GIS analysis of suitable localities for mussel farms along the county of Kalmar's coast

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Description

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Abstract
Work Package 4 in the Aquabest project develops a spatial planning manual, which is used in two Swedish cases in order to evaluate the usefulness of the manual. One identified important action in the spatial planning manual is the performance of a GIS analysis in order to identify suitable localities for aquaculture farms.

In this report, we present a GIS analysis developed for localising mussel farms at the Swedish South-East coast. The analysis is performed using ArcGIS 10. The analysis and the results are described in this report and in three separate maps (Figure 1, Figure 2 and Figure 3). The parameters used in the model are chosen and classified by a working group constituted by the project manager, personnel from different municipalities in the region of Kalmar and the Administrative County Board of Kalmar and a representative of the Royal Swedish Academy of Agriculture and Forestry (KSLA). The data used is mainly based upon data from national authorities, some of which is measured and some of which is modelled.

Based upon a previous pilot study which explored the resolution and availability of geographical data, the coastal zone of the Kalmar region was divided into smaller units according to the subdivision into bodies of water by the Swedish Meteorological and Hydrological Institute (SMHI). A model was then constructed to identify and rank the bodies of water in relation to the suitability of each body of water for mussel farming. Firstly, all areas with a depth of between 10 and 20 metres were included since these depths are considered to be suitable for mussel farms. Secondly, based on the availability of data and their recognised importance to affect the presence and growth of mussels, four parameters were chosen. These parameters were 1) salinity, 2) oxygen concentration, 3) chlorophyll concentration and 4) water exchange time. Each parameter was modelled so that it had a relevant overall influence with respect to suitability for mussel farms. Depending on these parameters, each body of water was given a value equal to the product of all four parameter values. This value was used to classify a specific area into one of five categories ranging from unsuitable to very suitable. The result from this analysis is presented in a map (Figure 1).

As a second step, opposing interests were excluded from the suitable bodies of water. This part of the study showed that it is important to clarify which other interest that really is in opposition to mussel farms. The opposing interests were set following discussions within the working group and the officials from municipalities and the Kalmar County Administrative Board. The remaining areas within the bodies of water after opposing interests were excluded are shown in a map (Figure 2)

The aim of this report was to identify the most suitable areas for mussel farms and identify possible administrative and physical obstacles for establishing them at certain localities in specific areas. Our hope is that the report will serve as a basis for further discussions and investigations for authorities, municipalities and companies interested in starting mussel farms in the county of Kalmar.

Keywords
GIS, Localisation, Mussel farm, Baltic Sea, Coastal zone

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Additional information
Photo on the front page: Odd Lindahl

Contents

1. Assignment

At the request of The Regional Development Council in Jämtland, Ecocom AB has implemented a spatial analysis with the aim of pointing out suitable localities for the large-scale farming of blue mussels along the county of Kalmar's coast. The analysis was implemented in June - September 2012 by Alexander Eriksson and Amie Larsson, Ecocom AB.

1.1. Background

In spring 2012, a pilot study (Ecocom 2012) was implemented with the aim of charting supporting data and opportunities for the modelling of suitable mussel localities along the Kalmar coast. The relevant study is a further development of the pilot study and aims to concretely indicate the areas along the Kalmar coast which have the best conditions for mussel farming with regard to both water quality and the absence of conflicts of interest. The current GIS analysis is a part of a larger AQUABEST project. The part that concerns mussel farms in the county of Kalmar is led by a working group with representatives from Borgholm, Mönsterås, Mörbylånga, Oskarshamn, Kalmar and Västervik municipalities together with a project manager from Torsta AB in Jämtland.

AQUABEST is an EU-financed project that aims to show that aquaculture can be an environmentally "neutral" way of producing food. As a part of this project, around 10 charr farms are planned in Jämtland. In order to prevent the farms from contributing a net supply of nutrients to the Baltic Sea, the possibility of taking up nutrients through mussel farms is concurrently being considered. The mussel supply can then be used as fish food for the charr and thus create an environmentally neutral cycle that simultaneously creates conditions for entrepreneurship in the rural area.

