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Coastal wetlands are the best marine carbon sink for climate mitigation

We thank Smale and colleagues for their comments on our recent paper, for highlighting areas where additional research is warranted, and for their overview of the recent literature that was not available when we submitted our manuscript. It is encouraging to see new papers being published that are helping scientists better understand carbon cycles in coastal and marine ecosystems and their important dynamics.

Our paper evaluated how coastal and marine ecosystems can be used for climate mitigation within the current international policy context, including existing mechanisms related to carbon accounting. To that end, we focused on those ecosystems that can be managed for permanent carbon sequestration and storage at globally relevant scales and that potentially contribute to countries' national greenhouse-gas (GHG) emissions reduction pledges. Oceanic and coastal carbon cycles and dynamics, while critically important for understanding climate change and its impacts, are not currently the focus of such policies. Rather, mitigation policy concentrates on human actions that *change – either by increasing or by decreasing* – carbon sequestration and storage beyond the naturally occurring "baseline" condition of the carbon cycle, and by so doing either accelerate or slow climate change. So, while many ecosystems are vital for moving carbon through the carbon cycle and for burying carbon in the deep ocean, these are not of explicit climate mitigation value because they do not provide additional carbon benefits (known as additionality) beyond the natural cycle, or baseline condition. For example, protecting a mangrove forest that is threatened by logging – where that logging would result in major losses of sequestered carbon – is a management activity that can have measurable impacts on current and future atmospheric carbon emissions. Similarly, restoring a degraded salt marsh and thereby improving its carbon sequestration capacity is a human action that directly affects long-term atmospheric carbon levels. Thus, these are the types of management activities that are relevant when countries are both (1) assessing their climate-change emissions and (2) determining the range of actions available for GHG emission reductions in order to meet climate-change mitigation goals.

To be included in the current climate-change mitigation policy framework (hereafter, "framework") and accounting mechanisms, not only must there be additional carbon benefits beyond the baseline carbon cycle conditions, but those benefits must also be quantifiable. Smale and colleagues suggest it is important to be "managing and protecting effective and widespread carbon donors" because this will increase "the magnitude of carbon capture and transfer". While this may be true, management actions in these donor ecosystems would need to be clearly distinguished from baseline conditions, and a great deal of science would be required to meet the burden of evidence it would take to incorporate these donor ecosystems into the framework. In reality, this burden of evidence would likely be too difficult or too costly an undertaking for many countries, which makes it difficult to include carbon from these donor ecosystems. Another hurdle for inclusion in climate mitigation policy is the need for the carbon management activity to fall within a country's jurisdiction. The current framework has been developed based on country contributions within country boundaries. The open ocean does not fit within the framework because it is neither owned nor managed by any one country. While we would support policy changes that would allow the open ocean to be included, we do not anticipate such a shift in ocean or climate policy in the foreseeable future.

To be clear, we support the protection and improved management of all coastal and marine ecosystems. However, practically speaking, trying to justify their conservation using the current framework is nearly impossible given the burden of proof necessary for integration into current carbon accounting schemes. As a result, the scientific community must carefully craft its messages about carbon sequestration to policy makers, in order to be clear about opportunities where human actions can have a *measurable* and *significant* impact on GHG emissions (as opposed to maintaining baseline rates of carbon sequestration through natural processes that are inherently difficult to manage). This is why our paper focused on coastal wetlands and why we continue to support their inclusion in the framework.

We look forward to more articles exploring the carbon sequestration potential and the carbon dynamics of marine and coastal ecosystems, because this body of work will ultimately help to improve their management and conservation.

Ariana Sutton-Grier[1,2]* and Jennifer Howard[3]

[1]*University of Maryland, College Park, MD;* [2]*Maryland/DC Chapter of The Nature Conservancy, Bethesda, MD* **(ariana.suttongrier@gmail.com);* [3]*Conservation International, Arlington, VA*

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Bioenergy production in Natura 2000 sites: added benefit or threat to biodiversity?

In a thought-provoking article, Van Meerbeek *et al.* (2016) called for the integration of bioenergy production with nature conservation within the Natura 2000 network of protected areas in Europe. Specific habitat types (including ones prioritized for conservation) are dependent on or benefit from agricultural activities such as grazing or mowing (Halada *et al.* 2011). Within such habitats, in the absence of biomass removal, ecological succession and forest encroachment are accelerated. However, excessive removal of biomass may lead to biodiversity losses (eg overgrazed pastures). Thus, an intermediate level of biomass removal is needed. In places where pastoral activities (including grazing) have ceased, these agriculturally dependent habitat types are threatened, and implementation of the proposal by Van Meerbeek *et al.* (2016) seems sensible.

Nonetheless, it is important to determine the intensity of ongoing agricultural activities in Natura 2000 protected areas and the extent to which traditional agricultural practices within those areas have been abandoned. Van Meerbeek *et al.* (2016) estimated the potential for bioenergy production on selected natural/semi-natural habitat types and assumed that agricultural activities within the total areal extent of these habitat types had been completely abandoned. Therefore, because this mode of bioenergy production "would not lead to the displacement of food production systems" and would thereby avoid indirect land-use change (ILUC), the authors argued that this strategy would be environmentally beneficial. Here lies the heart of the problem. If, within Natura 2000 sites, agricultural activities were no longer practiced, then bioenergy production would be viable and ILUC would be negligible; otherwise, the removal of biomass from both agricultural activities and bioenergy production would lead to habitat degradation and increased ILUC. From its inception, Natura 2000 explicitly recognizes the role of socioeconomic activities in conservation efforts (Article 2 of the Habitats Directive 92/43/EEC). Almost all Natura 2000 sites are affected by human activities to various degrees, with agriculture taking place on 85% of these sites (Tsiafouli *et al.* 2013). Indeed, more than 80% of the areal extent of some protected sites is devoted to agriculture (Kallimanis *et al.* 2008). Estimating the extent of agricultural abandonment is difficult; for instance, it is possible to mischaracterize periodically grazed lands as "abandoned". In light of these issues, I believe that the biomass-for-bioenergy scheme proposed by Van Meerbeek *et al.* (2016) should be applied only to agriculturally abandoned lands.

Every six years, EU Member States compile national reports on the conservation status of the habitat types listed in Annex 1 of the Habitats Directive. For each habitat type present in their respective territories, Member States supply conservation-related information such as area occupied by the habitat and the presence of threats. In the latest reports (covering the period 2007–2012, released in 2014), most habitat types that are linked to agriculture were not designated under the "Favourable Conservation Status" category, as Van Meerbeek *et al.* (2016) accurately reported. But the authors assumed that this was due to the absence of grazing and thus biomass on those lands must be removed. Although there are examples of abandonment of pastoral activities and the lack of grazing and mowing, these pressures are relatively rare and are hardly ever considered as high impact. In the reports on seven of these habitat types, lack of grazing/mowing is not mentioned at all. At the same time, overexploitation of these habitats (eg grazing [intensive and non-intensive] and the removal of plants) is often reported. To illustrate this issue, I compiled all reported pressures for a priority habitat type (6220, pseudo-steppe with grasses and annuals). The major pressures include grazing (intensive and non-intensive), roads, and urbanization, while abandonment of pastoral practices is considered a light impact activity, affecting few areas (WebFigure 1). The situation is similar for almost all other habitat types. On most of these lands, grazing is occurring, and in many cases it is already excessive and needs