AquaSense

Distribution and threats of Arctica islandica

A. islandica as an example for listing of species and habitats subject to threat or rapid decline

Sponsor	The Netherlands Directorate-General of Public Works and Water management (RWS), North Sea Directorate.

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Grontmij Groep

Inhoud

1. Introduction

The Biodiversity Committee (BDC) was established by OSPAR 2000 to facilitate the implementation of the OSPAR Strategy on the Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area. BDC carries out work formerly done by IMPACT.

One of the tasks of BDC is to develop a list of species and habitats, which need to be protected and to identify the impact of human activities on these species and habitats. The Netherlands is a lead country for this issue (BDC 00/15/1, Annex 6).

Criteria for selection of species and habitats have been developed by IMPACT (IMPACT 99/15/1, Annex 6) (Annexes 1 and 2). Given that the compilation of lists of habitats and species using these so-called Faial Criteria may take 2-3 years, an initial list of priority habitats and species is to be developed drawing on national experts and observers. Priority species and habitats are those under immediate threat or subject to rapid decline.

In this report, the ocean quahog *Arctica islandica* has been selected as an example species to describe and map the actual and potential distribution in the North Sea region of the OSPAR maritime area (fig. 1) in order to assess threats and decline. The threats and decline are visualised with maps, constructed with the GIS tool HABIMAP. This report also had the intention to evaluate this GIS-based approach for its usefulness in the selection procedure for threatened and declining species.

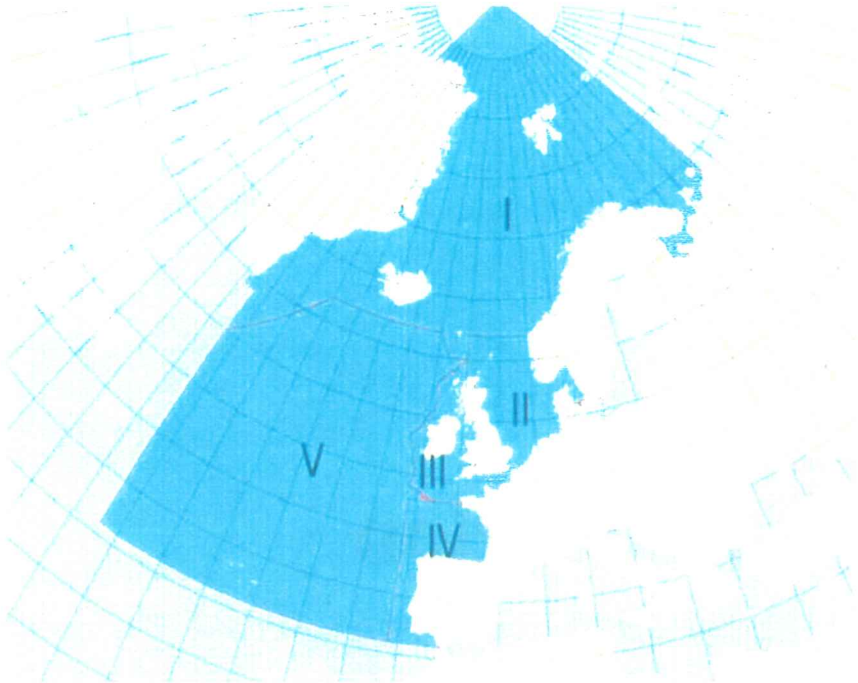

Fig. 1 The OSPAR Convention area. Subregions: I-Arctic Waters, II-Greater North Sea, III-Celtic Sea, IV-Bay of Biscay and Iberian Coast, V-Wider Atlantic.

2. Selection of *Arctica islandica*

2.1. Notes on the biology

The ocean quahog *Arctica islandica* is a cold-water species and one of the largest bivalve species inhabiting the marine waters of Europe and North America (Thórarinsdóttir & Einarsson, 1996). The maximum height is approximately 10 cm. It is an exceptionally long-living species, with a very slow growth rate. Populations of 40-80 years old specimens, with a substantial proportion of over 100 years old, have been observed.

The larval stage is pelagic and relatively long varying between 32 (Lutz *et al.*, 1980) and 60 days (Landers, 1976), which is dependent on temperature. The larval stages show very different swimming responses to varying temperature and pressure, this causes an accumulation of larvae just under or in the seasonal thermocline (Mann and Wolf, 1983). After the larval stage, they settle at the sea floor. At settlement the larvae have an average size of 230-290 m. At an age of 7.5 months the shell has attained a size between 1 and 6.5 mm (Lutz *et al.*, 1982; Muus, 1973). Reproduction starts between the 6th and 14th year (Klein & Witbaard, 1993; Rees & Dare, 1993), when they have reached a size of 45-50 mm. All animals larger than 50 mm are adults and active in reproduction. Senility in reproduction is not proven in literature (Witbaard, 1995).

Population structure is often skewed. On some locations only juveniles are present, and in others only adults. Many authors found only adults. This frequent absence of juveniles points at an irregular recruitment or low juvenile survival. This is illustrated by the fact that the building up and ripening of the eggs and sperms is a long-lasting process. Spawning takes place from July-October. The number of produced eggs per year is not known.

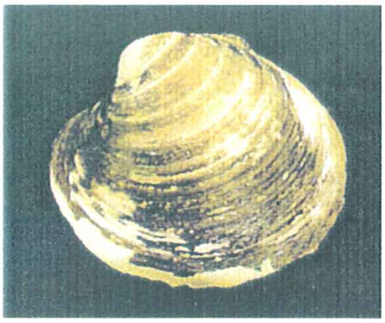

Fig. 2 The Ocean quahog, *Arctica islandica*

Normally, *Arctica* lives buried in the sediment with its short siphons just at the sediment-water interface, but sometimes it may bury itself several cm beneath the surface (Taylor and Brand, 1975). Adults are tolerant towards prolonged oxygen deficiency and have the capacity to respire anaerobically (Tebble, 1966; Witbaard, 1989; Rees & Dare, 1993).

A. islandica is a filter feeder, it filters small (food) particles out of overlaying water. It is not known to be a selective filter feeder, but some way of selection does seem to exist. Laboratory experiments have shown that the algae *Phaeocystis* are ingested, but immediately excreted. The filtration rate decreases with increasing particle size and the filtration efficiency can vary between 43 and 90% (Winter, 1969).

2.2. Application Faial-criteria

Application of the 'Faial-criteria' (see Appendix 1) is used to found the selection of *Arctica islandica* as a priority species. Since priority species and habitats are those under immediate threat or subject to rapid decline, special attention will be given to Faial-criteria 4 and 6. A summary of all criteria and their application to *A. islandica* is given in table 1 (See appendix 1 for more extensive guidance on the criteria). The application of the criteria to *A. islandica* will be discussed below.

Table 1. Summary of the Faial-criteria and their application for *A. islandica*

Faial Criteria species	Guidance	*A. islandica*
1. Global importance	> 75% species at any time of life cycle in OSPAR area	No
2. Local importance	> 90% OSPAR population in small number of 50x50 km grid squares	No
3. Rarity	occurs in small number of 50x50 km grid squares (sessile species)	No
4. Sensitivity	* very sensitive to human activities/long recovery period (>25 year)	Yes
	* sensitive to human activities/long recovery (5-25 year)	-
5. Keystone species	species which has a controlling influence on a community	No
6. Decline	* extinct within OSPAR AREA	-
	* severily declined	-
	* significantly declined	Yes
	* probability of significant decline	-

1. Global importance

It is not likely that the OSPAR area is of global importance to *Arctica islandica*, when the definition in the guidance is strictly applied (>75% of the species in OSPAR area).

The OSPAR area is the North-East Atlantic (fig 1.). This is defined as extending westwards to the east coast of Greenland, eastwards to the continental North Sea coast, south to the Straits of Gibraltar and northwards to the North Pole. This maritime area does not include the Baltic or Mediterranean seas.

