8.3 Intertidal Blue Mussel Beds

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Blue mussel bed
(Photo: G. Millat)

8.3.1 Introduction

Beds of the blue mussel (*Mytilus edulis*) are important biogenic structures in the Wadden Sea ecosystem, serving as habitat and as food source for a number of species. In the Wadden Sea Plan (1997), a specific trilateral Target was formulated aiming for an increase of the total area and a more natural development and distribution of natural intertidal mussel beds, providing a framework for habitat management.

Targets

- A natural dynamic situation in the Tidal Area.
- An increased area of geomorphologically and biologically undisturbed tidal flats and subtidal areas.
- An increased area of, and a more natural distribution and development of natural mussel beds, *Sabellaria* reefs and *Zostera* fields.

To protect intertidal mussel beds, in all three countries considerable parts of the intertidal area have been permanently closed for blue mussel fishing, but differences between countries are substantial. In The Netherlands, fishery is restricted to young, unstable beds outside areas that are permanently closed. In Niedersachsen, fishery of seed mussels is allowed in significant parts of the intertidal, in accordance with a management plan. In Schleswig-Holstein, mussel fishery is not allowed in the intertidal area, as well as, in most subtidal parts of the national park core zone. In Denmark, mussel fishery is allowed on a small scale, in intertidal as well subtidal areas, but the quotas since 1992 have been fished in subtidal areas only. A comprehensive overview of mussel fishing policies was drawn up by the Common Wadden Sea Secretariat (CWSS, 2002a) (see chapter 2.5).

The Governmental Conference in Esbjerg (2001) acknowledged 'the efforts that have been made with regard to the policy on the mussel fishery' and stressed 'that the implementation of the Targets on geomorphology, eelgrass beds and mussel beds still deserves attention and, therefore decided 'to evaluate before the end of 2004 the mussel fishery with special attention to stable mussel beds' (§9 Esbjerg Declaration) and 'to base the conservation and management of mussel beds on the protection of sites where stable beds occur and areas with a high potential for the development of stable mussel beds' (§10 Esbjerg Declaration).

The 1999 QSR focused on a description of the long-term development of intertidal mussel beds up to 1997. In the 1980s and 1990s, the area of beds and biomass were lower than before 1980. Therefore, it was concluded that the Target of an increased area and a more natural development of natural intertidal mussel beds had not been reached. In fact, the number and size of mature blue mussel beds had declined in the last decade.

Several factors relevant for survival of mussel beds were discussed. It was doubted whether an increase in storminess (as observed in some parts

of the Wadden Sea during the last decade) or ice-scouring (no significant differences with the long-term average) had been the main factors of the observed long-term decline. Fisheries, on the other hand, had caused large declines and prevented recovery, especially in periods of failing spatfall. Therefore, it was proposed that the management of mussel fishery should be based on protection of sites where stable beds occur and of sites with a high potential for the development of stable beds.

The following paragraphs report on the implementation of the recommendations in the 1999 QSR, the developments of the mussel beds and mussel stocks since 1999, the impact of mussel fishery, and the role of bio-invaders in mussel beds.

8.3.2 Implementation of 1999 recommendations

8.3.2.1 A protocol for harmonized description and area measurement of mussel beds

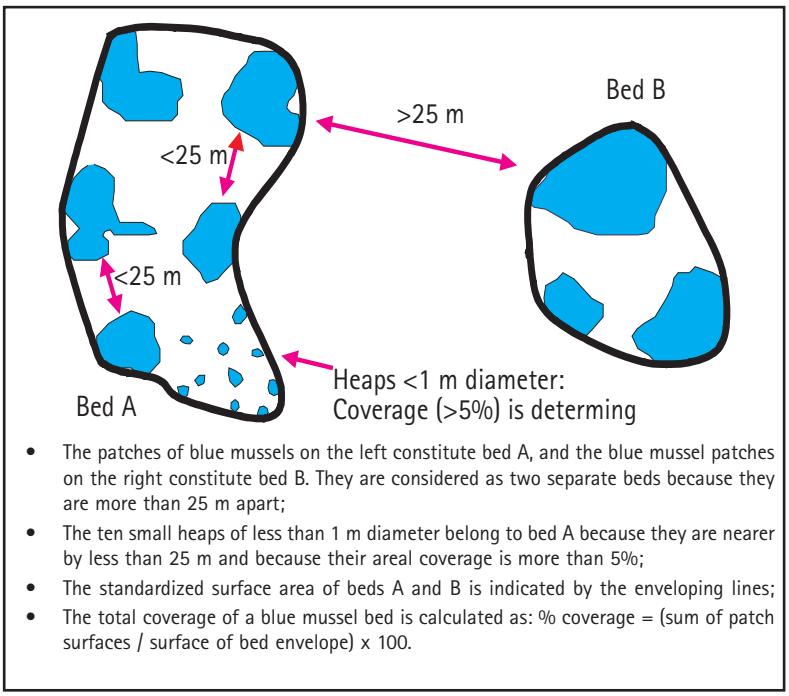
In 2002, a common trilateral definition of a mussel bed was developed (CWSS, 2002b; Herlyn, 2005). This definition is based on the structure of mussel beds:

'A mussel bed is a benthic community structured by blue mussels. It may consist of a spatially well-defined irregular collection of more or less protruding smaller beds, which may be called patches, separated by open spaces. This description also includes young beds with a high abundance of small mussels. The described structure may not be so distinct in young beds or just settled beds (spatfall).'

