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The history of intertidal blue mussel beds in the North Frisian Wadden Sea in the 20th century: Can we define reference conditions for conservation targets by analysing aerial photographs?

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ABSTRACT

Conservation decisions often rely on defining a reference status for habitats and species to enable targets to be set and progress measured. Long-lasting and continual anthropogenic impacts on habitats and species make the setting of undisturbed reference values such as diversity, distribution, population size or other ecological characteristics, difficult. In turn this hampers assessment of ecological status.

Within the Wadden Sea, intertidal blue mussel beds are important biogenic structures which can be clearly defined from the surrounding flats. As mussel beds are highly productive habitats, they are considered as biological quality indicators for coastal waters. Nonetheless the reference status provokes controversy in discussions between policymakers, stakeholders and researchers. In order to build on existing knowledge of intertidal blue mussel beds in the North Frisian Wadden Sea, we analysed aerial photographs from the 1930s, 1958, 1989, 1998 and 2010. We supplemented this remote sensing data with annual monitoring data from 1999 to 2009 obtained from analysis of aerial photographs and field surveys.

Results show a generally high persistency of blue mussel beds likely over eight decades, although sites were probably not permanent throughout the time period and their areal extent had changed. Mussel beds occur mainly on the east side of the islands which provide shelter against storms from the west. Studies of aerial photographs for the 1930s and 1958 demonstrate the importance of historical data to an assessment of the current status of the beds. In particular they help assess the distribution and extent of mussel beds over time.

1. Introduction

An important tool within nature conversation is the definition of a reference status. Assessing the current status of species or habitats demands reference data from undisturbed (=pristine) conditions (Muxika et al., 2007), defined during times with no or low anthropogenic impact (Vincent et al., 2002). Since most areas in Europe are heavily affected by ongoing anthropogenic impacts (Borja et al., 2004), it is extremely difficult to define a reference status that aligns to undisturbed conditions. In particular the Wadden Sea, along the coast of the SE North Sea, is subject to land reclamation, fishing, channel deepening, coastline modification and so on (Dolch, 2008; Lotze, 2005; Reise et al., 2008). Climate change and rising water temperatures (Martens and van Beusekom, 2008; Reise, 2005) affect the Wadden Sea's ecosystem, and with constant natural changes, the ecological baseline is permanently shifting (Lotze et al., 2005). Knowledge of historical states improves our understanding of the ecosystem and its present and future dynamics (Lotze et al., 2005). For example, historical investigations on benthic communities by Nienburg (1927) and Wohlenberg (1937) are important when evaluating the current status in the northern German Wadden Sea (Reise and van Beusekom, 2008). Within the Wadden Sea, blue mussel beds are unique biogenic structures; they are autogenic ecosystem engineers (Jones et al., 1994) and serve as habitat for various animal and plant species, forming important food sources for birds.

To meet various EU conservation objectives, shellfish stocks need to be maintained as food for migratory birds (Essink et al., 2005). To protect blue mussel eating birds, in particular eiders (*Somateria mollissima*), the Netherlands and Denmark implemented a policy that protects some mussel stock for birds and excludes some beds from fishery activities (Laursen et al., 2010; van Stralen, 2010). Implementing that approach and measuring its effects rely on having set reference values or thresholds, such as mussel bed area or biomass. Historical data on mussel stocks in the Wadden Sea may improve our understanding of the ecosystems and future possibilities in conservation (compare Lotze et al., 2005). Besides food policy requirements intertidal blue mussel bed are biological quality elements for example within the EU Water Framework Directive and potential indicators within the Marine Strategy Directive (BMU, 2012; de Vlas et al., 2005).

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Dijkema et al. (1989), Nehls and Thiel (1993), Brinkman et al. (2002), Hertweck and Liebezeit (2002) and Herlyn et al. (2008) analysed aerial photographs, older publications and mussel bed layers in a sediment profile to glean more information about bed distribution, site stability and area coverage back to the 1960s and 1970s. Analysing further older data, including aerial photographs from the 1930s and 1958 will enhance the knowledge. The 1930s data are of particular value because there was almost no mussel fishery (Ruth, 1994; Reise, 2005) and no eutrophication in pre-industrial times (van Beusekom, 2005). We analysed aerial photographs from the 1930s, 1958, 1989, 1998 and 2010 with these objectives:

1. to assess how accurate aerial photography was in estimating location and extent of blue mussel beds and to analyse the method's difficulties and/or limitations and if this method could be applied to historical photographs without ground truth.
2. to evaluate the development of blue mussel beds over 80 years and identify changes to the size and location of beds over the last eight decades, in the process assessing whether photographs from 1930s and 1958 provided sufficient detail to define reference conditions.
3. to examine whether reference values within the continuously changing Wadden Sea, with its high inter-annual fluctuations, could be defined.