Arctica is found on both sides of the North Atlantic. *Inside* the Ospar area it occurs off the coasts of Iceland, Faroes, Shetlands, British Isles and along the European coast from the White and Barentsz Sea to the Bay of Cadiz in Spain (Merill and Ropes, 1969). This covers about 60% of the total distribution area. *Outside* the Ospar area it occurs in the Baltic Sea and on the west side of the Atlantic, along the coast of North America, from Newfoundland to Cape Hatteras. This covers about 40% of the total distribution area. Assuming that densities are comparable in both areas, it is likely that about 60% of the species occurs in the OSPAR area[1], which is less than 75%. Since high densities are found in regions on both the eastside of the Atlantic (north-west Iceland and the White Sea) and the west side (Nova Scotia), the supposition that densities are comparable is valid.

2. Local importance

Arctica is widely distributed along the continental shelf of the OSPAR area. It is present in all the subregions of the OSPAR area, except for the Wider Atlantic (fig. 1). Within the subregions in which *Arctica* is present, it has a patchy distribution, like many other bivalves (Witbaard, 1997). Some areas clearly have higher densities than other areas. For example, densities of full-grown *Arctica*, as reported for northwest Iceland or the White Sea, are high (max. 100 ind/m^2) when compared to the North Sea (max. 16 ind/m^2) (Rowell and Chaisson,

[1] Some studies indicate that genetic differences exist between North-West and North-East Atlantic populations (pers. comm. Witbaard). The OSPAR area is of global importance when these differences are decisive for reproduction.

1983; Zatsepin and Filatova, 1961; Thórarinsdóttir and Einarsson, 1994). But still *Arctica* is found in many places in the OSPAR area. Therefore, it is concluded that no regions of local importance are present in the OSPAR area. When looking at the population structure regions of local importance could be pointed out. In most locations, juveniles are often absent or only present in small numbers in most locations. The population of the Keel Bight however, is dominated by juveniles.

3. Rarity

Arctica is not a common species, but it would go too far as to qualify it as being rare. The patchiness of its distribution is normal for bivalves. It is found in many places, although densities of adults are so low that they are rarely found in grab samples in most areas of the North Sea. For example, in the Dutch monitoring program BIOMON (since 1991) adults were found sporadically in the box core samples, juveniles however were quite abundant (Lavaleye *et al.*, 2000).

Maximum densities occur in the northern parts of its distribution range, which can be as high as 100 ind/m^2 (Zatsepin and Filatova, 1961; Thórarinsdóttir and Einarsson, 1994). In the North Sea, maximum densities range from 0.18 ind/m^2 in the southeastern part (Oyster Ground) to 16 ind/m^2 in the Fladen Ground area (northern North Sea) (Witbaard, 1997).

4. Sensitivity

Arctica is a slow growing, long living species with an irregular recruitment (K-strategist) and probably a low juvenile survival. Organisms with these features are characteristic for environments with high stability. It is therefore expected that (human) disturbances may have a substantial influence on populations of these kinds of species. Changes in survival or recruitment may strongly affect the population structure (Rees and Dare, 1993).

Mechanical damage, e.g. caused by the fishing gear, may have large effects upon sub-adult individuals, since shell strength is correlated with size (Witbaard, 1997). *Arctica* can continue to live with a slightly damaged shell, but repeated disturbance may cause death of many individuals before reaching maturity. Once the population is depleted, it may take many years before full-grown individuals reappear.

Another feature of *Arctica* that makes it vulnerable to disturbances is its immobility. The larval stage is pelagic, but once it has settled on the sea floor it remains stationary. Since it has only short siphons, it spends the greatest part of its life buried just beneath the sediment-water interface. However, sometimes it may bury itself several cm beneath the surface (Taylor and Brand, 1976). Since so many damaged shells are found in heavily fished areas (Witbaard, 1995), it is not likely that *Arctica* can escape fast enough from short-time (human) disturbance by burying itself. Changes in the environment will control survival, reproduction and growth (Witbaard, 1997).

5. Keystone species

Arctica is not known to be a keystone species. It acts as a host for the nemertean worm *Malacobdella grossa* (Gibson, 1967; 1968), but this worm also uses other bivalves as a host. Furthermore, juvenile *Arctica* is especially prone to predation by the sea star *Astropecten irregularis*. Its low preference for *Arctica* (Christensen, 1970) indicates, however, that *Arctica* does not have a primary controlling influence on this species either.

6. Decline

Arctica is mentioned in many faunal studies throughout the last century, but until the 1970s, distributional maps reveal little detail (Seaward, 1990). Therefore, a comparison of present distribution with historical data (without human influences) is hardly possible. These comparisons are further complicated by the great differences in sampling techniques.

However, some comparisons could be made for the North Sea, which clearly show a decline. Reconstructed historical epifauna data from 1902-1912 collected during ICES routine cruises in the North Sea were compared with epifauna data from the ICES-Benthos Survey 1986. *Arctica islandica* was among the many bivalve species, which showed a drastic decrease. It was only found at 20-30% of all sampling stations, whereas earlier it was 45% (Lindeboom and de Groot, 1998).

A comparison in density estimates between the 1970s and the early 1990s (fig. 3) also suggests a significant decrease in abundance since both the percentage of sampling stations where *Arctica* was found (north of 53°30'N) and the corresponding densities decreased.

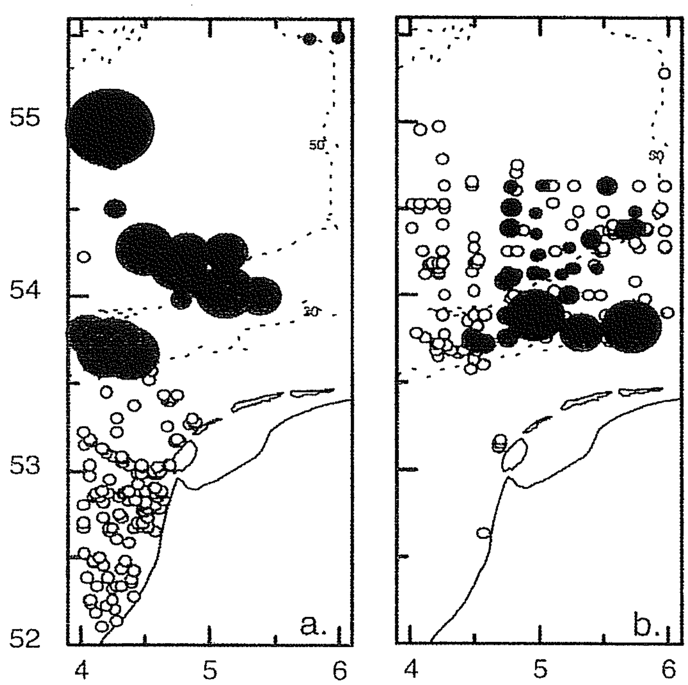

Fig. 3 After Witbaard (1997). The comparison of relative densities of *Arctica islandica* in the southeastern North Sea. The size of the circles corresponds to the relative abundance. Hollow circles indicate the absence despite sampling. (a), Abundance as estimated by Noort et al (1979-1986) between 1972 and 1980. (b), densities determined from cruises with RV "Aurelia" and RV "Pelagia" between 1990 and 1994.

A decline of Arctica has also been observed outside the North Sea. Pearson *et al.* (1985) have made a comparison for Danish waters (mainly on the eastside of Denmark). They showed a decrease in abundance in 80% of the sampling stations researched earlier by Petersen (1913). Total biomass/m^2 had also decreased. Weigelt (1991) also found a decline in abundance, for the population in the Keel Bight.

3. Ecoprofile of *Arctica islandica*

This chapter gives an outline of the natural (abiotic) conditions that are of influence on the distribution of *Arctica islandica*. Preferences and natural threats are discussed. This information is used to construct a map of the potential distribution of *Arctica* in the North Sea. In the following chapter, this map will be compared with a map of its present distribution.