In the field, boundaries between a mussel bed and the surrounding intertidal flat are not always clear-cut, which can easily lead to differences in size estimates among individual observers. Moreover, in the field, transition zones between mussel beds and the surrounding tidal flat do occur. The following criteria were developed in order to make standardized decisions on the boundaries of mussel beds when carrying out field surveys (see also Figure 8.3.1): A group of mussel patches less than 25 meters apart is considered as a bed, but only if at least 5% of the sea bottom is covered by these patches; the coverage of the area with mussel patches is >5% if the space between them is (on average) less than about four times the patch diameter. These criteria have been used since 2002.

Fields of scattered mussels are not included in the definition of mussel beds and consequently they are not included in the quality status judgement. These fields consist of individual and small conglomerates of mussels, often with some cockle shells attached to their byssus threads. They can originate from spatfall or from mussel beds that have been damaged by storms and can be transported over tens, hundreds or even thousands of meters. They are generally not able to form a sizeable biogenic structure, but fields of scattered mussel clumps may consolidate to mussel beds by spatfall or by more mussels being transported from other intertidal or subtidal locations to these areas. However, most scattered mussel clumps disappear within one or two years. That does not alter the fact that they may form an important food source for oystercatchers and gulls.

Aerial photographs and ground-surveys are used to determine the location, size and shape of mussel beds. For recognition of intertidal mussel beds on aerial photographs a stereoscope should be used. For monitoring purposes, it is important to carry out photographic surveys in a well-defined period of the year, because the surface covered by mussel beds can increase through spatfall during the summer months and will often decrease during autumn and winter due to storms and/or ice-scour. A relatively stable period is between March and July, after the winter and before new recruits can be detected on aerial photographs. Most of the maps of Dijkema (1989) were drawn from aerial photographs from this period. In The Netherlands (Ens *et al.*, 2004) and Niedersachsen (Herlyn and Millat, 2004), this period is recommended for aerial surveys of the sur-



- The patches of blue mussels on the left constitute bed A, and the blue mussel patches on the right constitute bed B. They are considered as two separate beds because they are more than 25 m apart;
- The ten small heaps of less than 1 m diameter belong to bed A because they are nearer by less than 25 m and because their areal coverage is more than 5%;
- The standardized surface area of beds A and B is indicated by the enveloping lines;
- The total coverage of a blue mussel bed is calculated as: % coverage = (sum of patch surfaces / surface of bed envelope) x 100.

Figure 8.3.1: Blue mussel bed measuring protocol, with mussel patches (blue) and envelope (black).

face covered with mussel beds. In Schleswig-Holstein aerial photographs are intentionally made in autumn and therefore potentially include new spatfall of the year.

8.3.2.2 The protection of young mussel beds

In general, only limited research has been done on how and where young mussel beds could be best protected.

In The Netherlands, habitat modeling was used to predict the stability of newly formed mussel beds in the intertidal (Brinkman and Bult, 2002). In areas with a high potential for stable mussel beds according to the habitat model, relatively more newly formed mussel beds appeared than in other areas, indicating the usefulness of this habitat modeling approach. Since 1995, all mussel beds in these 'high potential' areas have been protected. An index was developed for judging the expected stability of present beds, taking into account parameters such as sediment stability, and density and age composition of the mussels in the bed (Brinkman *et al.*, 2003).

In Niedersachsen, all the sites of mussel beds recorded during the last 50 years were documented in 1996 (Millat and Herlyn, 1999). The number amounted to 187 sites, of which 31 were protected by the National Park Law. From 1999 to 2003 17 additional sites were closed for fishery according to the 'Miesmuschelmanagementplan'. Additional data sets since then demonstrate that most of the blue mussel sites have shown a continuous occurrence of mussel beds. After an intensive revision in 2003, 102 sites were considered as locations where stable beds can occur (so called stable sites) (Herlyn and Millat, 2004). Under the new blue mussel fishery management plan (2004-2008), 17 out of these 102 sites are protected in addition to the 12 sites in areas closed for mussel fishery by the National Park Law.

In Schleswig-Holstein, all intertidal mussel beds, existing as well as new ones, have been protected since 1996.

In Denmark, some fishery was allowed until 2003. It was only allowed to take a part of the expected production of the standing stock each year. This approach is intended to keep the standing stock at a stable level over the years. If, for one reason or another, the standing stock falls to a lower level, the production will also decrease. The share to be reserved for the birds, however, will remain the same and the fishery will be given a lower quota for the following season (Kristensen, 1997, 2003; Munch-Petersen and Kristensen, 2001). During the last 15 years, annually 10,000–15,000 t of mussels have been protected to serve as food for birds, leaving 3,000–10,000 t for fishery.

In Denmark, the mussel fishery is restricted to harvesting of mussels of marketable size. The Danish regulations do not discriminate between intertidal and subtidal beds. This has been the precept since the beginning of the 1980s. Since 1992, mussel fishery has been allowed only in approx. 50% of the Danish Wadden Sea, the main fishing area being Ho Bugt and northern part of Lister Deep. These areas contain intertidal as well as subtidal beds, the latter being preferred by the fishermen. As a consequence, the intertidal beds in the Danish Wadden Sea have not been fished since 1992.

