworthy*

W. Judson Kenworthy

*Ken Moore*

Kenneth A. Moore

## External Advisors: Brief Biographies

*Dr. Chris Gobler*

Christopher J. Gobler is a Professor and Associate Dean of Research within the School of Marine and Atmospheric Sciences (SoMAS) at Stony Brook University. He received his M.S. and Ph.D. from Stony Brook University in the 1990s. He is also co-Director of the New York State Center for Clean Water Technology and co-Editor of the international, peer-reviewed journal, *Harmful Algae*. The major research focus within his group is investigating how anthropogenic activities and climate change combine to alter the ecological functioning of coastal ecosystems. Past research has emphasized interactions and feedbacks among nutrient delivery pathways, pelagic phytoplankton communities, benthic filter feeders, and benthic autotrophs such as seagrass. His research group also strives to understand how co-occurring stressors related to both climate change and shallow coastal ecosystems (hypoxia, thermal stress, algal blooms) may act and interact to affect the performance of marine animals. Finally, Dr. Gobler's lab specializes in studying harmful algal blooms (HABs) and how nutrients, $CO_2$ levels, zooplankton grazing and bivalve grazing influence the dynamics of HABS. His work has resulted in more than 150 manuscripts in peer-reviewed journals.

*Dr. Jud Kenworthy*
Dr. Kenworthy holds a BSc from the University of Rhode Island, a M.S. in Environmental Sciences from the University of Virginia and a PhD in Zoology at N.C. State University. Dr. Kenworthy is recently retired from the Center for Coastal Fisheries and Habitat Research, NCCOS, NOS, NOAA after 33 years of federal service. As a student and NOAA research scientist Dr. Kenworthy has over 40 years of experience in coastal ecology with emphasis on seagrasses and the effects of natural and anthropogenic disturbance on coastal environments. Dr. Kenworthy's areas of expertise in applied science include research on water quality impacts on seagrasses, seagrass restoration, disturbance ecology, designing and implementing environmental assessments and resource monitoring programs and assisting State, Federal and International Resource Management Agencies in planning and implementing conservation and restoration programs.

*Dr. Ken Moore*
Dr. Moore holds a B.S. from the Pennsylvania State University in Zoology, a M.S from the University of Virginia in Marine Science and a Ph.D. for the University of Virginia in Marine and Environmental Sciences. Dr. Moore is a Professor of Marine Science and past Chairman of the Department of Biological Sciences at the College of William and Mary, School of Marine Science. He is also the Research Coordinator of the National Estuarine Research Reserve in the Chesapeake Bay. His research studies, which have been conducted world-wide, have focused on the ecology of estuarine and coastal shallow water environments, especially those vegetated with marshes, seagrasses and other submersed aquatic vegetation. Specifically, he has studied the relationships between these aquatic macrophyte systems and their interactions with environmental factors including water quality and sediment conditions, as well as climate stressors that can limit their growth, reproduction, survival and restoration. These studies have been hierarchal in nature, ranging from laboratory studies of the physiological responses of individual organisms, to field studies of seagrass restoration, to ecosystem-level responses of these systems to management actions.  He has worked to develop and implement new, enhanced shallow water monitoring and measuring technologies to evaluate and quantify the highly variable conditions in space and time that are found there, and to connect these integrated conditions to seagrass bed and other community responses.

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