3.1. Natural conditions

Substrate

Arctica islandica is most common in the finer sandy sediments. Bearse (1976) and Fogharty (1981) found that the presence of fine sand (0.125-0.49 mm) had a positive influence on the abundance of *Arctica*. Silt and clay were found to have a negative influence on the abundance (Fogharty, 1981). It should be taken into account, however, that it is possible that not the sediment itself, but the factors determining substrate-type (e.g. hydrography) are responsible for the presence of *Arctica* (Bearse, 1976).

Although *Arctica* is most common in the finer sandy sediments, it has been recorded from coarse sand or gravel as well (Thórarinsdóttir and Einarsson, 1994; Zatsepin and Filatova, 1961). Locations within the North Sea where *Arctica* occurs on relatively coarse sediments are the Monkey Bank, Cleaver Bank and the southwestern part of the Dogger Bank. Witbaard *et al.* (1999) found for North Sea specimens, that shell growth is strongly positively correlated with grain size. Since sediment characteristics also depend on bottom currents, they suggested that these increased growth rates reflect lateral seston flux as additional food supply.

The reason for *Arctica* being less abundant in areas with coarse sand and gravel may be that survival of juvenile *Arctica* (spat) is a problem under these circumstances, since they can easily be crushed. Therefore, settlement of young individuals can be almost impossible in these sediments (pers. comm. Witbaard).

Depth

The depth range in which *A. islandica* is found is considerable. Catches have been reported from as shallow as 4 m to as deep as 256 m on the continental shelf (Merril and Ropes, 1969). In the North Sea, its southern limit of distribution closely follows the 30-meter depth contour up to the Danish coast where only a few specimens were found at shallower depths (Witbaard, 1997). Although the depth seems to be of influence here, it is likely that other factors than depth are controlling the distribution (Witbaard, 1995). See also 'Temperature', 'Stratification' and 'Soil turbation'.

Temperature

The temperature range in which *A. islandica* is able to live stretches from 0 to 20 °C. After exposure to temperatures of 27 to 30 °C in experimental conditions, death is reported (Loosanoff, 1953). Between 4 and 14 °C, both the filtration rate and phagocytosis increased by a factor of ~2 (Winter, 1969). While mature *Arctica* can withstand temperatures up to 20 °C (Loosanoff, 1953), such temperatures are detrimental to larvae. Lutz *et al.* (1982) observed optimum growth rates for larvae between 13 en 15 °C. At higher temperatures larval growth decreases and ultimately stops.

Water temperature seems to be an important factor on the distribution of *A. islandica* in general. In the most Northern part of the distribution area its presence is limited to the sediments, where the temperature never drops under 0°C (Zatsepin & Filatova, 1961). From north to south the minimum depth at which *A. islandica* is found increases (Mann, 1982), which has probably to do with temperature. The distribution limit in the North Sea could be set by the maximum bottom water temperature of 16 °C (Tomczak and Goedecke, 1964), which approximately follows the 30 m depth contour. A similar temperature controlled limit has been observed along the American east coast (Mann, 1982). No information is present about mass mortality caused by exceptionally warm summers or cold winters.

Witbaard *et al.* (1999) found that for growth of *Arctica*, in the North Sea, temperature effects seem less important than food supply.

Stratification

The southern distribution limit in the North Sea of *Arctica* closely follows the 30 m depth contour, which roughly follows the boundary between the tidally mixed waters in the south and the deeper, summer stratified waters in the north. No information is found on the direct effect of stratification on the distribution of *Arctica.*

Salinity

The sediments in which *A. islandica* is present vary in salinity between 16 g/l (Baltic Sea) and 35 g/l (Atlantic Ocean). Salinity does not seem to be a controlling factor for the distribution of *Arctica islandica* in the North Sea.

Soil turbation

High tidal currents are a possible reason for the absence of *Arctica* in the shallow waters (Witbaard, 1997). Sediment instability *i.e.*

resuspension or sediment scour might inhibit larval settling or impair their survival.

Suspended matter

The presence of suspended matter could be of influence on the distribution of *Arctica islandica*. Suspended matter can disturb the food supply, since *Arctica* is a filter feeder. When a high concentration of suspended matter is present, *Arctica* will filter it out of the water, but gain no energy from it. Therefore, growth rates are expected to be lower at regions with higher suspended matter content (pers. comm. Witbaard). However, no studies are known about the (quantitative) relation between the concentration of suspended matter and the presence of *Arctica*.

Nutrients

As a filter feeder, *Arctica* is directly dependent on the amount of suspended phytodetritus in the bottom water. This benthic food availability is determined by the quantity of sedimenting material, which arrives at the bottom water. This in turn will depend on primary production, water column processes and water depth (Witbaard *et al.*, 1997).

Growth rates in areas with higher water column productivity are generally higher (Witbaard *et al.*, 1997). Witbaard *et al.* (1999) found that food supply seems to be the most important factor for the growth of *Arctica islandica* in the North Sea, whereas in other areas, temperature is also very important. It should be noted that primary production varies considerably over the year.

Winter storms

Rees *et al.* (1977) found that in winter storms, incidentally *Arctica* came loose of the sediment and got washed ashore. Most populations in the North Sea, however, live deep enough not to be disturbed much by storms. This factor can therefore be seen as of minor importance in comparison with other threats (Witbaard, 1995).

Predation

Among the predators that prey on *Arctica* are eider ducks (*Sommateria mollisima*), common scooter (*Melanitta nigra*) (Meissner and Brager, 1990), gulls (Zatsepin and Filatova, 1961), fishes (Schafer, 1972; Arntz and Weber, 1970; Cramer and Daan, 1986), *Asterias rubens* (Anger, 1977; Hunt, 1925), *Natica* spp (Christensen, 1970) and *Buccinum undatum* (Nielsen, 1975).

Information on the effects of bird predators on population level is not available. For fishes, Arntz and Weber (1970) found that *Arctica* could be an important food source, especially for cod (*Gadus morhua*). The influence of predation by shellfish and cod is estimated to be 0.1-0.2 g/m^2 per year (Cramer and Daan, 1986). Since it is not plausible that cod is able to crack the shells of *Arctica* found inside its stomach, it is supposed that cod acts as a scavenger. It is supposed that cod only eats *Arctica* shells damaged by beam trawl fisheries. The correspondence of the high mean size of *Arctica* found inside cod (46 mm; 25 mm is the mean size for the entire population) and the size of mainly damaged *Arctica* (>35mm) by beam trawl fisheries supports this idea.

Evertebrate predators mainly eat juvenile *Arctica*, although predation on adult *Arctica* by *Asterias rubens* is also reported (Anger *et al.*, 1977). Spat are especially prone to predation by *Astropecten irregularis* (Christensen, 1970), since this species occurs in high densities in the

North Sea (100 to 1000 ind. per ha; van Noort *et al.*, 1986). The preference for *Arctica* however is low. Predation by *Astropecten* on juvenile *Arctica* seems to be controlled by the absence of other, more preferred prey species (Christensen, 1970).

3.2. Potential distribution

The above-presented ecological information is combined in a map of the potential distribution of *Arctica islandica* (fig. 4). This map is constructed following the HABIMAP concept.

The HABIMAP concept

The multitier HABIMAP concept is based on the following general assumption. The presence of a species (or community) is determined primarily by a combination of a number of abiotic parameters, like sediment composition, depth, wave action and climate, and may be influenced secondarily by human activities such as fisheries, recreation and shipping.
Relations can be determined between species and these parameters, i.e. a range for each parameter in which each species may be present. As the parameters generally can be presented in some sort of maps, these relations can be expressed into "maps with possible occurrence" per parameter (single tier maps or monoparametric Habitat Maps). These single tier maps are combined subsequently into Habitat Maps (multitier maps or multiparametric Habitat Maps) (Ruiter and De Jong, 1997).