8.3.3 Development of area, biomass and age composition since 1999

8.3.3.1 The Netherlands

In their evaluation of the historical development of intertidal mussel beds, Dankers *et al.* (2003) re-estimated the area of mussel beds in the period 1960–1990. This area may have varied between 1,000 and 6,000 ha. The value of 4,120 ha for

Definitions

Mussel bed

A mussel bed is a benthic community structured by blue mussels. It may consist of a spatially well defined irregular collection of more or less protruding smaller beds, which may be called patches, separated by open spaces. This description also includes young beds with a high abundance of small mussels. The described structure may not be so distinct in young beds or just settled beds (spatfall) (Blue mussel workshop, 2002).

Stable bed

Bed where the structure (patches, formed relief) is clearly recognizable over many years (Blue mussel workshop 2003, QSR 1999).

Stable site

Location where mature mussel beds (one or more) occur regularly over several years (Blue mussel workshop 2002).

Assessment criteria for persistence of a mussel bed

Age of bed, type of location, sediment structure of mussel bed basis (Blue mussel workshop 2002).

Larvae settlement

The first benthic migrating stage of blue mussel larvae smaller than 1 mm is defined as primary settlement. The larvae can settle several times on various substrates until they get larger and settle more permanently on structures such as existing mussel beds or stones (secondary settlement) (Blue mussel workshop, 2000).

Spatfall

Settlement of young mussels on a tidal flat. These small mussels are called 'spat' during the year of settlement only.

Recruitment

The addition of young mussels to the reproducing population. For blue mussels, the concept of recruitment is used for young mussels which survived the winter (age = 1 year).

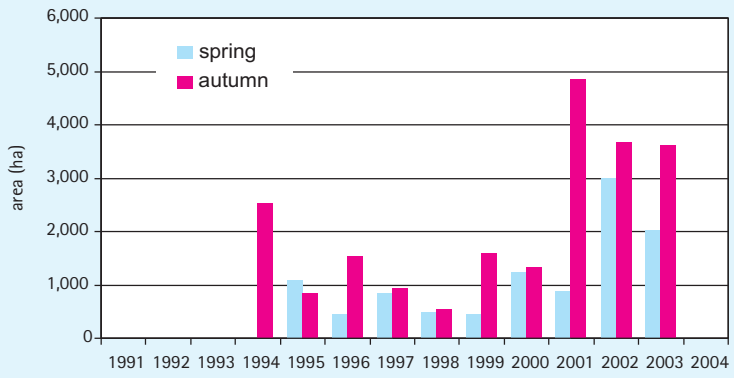


Figure 8.3.2: Surface area (ha) of intertidal mussel beds in the Dutch Wadden Sea since 1994. Data is achieved during a ground survey and reconstructed afterwards (Steenbergen *et al.*, 2003b). An update of the reconstruction was made in November 2004, and thus the data shown can be slightly different from data in Steenbergen *et al.* (2003b).

1976 and 1978, presented in the 1999 QSR and well documented in the habitat maps for the Wadden Sea (Dijkema, 1989), lies well within this range. These mussel bed areas occurred in spite of fishery, so these estimates can be considered as minimum values of the 'natural' area.

Dankers *et al.* (2003) and van Stralen (2002) described the dynamics of the Dutch intertidal mussel beds. They stated that in most years some spatfall occurs in existing beds. Losses due to storms and ice winters are often compensated by good spatfall outside the remaining beds, but mostly in the neighborhood of or on the remainders of these.

Most intertidal mussel beds in the Dutch Wadden Sea disappeared in the period 1988-1991, after intensive fishery in a period with low spatfall (Dankers *et al.*, 1999). The oldest intertidal beds now present in The Netherlands, with a total surface of about 200 ha (Dankers *et al.*, 2003), are from the 1994 spatfall. The spatfalls of 1999, 2001 and 2003 are the main contributors to the present situation. Based on ground survey and expert judgement the area of intertidal mussel beds in the spring of 2004 was estimated at about 2,200 ha (Steenbergen *et al.*, 2004).

An overview of the development since 1994 of areas covered with mussel beds in spring and autumn in the Dutch Wadden Sea is given in Figure 8.3.2. These areas are based on ground surveys, as well as a reconstruction of the data in areas that could not be included in the data surveyed completely due to shortage of time, mainly in autumn (Steenbergen *et al.*, 2003a, 2003b). In the reconstruction, data for mussel bed-areas of all years was used in order to compensate for the missing data in the ground surveys. Data of autumn 2003 and spring 2004 can only be reconstructed after the ground survey in spring 2005.

The total biomass of mussels in the intertidal (scattered mussels and mussel beds) is monitored in spring. It has increased from about 11,000 t fresh weight in 1999 to about 74,000 t in 2004 (Steenbergen *et al.*, 2004; Figure 8.3.3).

