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Marine angiosperm indices used to assess ecological status within the Water Framework Directive and South African National Water Act: Learning from differences and common issues

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ABSTRACT

This paper reviews and discusses the methods and metrics used for the assessment of the ecological status of marine angiosperms comparing the European with the South African situation. In Europe salt marsh and seagrasses are an important biological element for establishing the ecological quality status of transitional waters and in South Africa changes over time in the salt marsh and submerged macrophyte habitats (species richness, abundance and community composition) is used nationally to assess the health of estuaries. In Europe several studies have developed metrics that include salt marsh species composition and community structure to assess the ecological quality status. Deviation of taxonomic composition and abundance from a reference situation is investigated. Multi-metric approaches have been shown to provide a more holistic view of the ecological status of the ecosystem. Many indices are highly dependent on historical data to assess the deviation from reference conditions. Within the WFD spirit one widely used approach for salt marsh assessment, the Best's method, the baseline can be determined based on the first sampling effort, by the largest previously recorded size of the salt marsh or using the "maximum potential size" of the salt marsh from habitat prediction models. In South Africa all habitat below the 5 m contour line is considered estuary habitat and any land occupied here by agricultural or other developments is considered as a loss of habitat from the reference condition. For seagrasses European metrics are based on attributes from the community (e.g., taxonomic composition, epiphytes), the population (e.g., bed extent, shoots density), but also quantified at individual species (e.g., leaves length) or physiological levels (e.g., stable isotopic signatures). Seagrass habitats in South African estuaries are highly dynamic in response to floods and an understanding of this is needed before present ecological status can be assessed.

1. Introduction

On a global scale coastal and transitional waters have been severely altered by anthropogenic activities. Historically, developing human civilizations have often been concentrated in coastal areas where there has been access to water promoted trade, commerce, and disposal of wastes (Borja and Dauer, 2008). Globally environmental management strives for sustainable development while minimizing impacts to ecosystem integrity (Müller, 2005). Recent legislation in Europe, mainly the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD), covers this aspect by assuming … '*Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.*' (WFD, Directive 2000/60/EC), and even more specifically for marine environments when stating those ecosystems constitute…'*a precious heritage that must be protected, preserved and, where practicable, restored with the ultimate aim of maintaining biodiversity and providing diverse and dynamic oceans and seas which are clean, healthy and productive*' (MSFD, Directive 2008/56/EC). If natural resources are managed in a sustainable manner coastal ecosystems should be able to provide goods and services that support different uses to mankind (Borja et al., 2008).

Among the most significant anthropogenic impacts to these ecosystems are land reclamation, dredging, pollution (sediment discharges, hazardous substances, litter, oil-spills, eutrophication), unsustainable exploitation of marine resources (sand extraction, oil and gas exploitation, fishing), unmanaged tourism, introduction of alien species and climate change (Borja et al., 2008). But nowadays, more than just the assessment concern, international laws also prioritise the

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cooperative environmental improvement, such as highlighted in the WFD when stating that …‘ *Common principles are needed in order to coordinate Member States' efforts to improve the protection of Community waters in terms of quantity and quality, to promote sustainable water use, to contribute to the control of transboundary water problems, to protect aquatic ecosystems, and terrestrial ecosystems and wetlands directly depending on them, and to safeguard and develop the potential uses of Community waters*' … aiming in general … ‘*To contribute to the progressive reduction of emissions of hazardous substances to water*.’ With this stakeholders and ecologists intend to establish a connection between the generated anthropogenic activities and its consequent ecological impacts. This has been translated during the past couple of decades into regional and/or national levels such as the Australia Oceans Policy, the Canada Oceans Act and Oceans Strategy, the US Oceans Act of 2000, the EU Water and Marine Strategy Framework Directives (WFD and MSFD) and the South African National Water Act. All these initiatives aim to protect, monitor and restore the coastal environments along with a sustainable human growth. This is reflected in a common main objective, the maintenance of a good ecological or environmental status (GES) in marine and inland waters, habitats and resources (Borja et al., 2008). Elliott (2011) states that the main aim in marine management is to protect and maintain the natural ecological functioning and at the same time deliver the benefits for society (based on ecosystem services and societal benefits). This is the Ecosystem Approach concept, which integrates all aspects regarding the structure, function and processes of marine ecosystems bringing together natural physical, chemical, physiographic, geographic and climatic factors, and integrates these conditions with the anthropogenic impacts and activities in the area concerned (Borja et al., 2013).

Most evaluation schemes that assess the health or the ecological status of transitional and coastal european ecosystems are based, on a first step, on Biological Quality Elements (BQE) such as phytoplankton, macroalgae, marine angiosperms (including seagrasses and salt marsh plants), fishes and benthic macroinvertebrates (Birk et al., 2012). This assessment strategy is based on the assumption that the BQE can act as bioindicator (sentinel) organisms accumulating toxic substances or responding to disturbance, such as pollution, nutrient enrichment, habitat loss or overexploitation and hydrologic and sedimentary alterations (Adams, 2002). With the application of standard sampling procedures, the gathered information on occurring taxa and their abundances can be summarized in biological metrics and compared to reference conditions (undisturbed ecosystems) and classified into Ecological Quality Status (EQS) classes (Karr and Chu, 1999).