No human activities are included in the Habitat Map for *Arctica islandica* in fig. 4, only the abiotic factors discussed above. This results in a map of the potential distribution of the species, without human influences. The used response curves between *Arctica* and these abiotic factors were determined for the available parameters and classes in HABIMAP (Annex 3). Due to technical problems and lack of information, only the parameters depth and median grain size could be used to construct this Habitat Map.

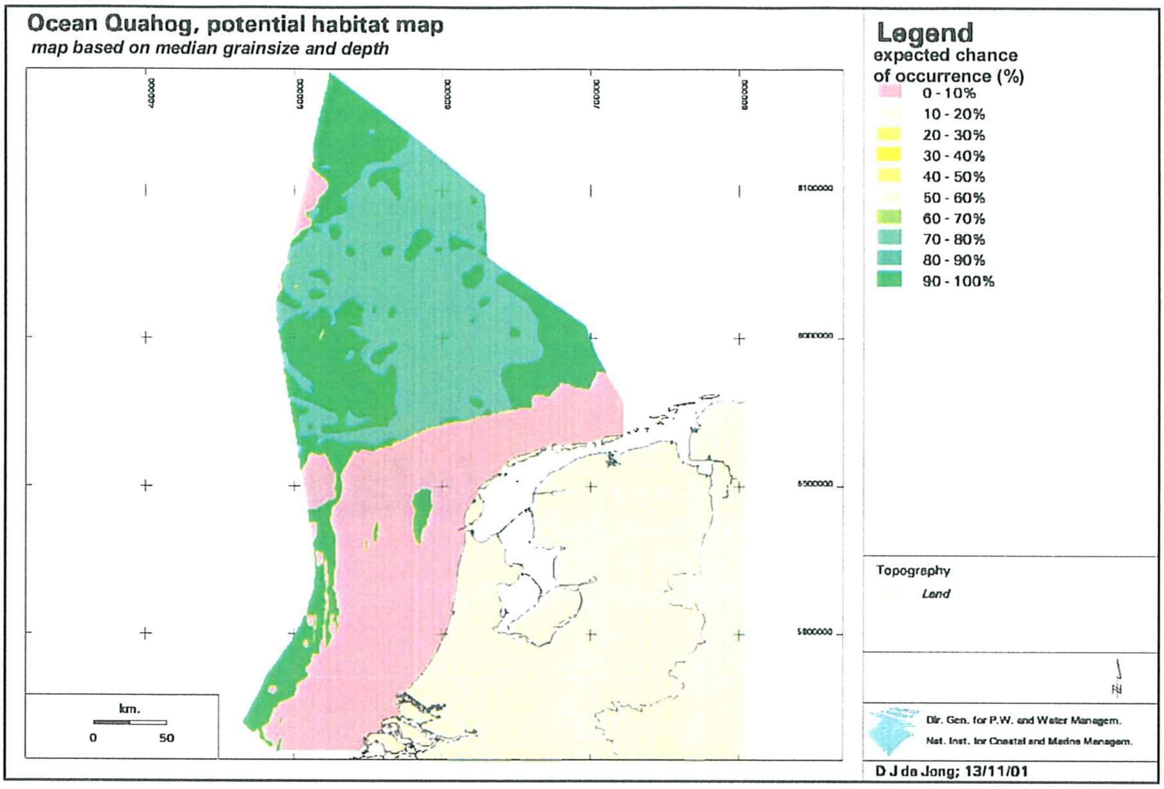

Fig. 4 Habitat map of *A. islandica*: Potential distribution, based on median grainsize and depth.

Although the use of only these two parameters seems to be a poor basis for constructing a relevant map, it will give a good idea of the potential distribution of *Arctica islandica*, since the parameters used are closely related to other factors, like bottom temperature and hydrography, that may be causative and/or more important for the distribution of *Arctica*.

4. Threats to *Arctica islandica*

This chapter describes the human activities that could be of influence on the functioning and presence of *Arctica islandica.* The information from literature is - where possible - complemented with an analysis of the differences between the habitat maps of the present (fig. 5) and potential distribution (fig. 4) and maps of the intensity of human activities in the North Sea.

4.1. Beam trawl fishery

Arctica is proven to be especially vulnerable to beam trawl fisheries. Certain parts (chains) of the fishing gear penetrate into the sea bottom, causing direct physical damage and even direct mortality to benthic species like *Arctica.* Mortality of *Arctica* when caught as by catch is also reported. Whereas nets have been refined to reduce the by catch of non-target species and undersized commercial species (Briggs, 1992), few attempts have been made to reduce by catch or the damage of fishing gears on invertebrate benthic species (Lindeboom and De Groot, 1998).

Experiments have shown that direct mortality of *Arctica* by single passage of a beam trawl is about 16 % (Piet *et al.*, 1998). Mortality of *Arctica* when caught by a beam trawl is estimated to be 74-90 % (Fonds, 1991).

Both field observations and literature data suggest that populations of *Arctica* are strongly affected by beam trawl fisheries in the heavily fished southeast North Sea. For example Klein and Witbaard (1995) found corresponding trends in the scar frequencies of *Arctica* and temporal fluctuations in the total engine capacity of the Dutch beam trawl fleet. The decline in *Arctica*, mentioned in chapter 2, between the

1970's and the 1990's coincides with the intensification of beam trawl fisheries. In the period 1972-1990 the total engine power of the Dutch fishing fleet increased from approximately 250,000 to 600,000 HP (Anon., 1991).