Since 1991, mussel fishery was restricted to the subtidal part of the Dutch Wadden Sea, with, however, two exceptions. First, some fishery was allowed in the autumn of 1994 on young seed beds of the 1994 spatfall. Most of these seed beds (both fished and unfished) disappeared in early 1995 due to storms. Second, a restricted experimental fishery was carried out in 2001 on beds that were considered unstable, to test the hypothesis that moderate fishery could increase the stability of

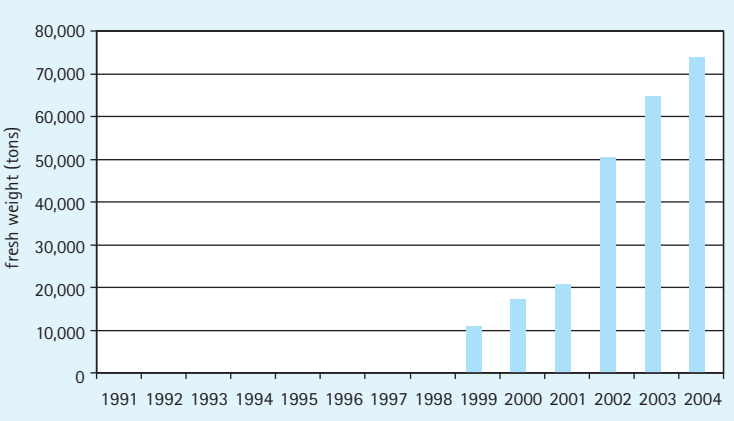


Figure 8.3.3: Total biomass (t fresh weight in spring) of intertidal blue mussels in the Dutch Wadden Sea since 1999 (from: Steenbergen *et al.*, 2004).

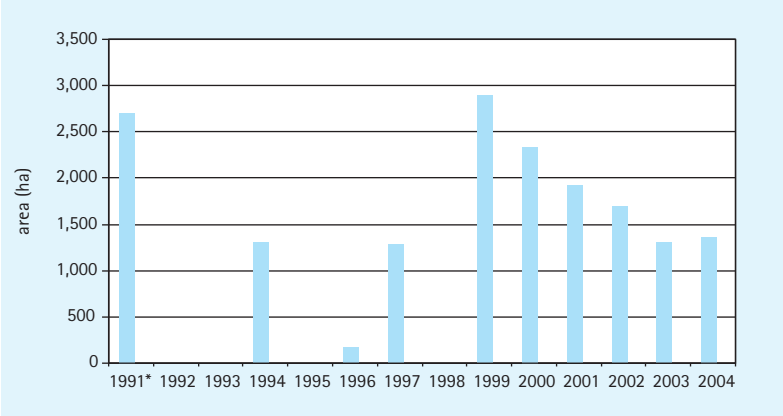


Figure 8.3.4: Development of the total surface area of intertidal blue mussel beds (ha) in Niedersachsen based on yearly spring surveys. (*1991: refers to the period of 1989–91) (from: Herlyn and Millat, 2004).

young mussel beds. The experimental fishery, however, was unable to prove the hypothesis as autumn and winter storms destroyed the fished as well as unfished mussel beds (Smaal *et al.*, 2003). Therefore, it can be stated that in the Dutch Wadden Sea the mussel fishery since 1991 had no, or at the most a negligible impact on the development of mussel beds on the intertidal flats.

The age structure of the mussels on the mussel beds in the past is not well known, but must have varied considerably (van Stralen, 2002; Steenbergen, 2003b). More than average spatfalls occurred about once per four years, and there are indications of large variations in the size of the beds.

8.3.3.2 Niedersachsen

Mussel beds covered a surface area of up to 5,000 ha during 1950-1987 (Dijkema, 1989; Michaelis *et al.*, 1995). After the mid 1980s, this area decreased to 1,400 ha in 1994, although there was intense spatfall in the summer of 1991. The decrease continued to 170 ha in spring 1996. In 1996, an intense spatfall resulted in the formation of new beds, which survived for some years. Of the young beds from 1996, 1,280 ha endured the ice winter 1996/97.

Some additional spatfalls have occurred since 1996, leading to a mixed population structure. In 2003 a part of the beds was still dominated by the year class 1996.

In spring 1999, a total area of about 2,900 ha of mussel beds was present. This area diminished gradually during 1999-2003, resulting in a surface reduction of 55%, to reach 1,300 ha in 2003 (Figure 8.3.4). In the area closed for fishery according to National Park Law mussel bed area decreased by 40% from 286 to 172 ha (Herlyn and Millat, 2004). The biomass decreased even more, by about 85%, from about 110,000 t to about 15,000 t (Figure 8.3.5).

8.3.3.3 Schleswig-Holstein

The area of mussel beds present in 1989 was reassessed by analysis of aerial photographs and estimated at 1,500 ha. This is the highest value documented so far in the Wadden Sea of Schleswig-Holstein (Nehls, 2003; Nehls and Ruth, 2004; Stoddard, 2003). Mussel beds at that time originated mainly from the very strong spatfall in 1987, *i.e.* after a series of three cold winters, and covered parts of the higher intertidal flats. The last good spatfall occurred after the severe winter of 1995/96. This 1996 spatfall occurred in locations that were considered to be low in hydrodynamics and mainly settled on the lower parts of intertidal flats; mussel beds were re-established on the high

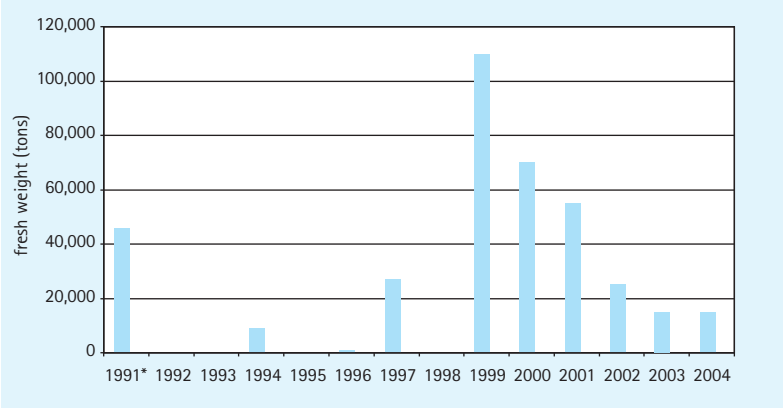


Figure 8.3.5: Development of total biomass (t fresh weight) of intertidal blue mussel beds in Niedersachsen based on spring surveys (from: Herlyn and Millat, 2004).

