



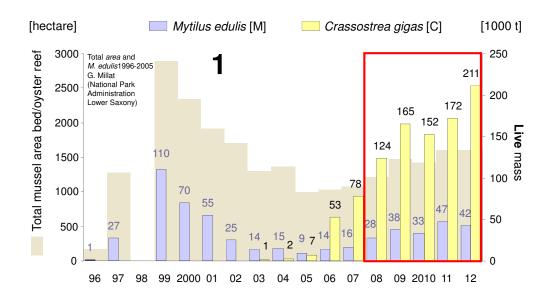




Biological habitat amelioration: Mytilus-stock supported by dense Crassostrea-reefs

Tidal flats of Lower Saxony (Central Wadden Sea)

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Introduction

The comprehensive **invasion** of intertidal blue mussel beds (*Mytilus edulis* [M]) by the non-indigenous Pacific oyster *Crassostrea gigas* [C] in all regions of the Wadden Sea is still considered to be a thread for native mussel populations. Mussels have to compete with high numbers of much larger oysters for food and for space, as the habitat is increasingly transformed. In its function as a strong ecosystem engineer, Pacific oysters form rigid shell aggregations, e.g. oyster reefs, which are characterized by complex habitat matrixes.

In the **Central Wadden Sea** (National Park of Lower Saxony), mussel biomass and total bed area continuously decreased after a peak of 110.000 tons live mass covering 3000 ha in 1999 to 9.000 tons and 1000 ha bed area in 2005 (Fig. 1). During this time, oyster occurrence was low but an exponential increase of oyster biomass was observed between 2006 and 2009. Live oyster stock is balancing since and biomass fluctuations between 2009 and 2012 are attributed to total mussel bed/reef area in the region which areal extension increases only slightly. Interestingly, mussel biomass shows an oyster-synchronous development and stock size increased to more than 40.000 tons up to date.

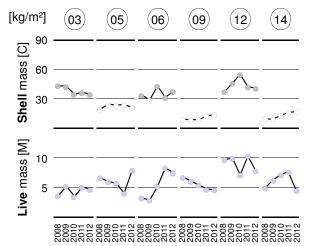
Where is this mussel biomass to be found? Are the mussels living preferentially in lesser oyster populated resp. lesser engineered areas and can we identify a characteristic distribution of mussel size classes in relation to reef density?

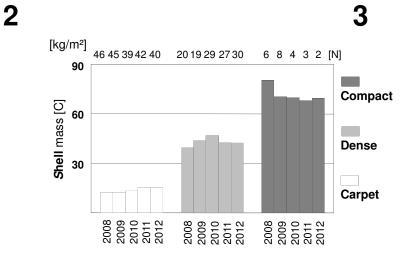
Methods

between reef types

(data 2008-2012)

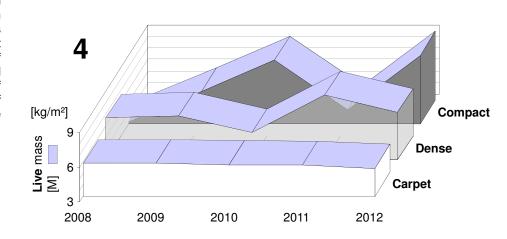
Data of 6 sites between 2008 and 2012 were analysed (Fig. 2). The sites are distributed from the most western (03) to the most eastern (14) part of the Central Wadden Sea, covering almost all tidal basins. 12 surface samples per site were taken annually in spring (site 05 autumn) with a 0.0625 m² frame. Sampling stations are distributed over the whole extension of a site. Mussel [M] and oyster [C] shell length [mm] was measured with a calliper rule in the lab. Additionally, length of shells of dead oysters was assessed as these shells contribute to form the habitat matrix. For each site and year, a conversion factor from length to biomass was calculated out of 5/Mytilusand 7/Crassostrea-size classes, 10 living individuals each, respectively. Analogous, shell mass was assessed after cocking and extracting the flesh content. The conversion factor for shell mass was also applied to shell length of dead individuals. All data were calculated to 1 m².