2. Conditions for the farming of blue mussels

The conditions for the farming of blue mussels differ between the Atlantic and the Baltic Sea in that blue mussels in the Baltic Sea grow considerably more slowly and achieve a size of 30-40 mm (Weijola, 2011) only in rare cases, which can be compared with the west coast where the size of the shell usually reaches 50-100 mm and in rare cases right up to 200 mm. The reason for the difference in the growth rate is that the blue mussel is adapted to salt levels in the sea. In a brackish water environment, such as the Baltic Sea, the blue mussel is exposed to physiological stress, which limits the growth rate and maximum size.

2.1.The blue mussel's water quality requirements

The blue mussel (Mytilus edulis) acts as a filter which feeds itself by pumping in surrounding water and filtering out phytoplankton. Since the blue mussel cannot move after it has fixed itself to a substrate, it is dependent upon a constant supply of phytoplankton.

As previously mentioned, the blue mussel is also limited by the salinity of the water. In the Baltic Sea, which has a falling salinity level in a northerly direction, this means that the blue mussels distribu-

tion limit is on a level with Kvarken and the Gulf of Finland (Weijola, 2011). The lower salinity limit for the farming of blue mussels has been assessed as a salinity of 4 PSU (Lindahl, verbally).
The temperature of the water also has an effect on the speed of growth since the blue mussel does not grow above temperatures of around 20 degrees Celsius. Since such high temperatures under natural conditions are only achieved locally and for a short while in the Baltic Sea, however, this parameter has a very small role to play.

The oxygen content of the water is also significant to the blue mussel. Oxygen contents of less than 2.8 mg/l are critical and farming ought not to take place at oxygen levels of below 5.7 mg/l (Lindahl, verbally), although higher oxygen contents probably have no greater an effect on the growth.

The blue mussel prefers hard beds but does also occur in lower numbers around sandy beds. Erosion from ice and waves usually prevents the blue mussel from establishing itself right next to the shoreline. Blue mussels rarely establish themselves at depths greater than 40 metres (Weijola, 2011). For the industrial farming of blue mussels, the effective depth has been assessed as being between around 8 and 30 metres (Lindahl, verbally)

3. Implementation

3.1. Depth analysis

The effective growing depth for blue mussels in the Baltic Sea has been accepted as 8-30 metres. Data on depths in the Baltic Sea has been obtained from the vector-based nautical chart (623, 624, 711-714). The nautical chart covers most of the county of Kalmar's coastal waters with the exception of the coastal areas east of Öland. However, not all depth curves are included in all nautical charts. For this reason, the analysis has been limited to depth in the range of 10-20 metres since these areas were available for all nautical charts. It is in principle also possible to produce depth data for depths of 20-30 metres and also for the coastal areas east of Öland. However, this requires the Swedish Maritime Administration to generate new depth curves and a special application to be made to the Military Defence.

Since the depth analysis includes only the areas with a depth of 10-20 metres, there is probably great potential to utilise the areas that are not included in the analysis, primarily in the depth range of 20-30 metres.

3.2. Water quality

In order to facilitate the use of water quality as a search parameter for suitable mussel farm localities, it is necessary to relate the water quality to the geographical areas. It is also necessary to weigh up different water quality parameters against one another to obtain a total "suitability value" per area.

The basis for the geographical division of the coastal waters is SMHI's coastal bodies of water. Data series for water quality parameters modelled with S-HYPE were obtained from SMHI's Waterweb (SMHI 1). Data for the areas with depths of < 8m or > 30 m was removed. The mean daily value of remaining parameters was then calculated. The parameters were than weighted using the following algorithm to one point (POMR) for each geographical body of water.

$$P_{OMR} = P_{SAL} * P_{OXYGEN} * P_{CHLO} * P_{OMS}$$

The algorithm weighs up points for four parameters; salinity (P_{SAL}), oxygen gas (P_{OXYGEN}), chlorophyll (P_{KLO}) and renewal time (P_{REN}).

At oxygen gas levels of < 5.7 mg per litre, mussel farming ought not to take place, and an oxygen gas value of < 5.7 therefore makes the relevant area unsuitable for mussel farming, irrespective of the values of other parameters, and has meant that one point = 0. Since an increase in oxygen levels probably does not have a positive effect on the growth of mussels, oxygen levels of > 5.7 have meant that point (sic) = 1.