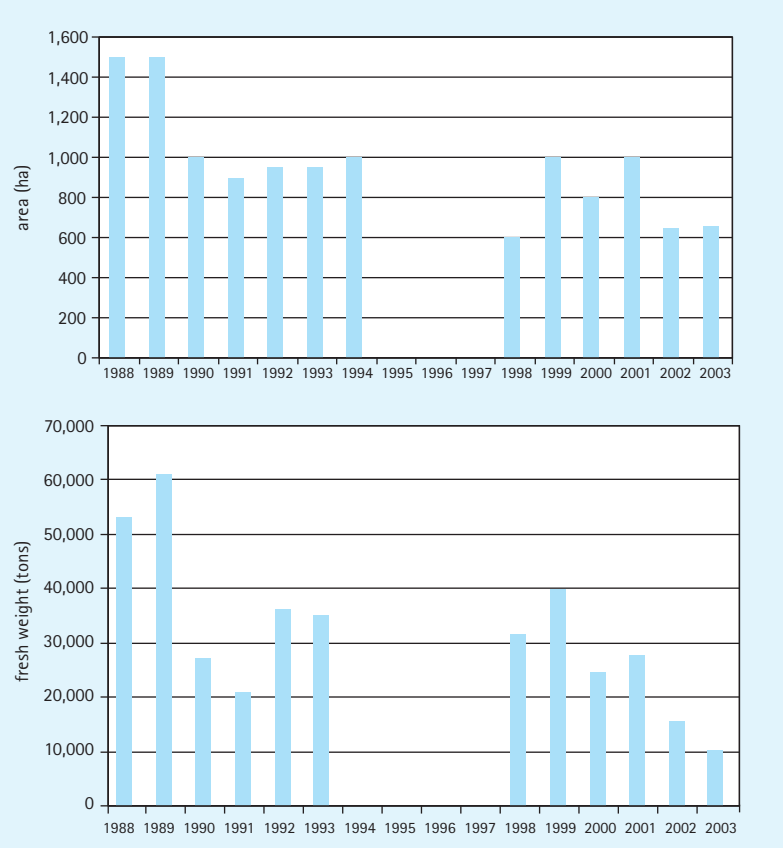


Figure 8.3.6: Development of total surface area (ha) and mussel biomass (t fresh weight) of intertidal blue mussel beds in the Schleswig-Holstein Wadden Sea based on yearly surveys (spring/summer) (from: Nehls and Ruth, 2004).

flats. Monitoring of blue mussel beds was resumed in 1998 (Nehls, 2003). The surface covered with mussel beds in 1999 was 1,000 ha (Figure 8.3.6). Subsequently, the mussel bed area decreased to 640 ha in 2002. The mussel bed area north of the Eiderstedt peninsula further decreased in 2003 but this loss was compensated by new spatfall in the area south of Eiderstedt. The decrease was mainly the result of storms and lacking recruitment into the mussel beds and was paralleled by a reduction in the coverage within the mussel beds, which decreased from 43% in 1998 to 26% in 2002.

Biomass estimates from before the intensive fisheries of the mid 1980s are not available. After the good spatfall of 1987, 60,000 t (wet weight of the living animal, including shell and enclosed sea water) were present in 1988 and 1989. This decreased to 35,000 t in the early 1990s due to fisheries on 30 of the 64 beds and strong winter gales in early 1990. Since 1992, the majority of the mussel seed fishery occurred in the subtidal and, since 1994, intertidal fishery has been abandoned. Total biomass of intertidal mussel beds reached 40,000 t in 1999 and decreased to 13,000 t in 2003.

Due to the high dynamics of mussel beds it is difficult to obtain a reference value of what might be a good ecological state. If the maximum values ever recorded of all individual beds are added up, an area of 2,500 ha would be obtained. This value can be considered as the highest possible mussel bed area which would be present if all intertidal beds reached their highest reported area simultaneously. However, it seems unlikely that this will occur frequently.

8.3.3.4 Denmark

For the Danish Wadden Sea, Munch-Petersen and Kristensen (1987) estimated the total area covered with mussel beds before the overfishing in 1984-1987 at 4,000 ha. This figure was based on aerial photographs and includes scattered mussels ('Streusiedlung') in very large areas. As these areas with scattered mussels do not meet the present criteria for mussel beds, these historic figures should be reduced to about 2,000 ha (Kristensen, personal judgment) to allow a comparison with recent data. After the period of heavy fishery, Munksgaard (1989) estimated the total area of mussel beds to be only about 500 ha in 1989; scattered mussels were not included. In 1991, 1,100 ha were present (Figure 8.3.7) but in 1996 the area decreased again to only 600 ha (Kristensen, 1994, 1995, 1997). In 1999, the area