2. Methods

2.1. Study site

This study focused on the tidal flats of the German North Frisian Wadden Sea, from the Eiderstedt peninsula in the south to the Danish–German border in the north (Fig. 1). The survey area of 1688 km^2 included the entire List tidal basin (not completely displayed in Fig. 1) and all the islands. The intertidal zone amounted to 962 km^2 (Spiegel, 1998). The Wadden Sea's regular tidal change, alternating every six hours (tidal range about 2–3.2 m) creates highly variable, constantly changing environmental conditions. Salinity in the survey area ranges seasonally between 25 psu in winter and 32 psu in summer, although variations within the tidal circle are only 1 psu (Becker, 1998a). Water temperatures range from winter values of −1.5 and −1.9 °C to around 23 °C in summer (Becker, 1998b). Particular influences are severe ice winters with ice rearing, storms with strong westerly winds and storm surges (Nehls and Thiel, 1993).

2.2. Aerial photographs

We analysed aerial photographs from the 1930s, 1958, 1989, 1998 and 2010 (Table 1). Three sets of images from the 1930s covered only

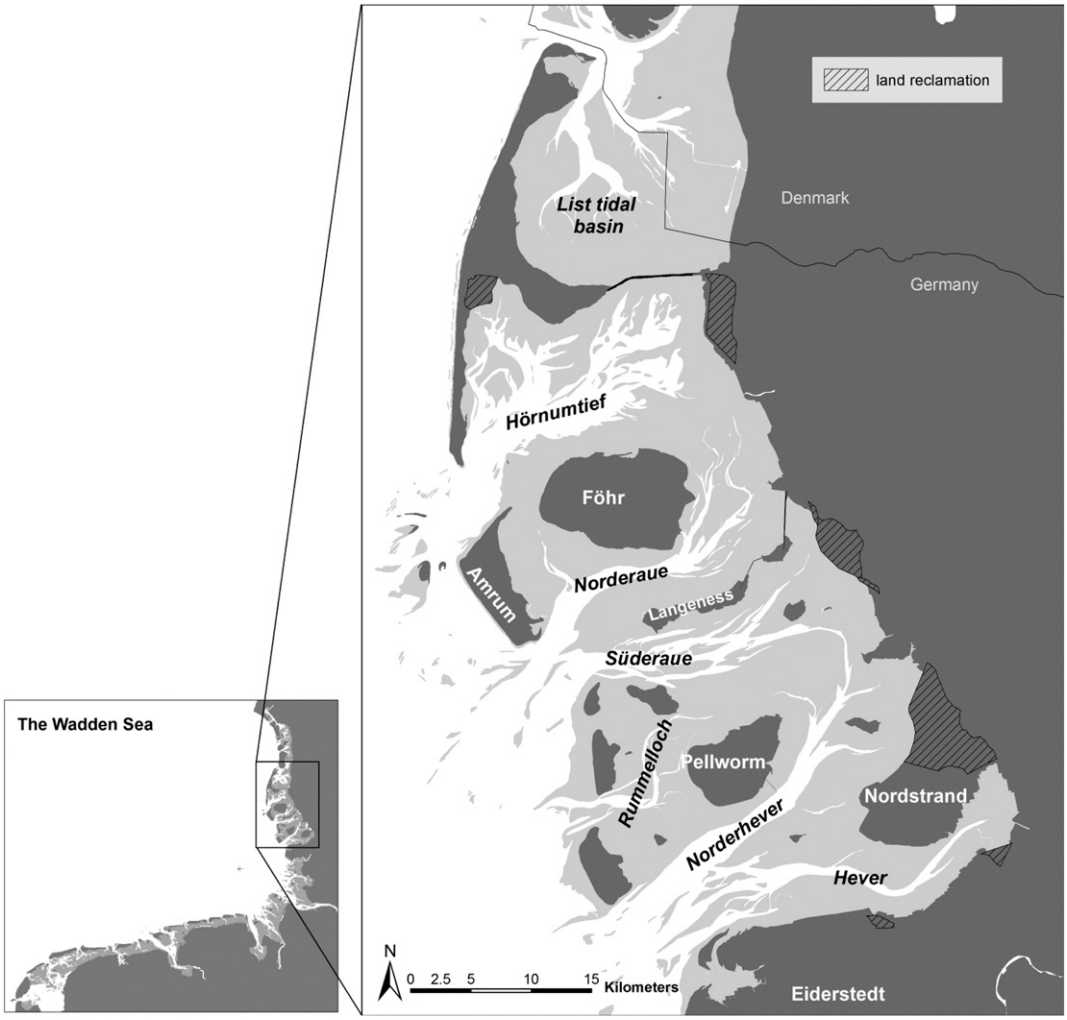

Fig. 1. Overview of the Wadden Sea (small map, trilateral map of the Wadden Sea by the CWSS, Wilhelmshaven) and the area of study in the Wadden Sea of Schleswig-Holstein (large map, both maps were provided by The National Park Administration of the Wadden Sea Schleswig-Holstein; dark grey = islands and mainland, light grey = intertidal, white = subtidal areas). Land reclamation since the 1930s is also plotted.