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Subtidal Mussel Beds in the Wadden Sea: Threatened Oases of Biodiversity

Figure 1: At the beginning of the 20th century European oysters *Ostrea edulis* were fished extensively with an oyster dredge in the northern Wadden Sea resulting in their local extinction in the 1930s. Many associated organisms shared this fate.

For the protection of the Wadden Sea, one of the adopted targets in the Trilateral Wadden Sea Plan is a more natural development of mussel beds. These are hot spots of biodiversity which occur in both the intertidal and subtidal zone. While intertidal mussel beds are mostly protected from fishery, only few restrictions exist for subtidal mussels. We argue that this is not a scientifically sound management strategy because intertidal and subtidal mussel beds show different ecological patterns including differential diversity of associated organisms. Subtidal mussel beds represent one of the most diverse habitats in the Wadden Sea ecosystem. Their protection should be improved.

Background and Introduction

Severe overfishing worldwide has caused a fishing down of marine food webs (Pauly et al. 1998, Jackson et al. 2001). Accordingly, in the present Wadden Sea, few fish are caught while harvesting shrimp and bivalves is a major issue. Overexploitation is considered responsible for the demise of European oysters (*Ostrea edulis*) in the northern Wadden Sea in the 1930s (Reise et al. 1989, Reise 1994, Fig. 1). Vast oyster reefs were once prominent along the gullies and represented structurally complex and diverse marine habitats on shallow subtidal bottoms. Through their destruction, many associated invertebrate populations severely declined or disappeared completely, for example, the sponge *Cliona celata*, the polychaete *Dodecaceria concharum* and the bryozoan *Alcyonidium gelatinosum* (Reise et al. 1989, Reise 1994). Further losses in the subtidal zone that are related to commercial fisheries include complex reefs structured by worm tubes of sabellid polychaetes *Sabellaria spinulosa*. Were there any gains?

Since the 1950s, mussel (*Mytilus edulis*) cultivation has been applied extensively in the Dutch and German parts of the Wadden Sea by means of subtidal bottom cultures (Dankers & Zuidema 1995). The vast majority of so-called seed mussels with a shell length of about 1.5 to 3 cm (equivalent to one year old) is dredged from wild mussel beds of the subtidal zone. Seed mussels are then distributed in optimal densities onto culture lots and are harvested having reached market size (4-5 cm). Successful mussel bottom cultures imply that the biomass of subtidal mussel stocks is intermittently enhanced. This provides more food for mussel eating birds, seastars or other predators. The dredging of seed mussels, however, can have strong negative impacts by, for instance, destroying the fauna and flora associated with the mussel beds or leading to a resuspension of bottom sediment which may cause oxygen depletion in parts of the fishery zones (Dolmer et al. 1999). Because of the fishing pressure and habitat disturbance through dredging, trilateral policies and management plans of Germany, The Netherlands and Denmark regulate the fishery of blue mussels in the Wadden Sea. Most intertidal mussel beds are protected to prevent food depletion for mussel eating seabirds (e.g. eider ducks, *Somateria mollissima*, and oystercatchers, *Haematopus ostralegus*), but few restrictions exist for subtidal mussel beds (de Jong et al. 1999). We argue that this may not be a wise management strategy if the characteristic features and a high species diversity in the Wadden Sea are to be maintained.

Differences between intertidal and subtidal mussel beds

Our arguments are based on comparative ecological studies of intertidal and adjacent shallow subtidal mussel beds near the island of Sylt in the northern Wadden Sea (Fig. 2). The investigations revealed that intertidal and subtidal sites are ecologically different with respect to both the biogenic mussel bed structure as well as associated organisms (Albrecht 1998, Buschbaum 2000, Saier 2000, Buschbaum 2001, Buschbaum & Saier 2001, Saier 2001, Buschbaum in press, Saier in press).

Differences in biogenic mussel bed structure

Structural differences include higher densities of mussels on intertidal beds. Additionally, individuals were smaller (most ranging between 30 – 45 mm shell length) and heavily overgrown by barnacles. In contrast, subtidal mussels were larger (45 – 60 mm shell length) and less fouled. Field experiments showed that both tidal emergence (time of starvation) and to some lesser extent barnacle epibionts negatively affected mussel growth rates and subsequent size distributions of mussels.

Apart from its negative effects on mussel growth, the additional structure provided by barnacle epibionts may improve the recruitment success of mussel brood. We showed that heavy barnacle cover can increase mussel recruitment up to 20-fold. Among other factors, we suggest that this facilitative mechanism leads to high abundances of juvenile mussels on heavily barnacle fouled intertidal mussel beds. Such rejuvenation may be advantageous on a population level, while individual mussels suffer from balanid epibionts through reduced growth.

Differences in species interactions

Field experiments on intertidal mussel beds revealed that grazing and bulldozing activity of periwinkles (*Littorina littorea*) can significantly reduce barnacle abundances during the short time period of balanid settlement (April to May in the study area). Survivors attained size refuges and were able to persist for years. On subtidal mussel beds, in contrast, snail densities were low due to strong predation pressure and snail recruitment restricted to the intertidal zone. Therefore, snails cannot be responsible for barnacle population dynamics in the subtidal zone. There, balanids were strongly preyed upon by abundant juvenile seastars, *Asterias rubens*, and adult green crabs, *Carcinus maenas*. So, predation may cause low barnacle densities on subtidal mussel beds which, in turn, decrease mussel recruitment success. This indirect negative effect of seastars on subtidal mussel densities is enhanced by juvenile seastars feeding directly on small subtidal mussels.