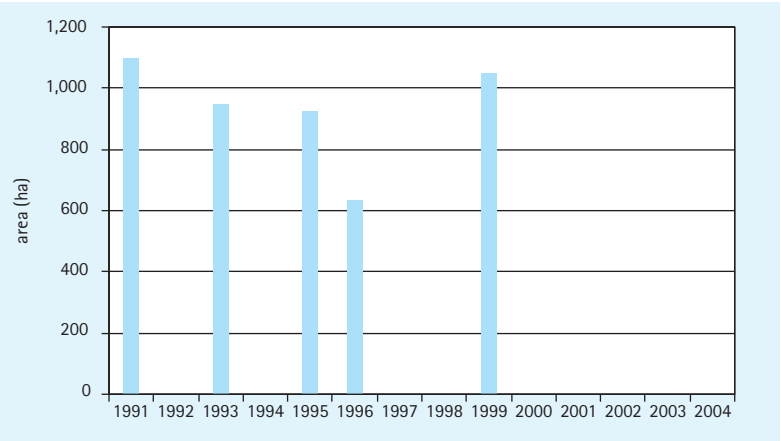


Figure 8.3.7: Development of total surface area (ha) of intertidal blue mussel beds in the Danish Wadden Sea based on yearly surveys in spring. A small amount of subtidal beds are included (source: DFU).

had increased again to 1,000 ha (Kristensen and Pihl, 2003). The areas with mussels have varied considerably since the mid 1980s, but never exceeded 2,000 ha. In the Juvre Dyb, Mandø and Knude Dyb areas, the beds have not returned since they were removed by the fisheries. A nature conservation project was started in 2002 to test whether transplantation of seed mussels to Jørgens Lo and Ribe Stream could contribute to the re-establishment of mussel beds in this area. In the Ho Bight area (partly closed for fishery), almost 70% of the original beds returned by an autumn settlement immediately after the breakdown in 1989. This situation remained stable in the years after 1999. Some intertidal beds disappeared and new ones have appeared either in the previous place or in new places. In 2002, 650 – 900 ha of mussel beds were present (Kristensen and Pihl, 2003). So, the area covered with mussel beds as well as their biomass has been very variable over the years (Kristensen, 1994, 1995, 1997; Kristensen and Pihl, 2003).

Most of the intertidal mussel beds in the Danish Wadden Sea are very old (>20 years). Some of the intertidal beds are highly dynamic, while others are not. The oldest and most stable beds are in the southern part of Jordsand, in Ho Bight at Sæding Strand and east and west of the isle of Langli. In a few years time they may deteriorate until suddenly a new settlement takes place, such as happened last time in 2003. This means a new era for these mussel beds; the mussels stay there for some years. Due to these dynamics, the biomass of intertidal beds varies considerably over the years. Figure 8.3.8 gives an overview of the biomass of all mussels in the Danish Wadden Sea. This figure includes subtidal mussels, but the contribution of the subtidal mussels is relatively small, both because most beds in the Danish Wadden Sea are intertidal and because the biomass per m^2 on intertidal beds is higher than on subtidal beds (Kristensen, 2003).

8.3.4 Impact of fisheries/mussel farming on mussel beds

The main reasons why mussel beds disappear under natural conditions are insufficient spatfall, ice covers and storms. These conditions lead to a gradual decrease in mussel bed area as observed in Schleswig-Holstein since 1998 (Nehls, 2003; Nehls and Ruth, 2004). Ice covers were absent from 1997 until 2002, and the storminess did not increase during the last decades (Schmidt, 2001).

As described above, there has been almost no

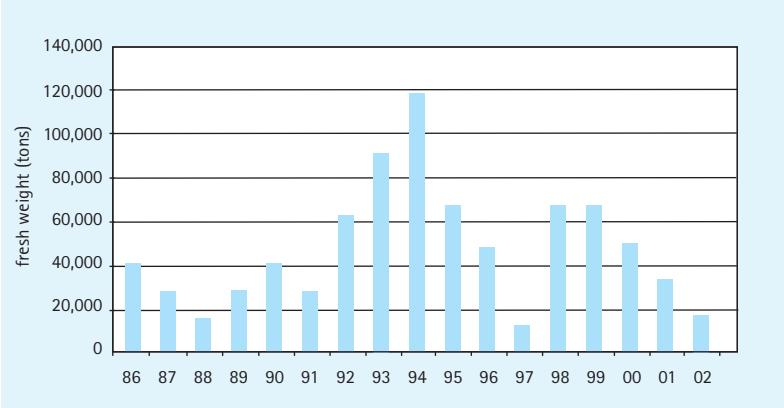


Figure 8.3.8: The annual estimated biomass (t fresh weight, in Sept.-Oct.) in the Danish Wadden Sea between 1986 and 2002, including a relatively small amount of subtidal mussels (from: Kristensen and Pihl, 2003).