Salinity and chlorophyll content are assumed to have a linear connection with the growth of mussels, i.e. the more mussel food and the higher the salt level, the better conditions. However, the salt level must not fall below 4 PSU, although this is not relevant in the southern parts of the Baltic Sea where the salinity is considerably higher at around 6-8 PSU.

The renewal time has been assumed to express the supply of new mussel food in the form of chlorophyll, which ought to be converted in proportion to the growth, i.e. the shorter time it takes for the water to be replaced, the more food is supplied. Since there is great variation in the parameters, points have been allocated in a special way for the renewal time (see table below).

Table 1. Water quality parameters that are used in the algorithm for the analysis of suitable mussel farming areas

Parameter	Relevance	Grading (P) in algorithm
Salinity (PSU)	Relevant. Farming can take place at 4.0 PSU. Connection with biomass is assumed to be linear.	Variation: 5,9–7,0 P_{SAL}= Salinity –4
Chlorophyll (mg/m³)	Relevant. Expresses the net supply of mussel food, i.e. the processed nutrient values. Connection with biomass is assumed to be linear.	Variation: 0,7–3,6 P_{CHLO} = (value used directly)
Oxygen gas (mg/l)	Critical under 2.8 mg/l. Farming ought not to take place below 5.7 mg/l. Oxygen levels of more than the stress level likely have no effect.	Variation: 7.3–11,9 X = Oxygen gas – 5.7 If X >0 => P_{OXYGEN} = 1p If X <= 0 => P_{OXYGEN} = 0p
Renewal time (days)	Relevant. Expresses the likely net supply of new mussel food.	Variation: 0.001–302 P_{REN}: <1–5 days = 4p, 6–15 days= 3p, 16–50 =2p, >50 days=1p

Modelled data from S-HYPE is also available for nutrients such as ammonium, nitrates, total nitrogen and total phosphorus as well as water temperature. The presence of nutrients creates conditions for the formation of growth algae. However, the assessment is that the prevalence of growth algae is best expressed by the presence of chlorophyll, so the nutrient parameters are not taken into account in the analysis. The temperature parameter has also not been taken into account since this parameter does not restrict the growth in natural water in the Baltic Sea.

Table 2. The number of bodies of coastal water in the county of Kalmar with different levels of suitability for the establishment of mussel farming, based on the grading algorithm.

Area category	Point limits	The number of areas
Lacking	0–2.3	0
A (least suitable)	2.4–6.2	9
B	6.3–10.1	11
C	10.2–13.1	14
D	13.2–18.9	13
E (most suitable)	19–28.9	9

3.3. Parameters that have not been analysed

For certain parameters that are of interest to assess the suitability when localising mussel farms there is insufficient information for them, to be used in a concrete analysis. This includes ice drifting, currents and bed structure.

3.4. Conflicts of interest

In this analysis, conflicts of interest (CI) can broadly speaking be defined as "known interests for nature preservation, trade and industry or outdoor life which may prevent or make it very difficult to establish mussel farms". Potential conflicts of interest have already been provisionally reviewed in the pilot study (Ecocom, 2011) which took the form of available GIS layers from different authorities. In the current analysis, however, the CI have also been discussed with representatives of the municipalities in the county of Kalmar and Kalmar's County Administrative Board.

With the broad definition presented earlier, there is an abundance of possible conflicts of interest. Two scenarios are presented below.

Scenario 1: CI – ALL (Table 3) covers all CIs that exist in the county of Kalmar's coastal waters. If all of these CIs are observed, this will completely prevent the establishment of mussel farms in the county of Kalmar's coastal waters.

Scenario 2: CI - CONSIDERATIONS (Table 4) is a reduction of scenario 1 and covers only the interests that are deemed to be absolutely necessary for requisite consideration to be possible as regards activities that risk conflicting directly with mussel farms.

Table 3. Conflicts of interest – ALL.