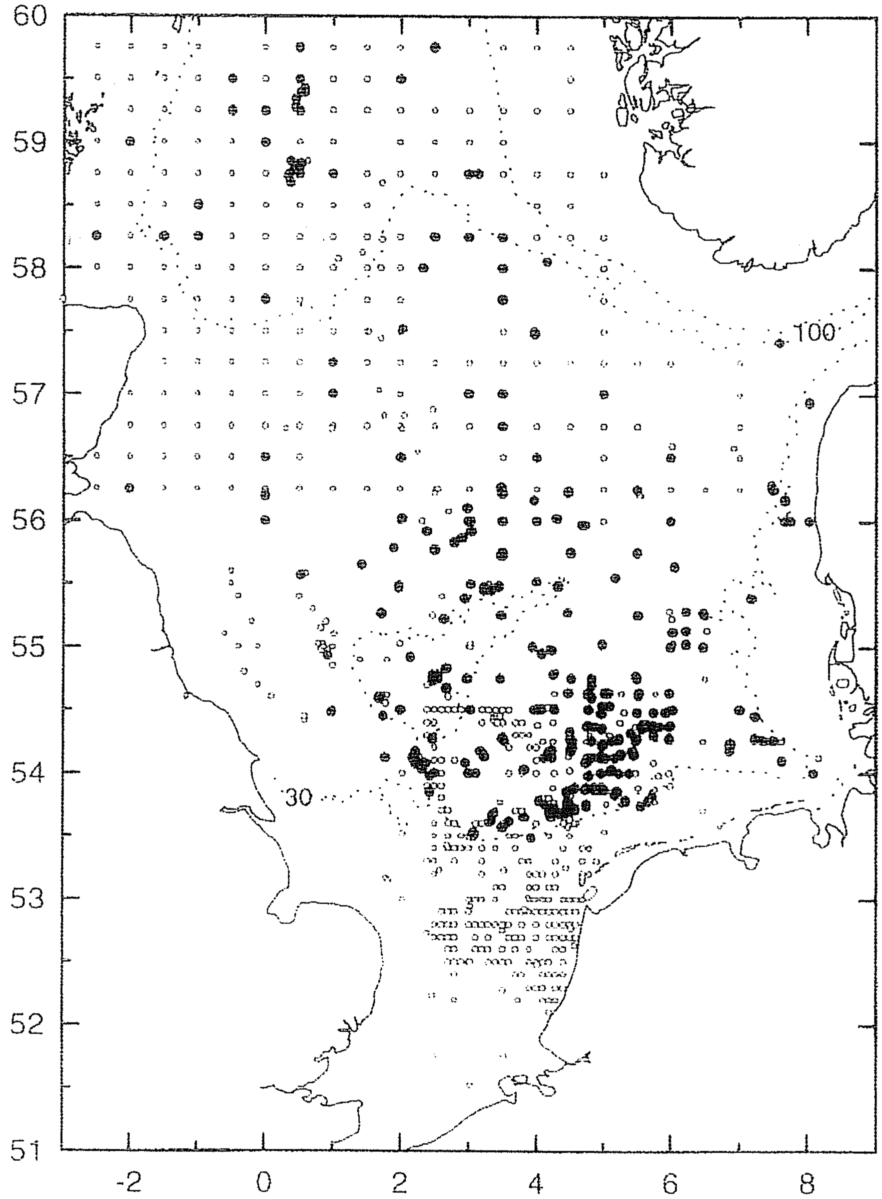

Fig. 5 (After Witbaard, 1997). Distribution of *Arctica islandica* in the North Sea. Solid circles denote the occurrence of living *Arctica* while open circles indicate absence in the sample. Only the occurrence of full-grown (non spat) animals is given. The map is composed of data collected between 1990 and 1999 by cruises with research vessels and commercial trawlers as well as data presented by Duineveld *et al.* (1991), Künitzer (1990), Eleftheriou and Bashford (1989), Heyman (unpublished), Van Moorsel (1993) and Van Noort *et al.* (1979-1986).

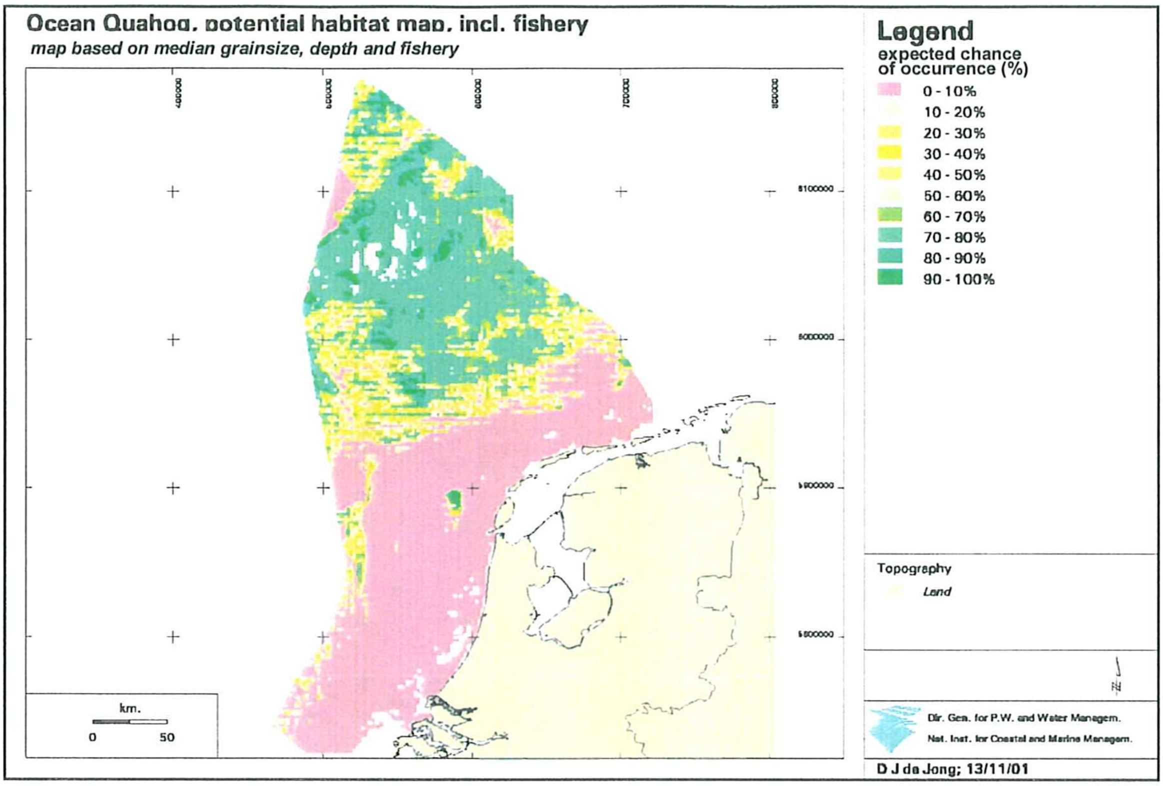

Fig. 6 Habitat map of *A. islandica*: potential distribution, based on median grainsize and depth *and* beam trawl fishery. Fisheries data based on Van Rijnsdorp et al., 1998, used with permission of RIVO IJmuiden.

Fig. 6 presents the potential distribution of *Arctica*, where fisheries are included. For the construction of this map, a response curve for *Arctica* on fishery-intensity is estimated (Annex 4), just like for median grainsize and depth.

When the present distribution (fig. 5) is plotted on the two given habitat maps (with and without the influence of fisheries), it can be made plausible that fisheries indeed have a negative impact on the occurrence of *Arctica*, since the highest numbers of observed *Arctica* are present at locations where fishing intensity is low and *Arctica* is mainly absent in places with high fishing intensity. This is illustrated by figures 7 and 8, in which the number of observed individuals (Y-axis) is plotted against the expected suitability (X-axis), for both the situation with and without fisheries. The size of the bubbles corresponds with the frequency of observations for places with similar suitability (e.g. in 21 cases 0 *Arctica* were found in a place with a suitability of 0%).

When figure 7 (present vs. potential distribution) is studied in detail, the following remarks can be made:

- High numbers of *Arctica* (>75) are only found in places with a high suitability;
- In many cases, *Arctica* is *not* present (0 n/m2 observed) in places with *low and high* suitability;