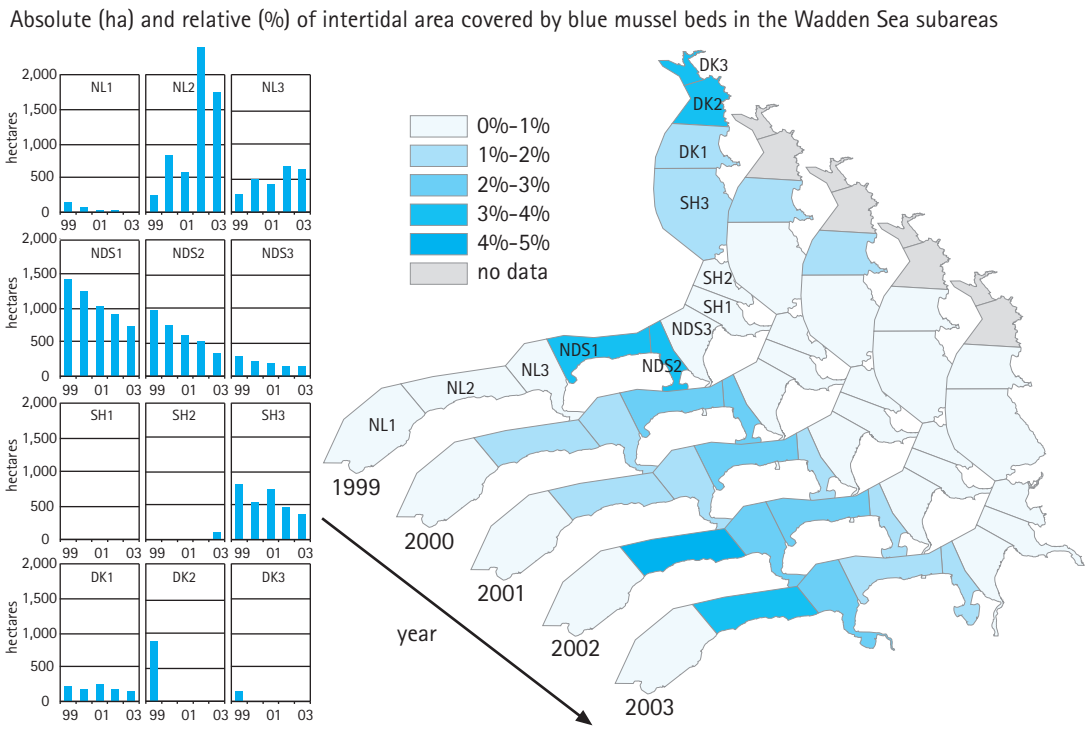


Figure 8.3.9: Distribution of intertidal blue mussel beds in the Wadden Sea in the period 1999–2003. Shown is the development of the surface area of mussel beds (ha) and the area of intertidal flats coverd by mussel beds (%) (calculation based on GIS data, source TMAP data unit).

impact of mussel fishery in the intertidal area of The Netherlands since 1991. Nor has there been any impact of mussel fishery in the intertidal area of Schleswig-Holstein since 1995. In these parts of the Wadden Sea, the seed mussels to stock the culture lots have been obtained from subtidal areas.

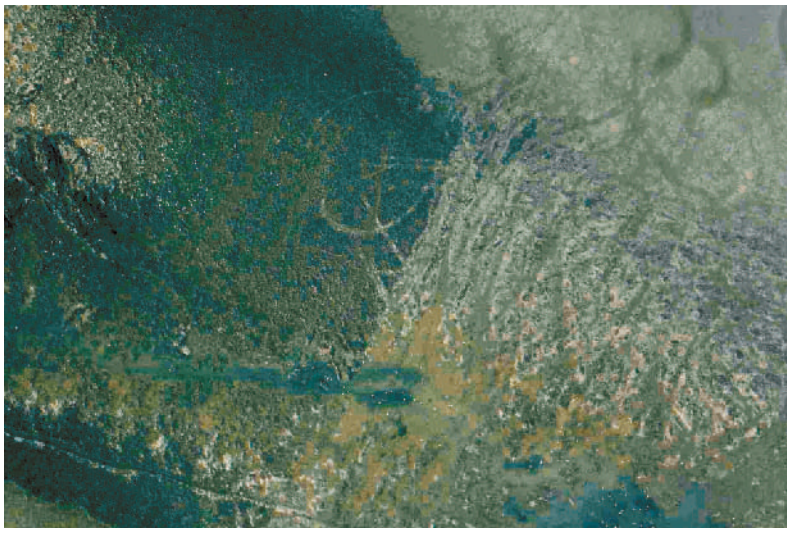
In Niedersachsen, the mussel culture still depends on seed mussels from intertidal mussel beds. It is unknown to what extent the harvesting of seed mussels has contributed to the observed losses of hectares and biomass of intertidal mussel beds. In a study on the influence of mussel fishery on stable sites of blue mussel beds in the Niedersachsen Wadden Sea, Herlyn and Millat (2000) showed that in most of the investigated beds mussel fishery led to heavy or even complete losses. These losses were larger than the amounts of mussels actually removed by fishery.

By the end of 2004, a new management plan for mussel fishery in Niedersachsen was adopted which allows continuation of the seed mussel fishery in the intertidal area.

In Denmark, the intertidal beds remained unfished since 1992.

In conclusion, it can be stated that in The Netherlands, in Schleswig-Holstein and in Denmark the direct impact of mussel fishery on the natural development of intertidal mussel beds has been limited or absent during the last years. Fishery went on in Niedersachsen. Further research on long-lasting effects of mussel fishery on the fate of fished beds and on the effects on mussel stocks of larger areas, *e.g.* tidal basins, is necessary.

The recovery of mussel beds as observed in The Netherlands is mainly attributed to the prohibition of the mussel seed fishery on the intertidal flats (Ens *et al.*, 2005). Observations in Schleswig-Holstein and Denmark show that in the long run existing mussel beds will deteriorate when no recruitment occurs, and the total surface of beds will diminish due to storms and ice cover as long as these losses are not compensated by new settlement of mussel spat.