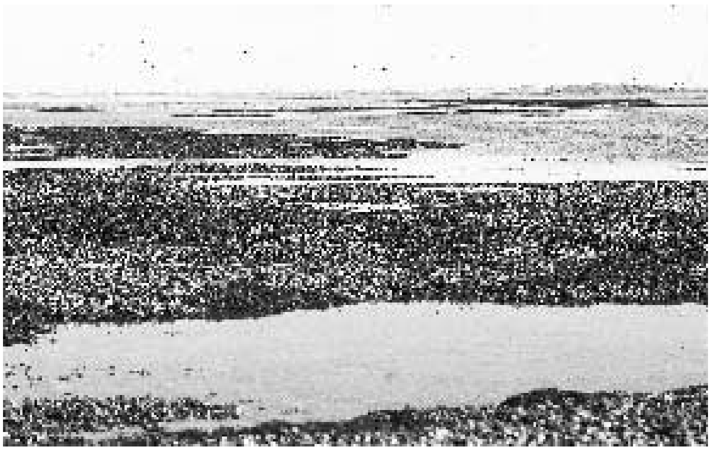

Figure 2: On intertidal and subtidal bottoms of the Wadden Sea, blue mussels *Mytilus edulis* provide living conditions for a wide range of associated organisms. They often form extensive beds, with a conglomerate of empty shells and living mussels attached to each other by byssus threads (Photo: C. Buschbaum).

Differences in associated organisms

Further differences between intertidal and subtidal mussel beds were found with respect to the total number and distribution of associated species. We recorded 69 sessile species on the shells of intertidal and subtidal mussels (31 invertebrates, 37 algae and 1 lichen). While some species occurred in both tidal zones several were limited to either intertidal or subtidal sites. For example, green and brown algae (*Enteromorpha* spp., *Cladophora sericea*, *Fucus vesiculosus*) were abundant on intertidal mussels while many red algae (e. g. *Antithamnion plumula*, *Colaconema daviesii*), hydrozoans (e. g. *Coryne pusilla*, *Sarsia tubulosa*) and bryozoans (e. g. *Bowerbankia* spp., *Alcyonidium mytili*) were restricted to subtidal mussel beds (Fig. 3).

Finally, the species composition, abundance and diversity of non-attached epifauna were also shown to be significantly different between mussel beds in the two tidal zones. Higher diversity and species richness were recorded on subtidal mussel beds. For example, shallow subtidal mussel beds provided habitat for species susceptible to desiccation, e.g. sea urchins (*Psammechinus miliaris*), or freezing, e.g. whelks (*Buccinum undatum*). Total abundance of individuals of non-attached epifauna was higher at intertidal sites, which were dominated by periwinkles (*Littorina littorea*) and juvenile crabs (*Carcinus maenas*), which may find spatial refuges from predators in the structurally heterogeneous intertidal mussel beds.

The general conclusion of our study is that intertidal and subtidal mussel beds are ecologically not the same. In particular, subtidal mussel beds harbor a distinct and more diverse community of associated organisms.

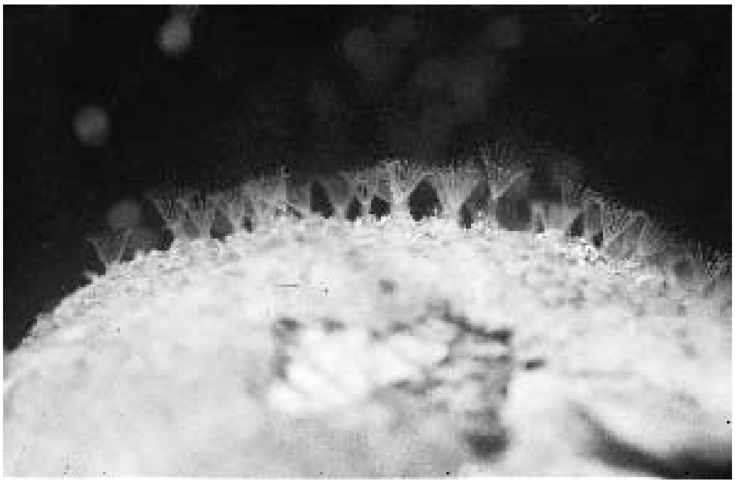

**Figure 3:
Many sessile organisms use mussel shells as substratum. The bryozoan *Alcyonidium mytili* is predominantly found on subtidal mussels (Photo: C. Buschbaum).**

Implications for the Management of Mussel Fishery

Our studies imply that the common practice in the Wadden Sea to selectively protect intertidal mussel beds and exclude many subtidal mussel beds from conservation, needs to be revised. A more effective protection of subtidal mussel beds is required. The loss of mature subtidal mussel beds is not in agreement with a sustainable mussel fishery, because subtidal mussel beds harbor a distinct and diverse suite of associated species and may not simply be considered as submerged copies of intertidal mussel beds. In areas where subtidal mussel fishery is prohibited we expect mature subtidal mussel beds with their distinct species community will reestablish and contribute to the dynamic and diverse character of the Wadden Sea.

The ephemeral beds on mussel culture plots cannot be regarded as a substitute. Since oyster beds and *Sabellaria*-reefs are already gone, subtidal mussel beds remain as the only natural hard-bottom community in the gullies of the Wadden Sea.

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