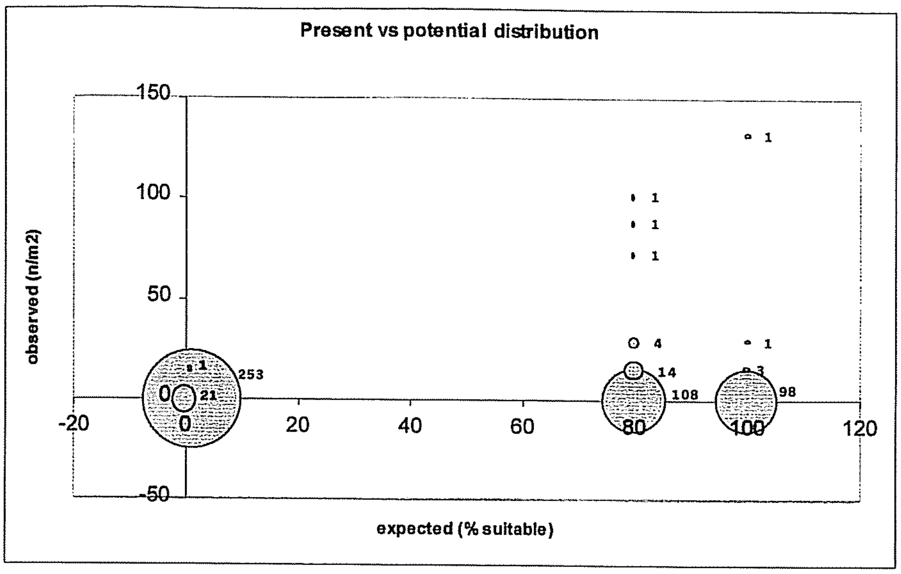

Fig. 7 Present vs. potential distribution of *A. islandica* in the NCP

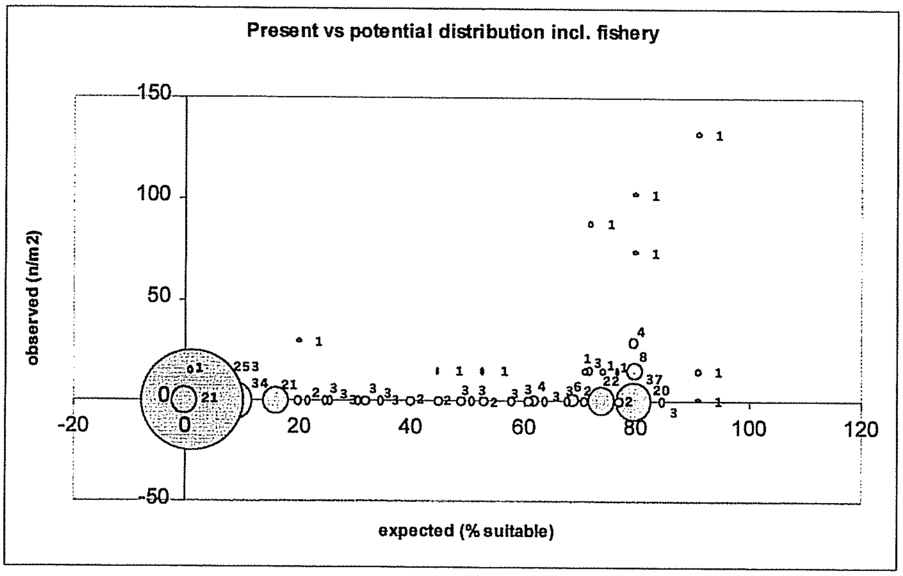

Fig. 8 Present vs. potential distribution including fishery of *A. islandica* in the NCP.

When figure 8 is compared to figure 7, the following remarks can be made:

- High numbers of *Arctica* are still only found in places with a high suitability, *thus* high numbers of *Arctica* only occur at places with suitable abiotic conditions *and* low fishing intensity;
- Many cases, where *Arctica* is not present, have shifted from places with a high suitability (100%) to places with lower suitability (=80%), which can be attributed to a high fishing intensity. The cases where *Arctica* is still not present at places with a relatively high suitability (80%), can be explained by the patchy distribution of *Arctica* and the inadequate sampling method for determining the presence of *Arctica*.

- Despite of the intensified beam trawl fisheries, *Arctica* is still present. Reasons for this could be the relatively long pelagic larval stage of its life-cycle (30-60 days), in which *Arctica* is not sensitive to beam trawl fisheries. Together with the low catch-efficiency of the beam-trawl for this species and the wide-spread distribution in the North Sea, this makes it unlikely that the complete North Sea population will disappear (Witbaard, 1995).

4.2. Extraction of natural resources

Sand and gravel

When sand and gravel are extracted from the sea, large bivalves like *Arctica* can also be extracted. Up till 2000, sand is mainly extracted in the Wadden Sea area, so this is not expected to have a negative effect on *Arctica*. The most important (possible) offshore location for the extraction of gravel at the Dutch Continental Shelf however, is the Cleaver bank, where *Arctica* is present. After explorative extractions in 1989, the density of all large bivalves was strongly reduced (Witbaard, 1995). In the two years following the extraction, no recovery occurred. This shows that for species with slow and irregular recruitment, like *Arctica*, this activity could lead to decreasing densities and possibly local extinction.

Oil and gas

Oil and gas-extractions can also have negative influences on *Arctica*, direct as well as indirect (oil-contamination). Indications exist that growth has decreased in the surroundings of an exploration platform (Witbaard, 1995).

It was not possible to use HABIMAP for studying the influence of these factors, since the extractions are very local and not widely distributed (as is *Arctica*).

4.3. Pollution

Since *Arctica* is mainly present in the finer sediments, it is likely to be exposed to pollutants that are bound to these fine sediments. However, the degree of exposure to pollution is mainly determined by the concentrations of pollutants in the water phase (Steimle *et al.*, 1986). Swaileh and Adelung (1994) found that the highest concentrations of heavy metals were found in the organs that were most in contact with its environment. Nothing is known about the influence of these and other pollutants on the functioning of *Arctica*.

There was no sense in using HABIMAP for studying the influence of pollutants, since no reliable maps of important pollutants were available. The available maps of pollutants (e.g. cadmium) are based on (extrapolated) a very limited number of sample points that are mainly situated in the coastal zone. Therefore, the reliability of these maps is doubtful.

4.4. Eutrophication and anoxic conditions

The direct effects of eutrophication (an increase in primary production or a change in the phytoplankton community) can have an influence on *Arctica*. This is illustrated by the observation of Witbaard (unpublished data), that *Phaeocystis* colonies could not be used as food. Detailed knowledge about the direct effects of eutrophication on *Arctica* is not available. However, since *Arctica* populations in the North Sea live relatively far from the coast, the direct effects of eutrophication will probably be small (Witbaard, 1995).

An indirect effect of eutrophication is the occurrence of anoxic conditions, due to the decomposition of large amounts of algal material. According to Dries and Theede (1974) *Arctica* may survive anaerobic periods exceeding 40 days because of its ability to shift to anaerobic metabolism (Oescher, 1990; Taylor, 1976). The resistance to anoxic conditions is however dependent on ambient temperature (von Oertzen and Schlungbaum, 1969), animal size (Schultz, 1969) and probably also the H_2S concentration of the environment. Despite the tolerance of *Arctica* to anaerobic periods, a mass mortality due to anoxic conditions was recorded along the New Jersey coast (USA) in 1976 (Murawski *et al.*, 1989). The gradual decrease of *Arctica* in the southern parts of the Baltic Sea is also thought to be the result of short but repeated anoxic periods (Gosselck, 1987).

In the North Sea, anoxic periods are reported for the German Bight (OSPAR, 1992), but this does not seem to be of influence on the absolute presence of *Arctica*. This can be seen from its present distribution (fig 5) compared with the oxygen deficiency map from this OSPAR report (Annex 5). This shows that *Arctica* is present in the German Bight, where seasonal oxygen deficiency occurrs (in 7 out of 9 observations).

It was not possible to use HABIMAP for studying the influence of low oxygen concentrations, since this information was not available in HABIMAP.

5. Evaluation of the used methods

In this report, the actual and potential distribution of the species were described and mapped using the HABIMAP concept in order to assist in the assessment of the threats and decline to one species. In this chapter, this approach is evaluated for its usefulness for the selection procedure of other threatened and declining species and habitats.

5.1. Evaluation of the use of HABIMAP

A comparison of the actual and the potential distribution of *Arctica* has founded that *Faial criteria 4 (sensitivity)* applies to this species. It is made plausible that the species is very sensitive to at least one human activity: beam trawl fisheries.

The construction of the potential distribution map following the HABIMAP method can be used for the evaluation of other Faial criteria, as well. The potential distribution map can give input for the application of criteria 2, 3 and 6:

- For *Faial criteria 2 (local importance)* and *3 (rarity)*, the potential distribution map comprises the scientific judgement regarding natural abundance, which is needed to make a statement about the regional importance and rarity.
- For *Faial criteria 6 (status of decline)*, the potential distribution map can be seen as a reference situation, in case no historical data are available.

After construction of the potential distribution map, other GIS processing may be conducted in HABIMAP. For instance, it is possible to make a map of the expected decline by subtracting the actual distribution map from the potential distribution map.

In this project, a few limitations of the HABIMAP method were come across, which will be of importance during the application of any of the above-mentioned criteria. The found limitations are described below.

Geographical limitation

The geographical limitation is the most obvious restriction of the use of HABIMAP at this moment. For most parameters, the available maps are restricted to the Dutch Continental Shelf (NCP) and do not cover the entire North Sea. This also goes for the DONAR-data on species abundance, which were used in this project.

Complexity

The second restriction of the used method is the possibility that the chosen combination of abiotic parameters will not give a valid representation of the potential distribution. The complexity and incompleteness of the knowledge in literature about the key factors that are controlling a species' presence may make it hard to select the most relevant parameters and to set the borders for the construction of a potential distribution map. For this project, the following example can be given: recent research has shown that oceanographic parameters like the occurrence of eddies could also be of great importance for the presence of *Arctica*, maybe even more important than fishery and predation together (Witbaard, 1997). No information on these factors is available in maps that can be used in HABIMAP. And if it were, it would be very difficult to handle these complex and possibly interacting factors.