Aerial photograph of a fished blue mussel bed ('Jan-Louw'-bank), Texel, (Photo: K. Kersting)

8.3.5 Bio-invaders

Mussel beds represent a hard substrate favorable for settlement of sessile epibionts. The most important invaders are the gastropod *Crepidula fornicata*, the Pacific oyster *Crassostrea gigas* and the Australian barnacle *Elminius modestus*.

Crepidula is increasingly abundant on subtidal culture lots in the Dutch Wadden Sea. Currently, high population densities are present on mussel beds of the Jade-Weser-Elbe estuary and in the northern Wadden Sea (Thieltges *et al.*, 2003, Wehrmann and Schmidt, unpubl.). Being a filter-feeder, *Crepidula* competes for food with the mussels when occurring in high abundances, causing significant reduction in growth of blue mussels (Thieltges, 2005).

The most obvious change in the community structure of mussel beds is being caused by the Pacific oyster. This species competes with the native blue mussel for food as well as for space. Due to its high growth rate and successful recruitment, the Pacific oyster is considered a potential risk to the mussel beds of the Wadden Sea. On the other hand mussels and oysters can form complex and biodiverse communities with algae, periwinkles and abundant mussel spatfall (see also chapter 6 'Introduced Species').

Elminius modestus was introduced from Australia. It strongly outcompetes other barnacle species (Nehring and Leuchs, 1999). Although barnacles have negative effects on mussel growth (Buschbaum and Saier, 2001), they also have a positive effect by increasing mussel recruitment (Saier, 2001; Buschbaum, 2002).

Pacific oyster in a blue mussel bed (Photo: G. Millat).

8.3.6 Conclusions

Spatfall is a crucial process in the population dynamics of blue mussels. The determining factors for spatfall are still not well understood, nor is the cause of regional differences in spatfall within the Wadden Sea.

In The Netherlands, measures to increase the area of naturally developing mussel beds have been successful, but this lasted more than 10 years until a surface of about 2,000 ha of more or less stable beds (most of these having survived two winters) was reached. Most of these beds are situated in the eastern part of the Dutch Wadden Sea, where good recruitment occurred in 1994, 1999, 2001 and 2003. Very few beds, however, have developed in the western half of the Dutch Wadden Sea. In Niedersachsen, Schleswig-Holstein and Denmark, there was a rather good spatfall in 1996, leading to establishment of beds that still survive. However, lack of recruitment since 1999 has caused deterioration and overall loss of biomass.

Besides recruitment success, the impact of storms and ice cover is of major importance for the long-term development of mussel beds, especially in the Schleswig-Holstein and Danish part of the Wadden Sea.

In The Netherlands and in Schleswig-Holstein the direct impact of mussel fishery on the natural development of mussel beds has been limited or absent during the last years. In Denmark, the impact was restricted to subtidal areas in Ho Bight and in the northern part of the Lister Deep. In Niedersachsen, mussel fishery may have contributed to additional reduction of mussel bed area and biomass.

Progress was made regarding the protection of young mussel beds on old sites of mussel beds, which are considered to provide the best chances for settlement of new beds. In The Netherlands, fishery of seed mussels will be allowed in 'unstable' locations only, and in Schleswig Holstein no fishery is allowed at all in the intertidal. In the Danish Wadden Sea, part of the intertidal beds are still open to fishery, irrespective of their potential to develop stable mussel beds. In Niedersachsen, the management plan was amended in 2004 and allows for seed mussel fishery in the intertidal.

As a follow-up of the 1999 QSR, a protocol was developed for harmonized description and area measurement of intertidal blue mussel beds, providing a useful tool for further assessments.

8.3.7 Target evaluation

The targets of the Wadden Sea Plan are (1) an increased area and (2) a more natural distribution and development of natural mussel beds. This target was set after a period of overfishing of many intertidal beds and relatively low stocks. Since then, strict regulations have been applied in most of the areas.

The increased area was reached in the middle and the eastern part of the Dutch Wadden Sea, but not in the western part. In Niedersachsen, the current total area of mussel beds is still below the level present in the late 1980s despite the recovery after the spatfall of 1996. In Schleswig-Holstein, the area of mussel beds is still below the level present in the early 1990s. In the Danish Wadden Sea no development according to the target occurred.

The more natural distribution and development of intertidal mussel beds, as far as possible with competition by bio-invaders and changes in climate, may have been achieved in all areas where there was no fishing on intertidal mussel beds. This applies to most of the beds in The Netherlands, 25-30% of the mussel bed sites in Niedersachsen, all beds in Schleswig Holstein and all beds in Denmark.

8.3.8 Recommendations

Research is needed to provide insight into the spatfall process in general, and the cause of low recruitment of intertidal mussels and mussel beds.

The biotope 'intertidal blue mussel bed at stable sites' should be considered within the Water Framework Directive as a biological quality element for coastal waters.

The settlement of Pacific oysters may have a major impact on the mussel beds and their biomass in the near future. Therefore, the proliferation of the Pacific oyster in and outside mussel beds should be monitored together with associated changes in the structure of the mussel beds. A common approach should be developed also aiming at the development of management tools that could be used to reduce the influence of Pacific oysters on mussel beds.

To extend – if possible – the habitat model for intertidal mussel beds developed as a management tool for the Dutch Wadden Sea to the German and Danish Wadden Sea too.

The management measure of protecting stable mussel beds or sites is still valid.

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