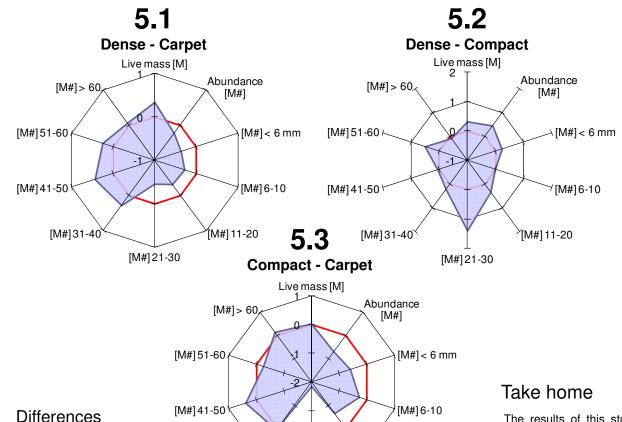




Reef density – here introduced as a factor for habitat matrix - is defined as shell mass of live and dead oysters [kg/m²]. Mean reef density (Shell mass [C] in kg/m²) and mean mussel biomass (Live mass [M] in kg/m²) between 2008 and 2012 are displayed for single stations in Figure 2. The maximum shell mass determined for one station was 98.7 kg/m², resp. 640 oysters > 10 cm. To relate mussel density to habitat characteristics, respectively ecosystem engineering effects of the Pacific oyster, we classified three reef types: **Reef carpet** [0 to < 30 kg/m²], **Dense reef** [30 to < 60 kg/m²] and **Compact reef** [\geq 60 kg/m²]. All stations of one year of investigation (72 per year) were sorted according to reef type. Mean shell mass of each reef type for each year of investigation is shown in Figure 3, number of stations [N] allocated to a reef type on top of figure frame. Mean mussel biomass (Live mass [M] in kg/m²) according to all stations of the respective reef type (Carpet, Dense or Compact) between 2008 and 2012 is shown in Figure 4.

The **AMOEBA** model was used to display different variables, mussel biomass (Live mass [M]), total abundance of mussels (Abundance [M#]) and of different shell length classes ([M#] < 6 mm, 6-10, 11-20, 21-30, 31-40, 41-50, 51-60, > 60) related to an arbitrary reference level. Variables were separated according to reef type (t) and standardised with respect to the long-term signal (N 2008-2012): mean value X(t) has an expected value E(N) = μ with a variance of VAR(N) = σ^2 . The corresponding standardised variable is given by S(t)=(X(t)- μ)/ σ with E(S) = 0 and VAR(S) = 1. Differences of the variables between reef types are presented in Figure 5.





[M#] 21-30

[M#] 11-20

[M#]31-40

Results & Discussion

The distribution of mussel biomass in the study area between 2008 and 2012 is not site specific or related to mean reef density of the sites (Fig. 2). Sites with high oyster impact have low or high mussel biomass. In contrast, mussel biomass is positively related to the reef type dense reef (Fig. 4, 5).

The invasion strength of the Pacific oyster differs between and within sites. Distinct reef density distributions (shell mass of live and dead individuals) of a single site is characteristic. All reefs have high or low invaded areas while the proportion of reef types differs between sites. Within the extension of a site, reef density may vary between some kg/m² and reefs may be compacted with 60 up to 100 kg/m². In general, compacted reefs are uncommon areas (Fig. 3) while the majority can be classified as reef carpets (< 30 kg/m²). Between 2008 and 2012, the proportion of dense reefs (30 to < 60 kg/m²) is slightly increasing.

Mussel recruitment is more successful in reef carpets (Fig. 5.1, 5.3) while survival is safeguarded within dense reefs. Almost every year, mussel biomass values in dense reefs exceed values in reef carpets (Fig. 4). Long-term analysis (Fig. 5) detected that dense reefs are populated by higher abundances of older mussels than reef carpets what subsequently increases biomass values. Low temperatures during the ice winter 2009/2010 resulted in high mortality of mussels, decreasing biomass of dense reefs in 2010. Mussels in dense reefs benefit from a sheltered habitat with enough food provision and predator-protection. Compact reefs are not providing ample moving space for higher numbers of large mussels but this may strongly depend on matrix structure. Mussels over 60 mm are scarce, irrespective of reef type.

The results of this study document a positive feedback for mussels in the Central Wadden Sea by the formation of dense oyster reefs. We expect progressively sustained mussel populations, supported by increasing proportions of dense reefs. The alien Pacific oyster is hereby providing an important service from one ecosystem engineer for another even though mussels are not available for mussel fishery.