Data availability

The third restriction of the used method is the lack of reliable maps of controlling factors (abiotic *and* human). In this project, bottom water temperature was shown to be of influence on the presence of *Arctica*, but this factor was not available in maps. Data on surface water temperatures were available, but this is not solely correlated to bottom water or sediment temperatures. However, bottom water temperatures correlate quite well with water depth, for which data were available in HABIMAP. Besides abiotic parameters, also biotic parameters can be of importance for the potential distribution. No biotic parameters are known to be available in maps that can be used in HABIMAP.

5.2. Suggestions for following studies

The geographical limitation could be overcome, when all data collected for the Joint Assessment and Monitoring Programme (JAMP) and other monitoring programmes are combined and made available for the use in HABIMAP. For this moment, using HABIMAP (and DONAR) at least gives an indication for the entire North Sea.

The second limitation, the complexity of the controlling factors and gaps in scientific knowledge, will probably always be hard to deal with. This can be overcome by using expert judgement for the assumptions on the potential distribution. This seems absolutely necessary when drawing conclusions from incomplete data.

The third restriction, limited data availability, will also not easily be overcome, since monitoring programmes do not sample every inch of the ocean for every parameter. But it would help if all monitored parameters will be combined in an easily accessible database.

When the availability of spatial information on abiotic, biotic and human parameters is increased, the method is a valid way of making statements about the threats and decline of species and habitats.

6. Literature

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Annexes

Annex 1. Selection criteria for species and guidance*

In order to implement elements of the OSPAR Strategy on the Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area (in particular its § 2.2, its chapeau and its subparagraphs a. and b.), Contracting Parties and Observers have developed the attached criteria and draft guidance.

Selection criteria for species

1.	**Global importance:** Global importance of the OSPAR area for a species. Importance on a global scale, of the OSPAR Area, for the species is when a high proportion of a species at any time of the life cycle occurs in the OSPAR Area.
2.	**Local importance**: Importance within the OSPAR Area, of the regions for the species where a high proportion of the total population of a species within the OSPAR Area for any part of its life cycle is restricted to a small number of locations in the OSPAR Area.
3.	**Rarity**: A species is rare if the total population size is small. In case of a species that is sessile or of restricted mobility at any time of its life cycle, a species is rare if it occurs in a limited number of locations in the OSPAR Area, and in relatively low numbers. In case of a highly mobile species, the total population size will determine rarity.
4.	**Sensitivity**: a 'very sensitive' species is one if very easily adversely affected by a human activity, and / or if affected is expected to only recover over a very long period, or not at all. A 'sensitive' species is one if easily adversely affected by a human activity, and / or if affected is expected to recover in a long period .
5.	**Keystone species**: a species which has a controlling influence on a community.
6.	**Decline**: means an observed or indicated significant decline in numbers, extent or quality (quality refers to life history parameters). The decline may be historic, recent or current. 'Significant' need not be in a statistical sense.

* Study reservation by Spain.

Guidance on the selection criteria for species

Criterion	Guidance
1.	'High proportion' is considered to be more than 75%, when known.
2.	'High proportion' is considered to be 90% of the population in a small number of locations of 50 km x50 km grid squares. This is dependent on scientific judgement regarding natural abundance, range or extent and adequacy of recording. A different scale may be needed for different taxa.
3.	'A limited number of locations' could be in a small number of 50 km x 50 km grid squares, but a different scale may be needed for different taxa. This is dependent on scientific judgement regarding natural abundance, range or extent and adequacy of recording Species which are present in high abundance outside of the OSPAR Area and only occur at the edges of the OSPAR Area will not generally qualify as 'rare' species.
4.	A 'very long period' may be considered to be more than 25 years and 'long period' in the range of 5 to 25 years. The time frame should be on an appropriate scale for that species. Sensitivity to human activities is measured by a. life history characteristics b. dependence on other specific ecological attributes e.g. restricted / specific habitats requirements.
5.	No guidance
6.	'Decline' is divided into the following categories: 1. Extirpated (extinct within the OSPAR Area): a population of a species formerly occurring in the maritime area is defined as extirpated: • if it was still occurring in the area at any time during the last 100 years • and if there is a high probability, or it has been proved, that the last individuals have since died or moved away. • or if surveys in the area have repeatedly failed to record a living individual in its former range and / or known or expected habitats at appropriate times (taking into account diurnal, seasonal, annual patterns of behaviour) for at least 10 years. 2. Severely declined: a population of species occurring in the maritime area is defined as severely declined • if individual numbers show an extremely high and rapid decline in the area over an appropriate time frame, or the species has already disappeared from the major part of its former range in the area. • or if individual numbers are at a severely low level due to a long continuous and distinct general decline in the past. 3. Significantly declined: means a considerable decline in number, extent or quality beyond the natural variability and in an appropriate time frame for that species. 4. High probability of a significant decline in number, extent or quality in the future.

Annex 2. Selection criteria for habitats and guidance*

In order to implement elements of the OSPAR Strategy on the Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area (in particular its § 2.2, its chapeau and its subparagraphs a. and b.), Contracting Parties and Observers have developed the attached criteria.

Selection criteria for habitats

1.	**Global importance** (importance of the OSPAR Area for the habitat in a global context):a high proportion of the habitat occurs in the OSPAR Area.
2.	**Regional importance** (importance of the sub-regions of the OSPAR Area for the habitat): a high proportion of the habitat occurs within a specific biogeographic region and/or region of national responsibility within the OSPAR Area.
3.	**Rarity**: a habitat is assessed as being rare if it is restricted to a limited number of locations or to small, few and scattered locations in the OSPAR area.
4.	**Sensitivity**: a 'very sensitive' habitat is one that is very easily adversely affected by a human activity and / or would be expected to, recover only over a very long period, or not at all. A 'sensitive' habitat is one that is easily adversely affected by a human activity and would be expected to recover only over a long period. Sensitivity will be expressed in terms of: a. impact of human activities (resistance) b. capacity to recover (resilience), including a reflection of its degree of isolation or confinement to a small area.
5.	**Ecological significance**: the habitat is very important for the wider significance of the ecological processes, functions and species that it supports.
6.	**Status of decline**. Decline means a significant decline in extent or quality. The decline may be historic, recent of current. The decline can occur in the whole OSPAR maritime area or regionally.

* Study reservation by Spain.

Guidance on the selection criteria for habitats

Criterion	Guidance
1.	'High proportion' is considered to be more than 75%, when known. This criterion may require knowledge of the distribution of habitats at a global scale.
2.	'High proportion' is considered to be more than 75%, when known.
3.	'The 'limited number of locations' is set at 2% of the 50 km by 50 km UTM grid squares for each of the following three bathymetric zones: a. littoral (intertidal zone and splash zone) b. sublittoral (down to 200 m depth) c. bathyal / abyssal (below 200 m depth) The assessment is dependent on scientific judgement regarding natural abundance, range or extent and adequacy of recording.
4.	A 'very long period' is considered to be more than 25 years and a 'long period' in the range of 5 to 25 years, dependent on the habitat. It is considered that the sensitivity of a habitat differs according to specific impacts of different human activities and, as such, should be applied at the end of the selection process with respect to the specific impacts of human activities.
5.	Example habitats could be: spawning, breeding, reproduction, or nursery areas for fish, mammals or birds, resting and feeding areas, areas with a high natural productivity or diversity, areas with a high proportion of endemic species, and areas important as migratory routes.
6.	'Decline' will be assessed according to categories 1 to 4 described in the table below for both decline in extent and quality, recognising the following descriptions: a. Extent – based on distributional coverage or areal extent. b. Quality – judgement of decline in quality should be based on change from natural condition caused by human activities. Such judgement is likely to include aspects of biodiversity, species composition, age composition, productivity, biomass per area, reproductive ability, non-native species and the abiotic character of the habitat.