In the case of South Africa (a developing semi-arid country where the demand for freshwater exceeds the available supply), great pressure exists on the 300 odd estuaries and only less than 5% of all estuaries experience no flow modification pressures (Van Niekerk and Turpie, 2012). The National Water Act (NWA) of South Africa (Act 36 of 1998) gives two rights to water, basic human needs and protection of aquatic ecosystems in order to secure ecologically sustainable development and use of relevant water resource. The need to ensure that aquatic ecosystems receive sufficient water to maintain adequate functioning and future persistence has only recently been realised. Ecological Water Requirements (EWRs), quantifies the water regime (quality, quantity and timing) required to ensure the adequate functioning and future persistence of estuaries. Estuaries are unique (e.g. shape, size, protection from wave energy) and have different responses to altered freshwater inflow. Thus studies of individual systems need to be undertaken. South Africa has been a forerunner worldwide for determining methods to assess EWRs. The South African Resource Directed Measures developed in 1999 in response to the National Water Act (Act 36 of 1998) has been consistently applied to different estuary types (permanently open, temporarily open/closed, river mouths, estuarine bays and estuarine lakes) in the country (Adams et al., 2016a). A component of the EWR study is a present ecological status assessment using the Estuarine Health index. For South Africa the estuary health was considered the basic unit for the transitional systems ecological quality assessment and defined as the maintenance of ecosystem structure and function, including natural variability and resilience, on a landscape scale. Somehow, following a similar perspective, as a second step required in WFD assessments, the ecological quality status obtained based on BQE must be meanwhile confirmed or downgraded by the statuses of Hydromorphological Quality Elements and Physicochemical Quality Elements under a decision-three based sequential approach (Borja et al., 2009).

Worldwide, marine angiosperms such as salt marsh communities and seagrasses are of ecological value in coastal environments, forming extensive intertidal or shallow water habitats, providing food, shelter, and important nursery areas for fish and macroinvertebrates (Hemminga and Duarte, 2000). Their presence is associated with good environmental conditions, either due to their recognised sensitivity to pollution (e.g., seagrasses), their contribution to protection against coastal erosion or in the improvement of water transparency through trapping particles suspended in the water column (Terrados and Borum, 2004). Because of these important ecological services they provide to coastal zones, salt marshes and seagrass meadows rank among the most productive and valuable ecosystems on Earth (Costanza et al., 1997, 2014). They normally occur in hydrological areas with low-energy allowing the sediment to settle down, the shoreline to elevate and expand and the establishment of halophyte species (Boorman, 2003). In spite of relatively stable hydrological environments, salt marshes are subjected to the long-term dynamic nature of coastal processes (waves, tides, currents, sediment supply), as well as local geology and the relative sea level movement (Duarte et al., 2013; Valentim et al., 2013). This leads to natural cycles of erosion and accretion which may span decades or hundreds of years (Carpenter and Pye, 1996). Chemically, salt marshes are also affected, since tidal flooding often brings large amounts of organic matter, nutrients and contaminants. These substances settle in the salt marsh and accumulate in their sediments and biota (Caçador et al., 2000). Thus, salt marshes are considered to be important sinks of both contaminants and nutrients (Caçador et al., 1993; Davy, 2000; Mitsch and Gosselink, 2000; Caçador et al., 2009; Duarte et al., 2010). Salt marsh vegetation is inevitably affected by these hydrological and chemical constrains, reflecting them in its community structure (Caçador et al., 2007). Also due to its location on the margins of the estuaries and coastal lagoons, these ecosystems are particularly prone to land reclamation, urbanization and direct human pressure. This vegetation type consists of a limited number of species with halophytic characteristics (salt tolerance), adapted to regular submersion, root hypoxia and other unfavourable conditions inherent to the aquatic medium (Best et al., 2007; Boorman, 2003). Hydraulic and anthropogenic factors influence the development of salt marsh (Boorman, 2003). Hydraulic factors include: wave and weather climate, cyclical and secular hydrodynamic features, and sedimentation. The anthropogenic factors include: physical (enclosure, coastal squeeze, land claim, grazing, ship and boat movements, dredging activities) and chemical disturbances (pollution, eutrophication, refuse disposal) (Boorman, 2003). Anthropogenic pressures such as wastewater discharge, pollutants, land reclamation and urbanization, boating, dredging, fisheries and aquaculture activities are the main causes affecting seagrass meadows survival (Duarte, 2002; 2011; Orth et al., 2006; Walker et al., 2006; Duarte et al., 2008; Waycott et al., 2009). Moreover, the processes controlling seagrass decline are not understood on a global scale, and Chefaoui et al. (2015) suggested this is due to multifactor influence of coastal habitat alterations, the impacts of climate change, and ecological general degradation of aquatic ecosystems. Indeed, local declines could, in some cases, be related to large-scale biogeographical range shifts rather than local factors, in which temperature, salinity, nutrient concentration, transparency and oxygen in the water constitute important parameters influencing the success of seagrass worldwide (Chefaoui et al., 2015).

The Habitats Directive (92/43/EEC) stated that salt marshes and seagrass meadows in Europe constitute important and sensitive