	Extent	Quality
1. Extirpated (extinct within the OSPAR Area)	A habitat which was previously present in the OSPAR Area, but no information is available that it still exists.	A habitat for which quality is affected so severely that it's typical or natural components are completely destroyed.
2. Severely Declined	A habitat for which only 25% or less of its former natural distribution in the OSPAR Area still exists. If impacts start or continue and no protection or management measures are taken the habitat may be completely destroyed.	A habitat for which quality is negatively affected in the entire OSPAR Area so that typical or natural components can only be found in one or very few sub-regions.
3. Significantly Declined	A habitat that has declined in extent to between 25% and 75% of its former natural distribution in the OSPAR Area, or that has become extinct in several sub-regions.	A habitat for which quality is negatively affected by: (1) a change of its typical or natural components over almost the entire OSPAR area, or (2) the loss of its typical or natural

Note: Lesser degrees of decline than Significantly Declined will occur but will not qualify under this criterion. Evidence for decline can be based on actual evidence or reasonable expert judgement.

Annex 3. Response curves for abiotic parameters

Table 1. Available parameters and classes in HABIMAP (in maps)

nr	Factor	Characteristic	Classes
1a	Substrate	median grainsize	63-125-250-500-2000
1b	Substrate	silt (grainsize<60um)	0-10, >10%
1c	Substrate	hard substrate (grain)	0-30, 30-80, >80%
2a	Depth	Coastal zone	
2b	Depth	NCP	per m; grid 0.5*0.5 km
3a	Soil turbation	Current velocity (normal	m/s
3b	Soil turbation	Current velocity (storm)	m/s
3c	Soil turbation	Coastal zone	wave height/water dept
4	Surface temperature	C	
5	Salinity	g/l	
6	Suspended matter	mg/l	mean, med, min, max
7a	Nutrients	PO4, NO3, NH4, Silicaat	mean
7b	Nutrients	Chlorofyl a	mean

Table 2. Estimated response curve of *A. islandica* for the given classes of abiotic parameters in HABIMAP, based on literature. Estimated chance of occurrence is given in percentages.

nr	Factor	Literature	Classes	Chance	Weight
1a	Substrate (median grainsize)	Preference:	63-125 um	85%	1
		125-490 um	125-250 um	100%	
			250-500 um	100%	
			500-2000 um	5%	
1b	Substrate (slib)	Preference:	0-10 %	100%	1
		little slib	>10%	10%	
1c	Substrate (grain)	Preference:	0-30%	100%	1
		little grain	30-80%	10%	
			>80%	1%	
2a	Depth (kustzone)		nvt	nvt	0
2b	Depth (NCP)	Preference:	0-4m	0%	2
		>30 m in North Sea	4-30m	1%	
			>30m	100%	
3	Soil turbation	?	nvt	nvt	0
4	Surface temperature	Preference:	0-13 C	50%	2
		13-16: optimum for growth	13-16 C	100%	
		0-16: found in this range	>16 C	0%	
5	Salinity	Preference:	0-16 g/l	0%	1
		>16 g/l (=9 pro mille)	> 16 g/l	100%	
6	Suspended matter	?	not apliccable	nvt	0
7a	Nutrients	?	not apliccable	nvt	0
7b	Nutrients	Preference: high prim. prod	-	linear relation	3

Annex 4 Response curve for fishery

The assumptions for determining of the response curve for fishery are:

- When an area is fished once, 80% of the individuals survives;
- The intensity of 450 fishing movements in 3 years is equal to fishing the complete area once per year;
- There is a stable population: natural mortality is completely compensated by natural recrution, extra mortality caused by fishery is not;
- Average life span of *Arctica* is 40 years;

Based on these assumptions the response table 3 is calculated. This table should be seen 'over 40 years'. When the intensity of 11 fishing movements in three years is continued over 40 years, the complete area is fished once in this period. Therefore, the percentage of survival, here translated to suitability for the species, is 80.

Table 3 The response curve of Arctica for the fishery. The fishing-intensity is given in the number of fishing movements/3 years.

Intensity	Suitability
0	100
11	80
22	64
33	51
44	41
55	33
66	26
77	21
88	17
99	13
110	10
5000	0

Annex 5 Map of oxygen deficiency

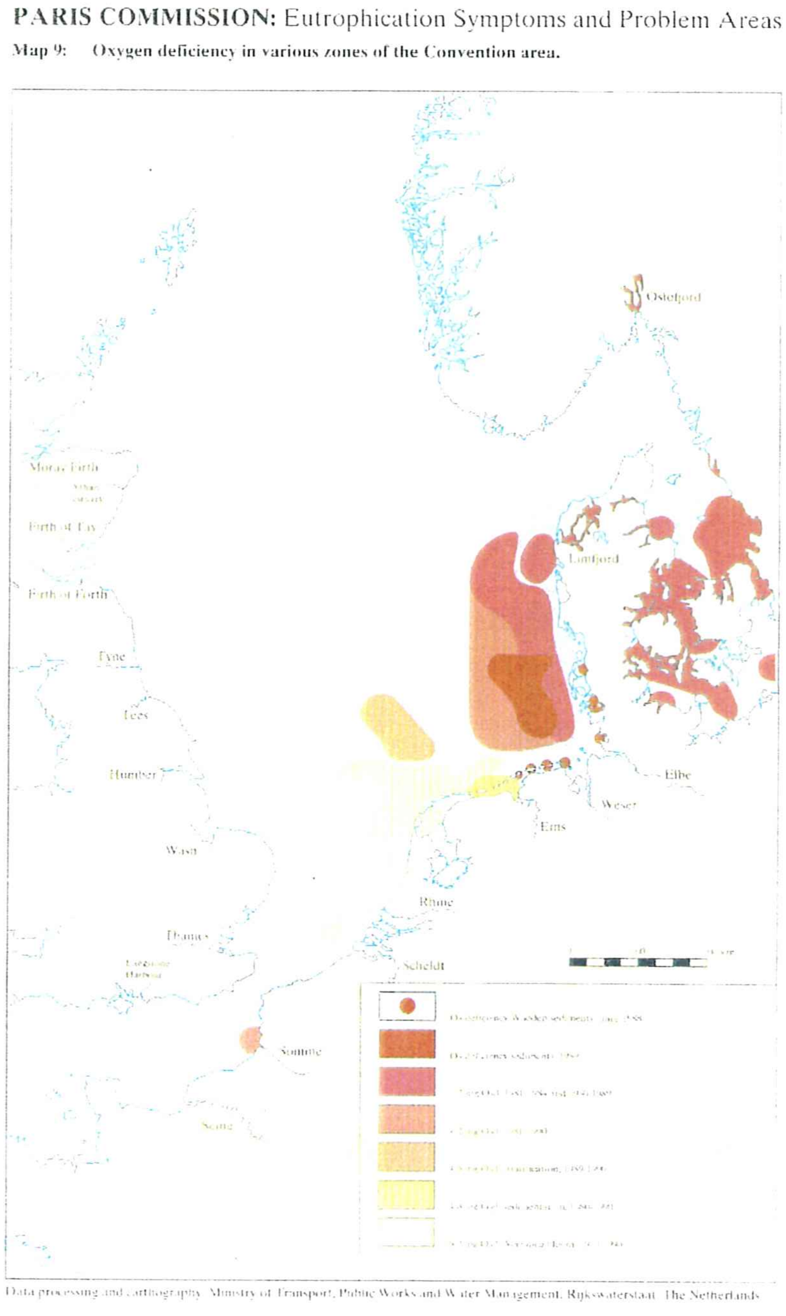

Fig. 1 Map of oxygen deficiency in various zones of the Convention area. *From*: OSPAR (1992). Nutrients in the Convention Area. Part B. Eutrophication Symptoms and Problem Areas.