Scenario 1: Conflicts of interest
Anchorage points (buffer 250 m)
Bathing places (buffer 250 m, special Böda sand)
Animal and plant protection areas
Private water
Shipping routes and ferry routes
The Birds Directive (SPA)
The Locality Directive (SCI)
Harbours (buffer 500 m)
Slipways (buffer 250 m)

Municipal detailed plan of coastal water (Borgholm/Kalmar)
Play areas, fishing
National parks (Blå jungfrun)
Nature reserves
National interest in accordance with Chap. 4, Sections 2–3 of the Environmental Code
National interest, fishing
National interest, outdoor life
National interest, culture
National interest, nature
National interest, Natura 2000
National interest, wind
Shoreline protection
Underwater cabling and pipes (buffer 200m)
Water scooter permit
Valuable landscape

Table 4. Conflicts of interest – CONSIDERATION:

Scenario 2: Conflicts of interest
Anchorage points (buffer 250 m)
Bathing places (buffer 250 m, special Böda sand)
Shipping routes and ferry routes
Harbours (buffer 500 m)
Slipways (buffer 250 m)
Municipal detailed plan of coastal water (Borgholm/Kalmar)
Play areas, fishing
Shoreline protection
Underwater cabling and pipes (buffer 200 m)

When producing the reduced "consideration scenario", very large area protection factors such as national interests, nature reserves, habitats and the Birds Directive, etc. were eliminated. This approach was registered with the Kalmar County Administrative Board, and the latter writes in a statement (the County Administrative Board, the County of Kalmar, 2012):

> *"The County Administrative Board has looked at the GIS analysis that was done within the frameworks of the project and the proposed 4 different scenarios for the localisation of mussel farms which were presented to the County Administrative Board. The County Administrative Board believes, in principle, that the current knowledge situation shows no obvious conflicts between the establishment of mussel farms and scenarios 1, 2, 3 and 4, but this may need to be tested for it to be allowed in each individual case".*

Scenario 1 in the County Administrative Board's letter corresponds to the final scenario 1 (this report): CI – ALL, while scenario 4 in the County Administrative Board's letter corresponds largely to the final scenario 2 (this report): CI – CONSIDERATION.

In the near-shore areas, private water takes up very comprehensive surface areas. The choice has been made not to consider these areas to be essential conflicts of interest since private water for anyone who has the right of disposal is to be considered an option. However, for someone who wishes to establish a mussel farm in

the near-shore areas and does not have the right of disposal, it is advisable to speak early on to the person who has the water rights.

4. Results

The result of the analysis are described the most clearly in the maps presented on the following pages and which show the areas of coastal water that, according to the analysis, are best suited to mussel farming (Figure 1) and which of these areas will remain after the conflicts of interest have been removed in accordance with the consideration scenario, scenario 2 (Figure 2). As previously mentioned, no mussel farm localities would remain were all the potential conflicts of interest to be applied, and no map for such a scenario is therefore presented.

The result is also available in a GIS database (ArcGIS 9.3), which has been supplied to all contributing municipalities.

5. Conclusions

The areas that appear to be very suitable for mussel farming are primarily in Kalmarsund but also along the coast of northern Öland. In the inner sections of Västervik's and Oskarshamn's archipelago, the conditions do not appear to be as good, probably mainly owing to a longer renewal time, but outside the archipelago there are several smaller areas that come up to the highest potential according to this analysis.

However, the analysis does include only the areas at depths of 10-20 metres. On comparison with Figure 3, it is clear that deep areas of > 20 metres are available, particularly beyond the cost of Oskarshamn and Västervik. Since the areas at a depth up to 30 metres have been assessed as suitable for large-scale farming, it is extremely likely that additional relatively large areas may be used for farming. The same applies to Öland's eastern coastal stretch where there is no depth data at all.

With regard to the conflicts of interest, it is important to emphasise that a routine application of existing GIS layers would entirely disqualify the Kalmar coast from mussel farming, which is not reasonable. In its principal statement (the County Administrative Board, the county of Kalmar, 2012), the Kalmar County Administrative Board has clarified that the attitude to mussel farming is positive and that mussel farms are not thought to conflict with the majority of the potential conflicts of interest.

However, a developer ought to be prepared for testing in each individual case and that mussel farms with the scope referred to here will probably have to undergo a licence application process in accordance with the Environmental Code.

It should be pointed out that the study gives only a general picture of where mussel farming is the most suitable. However, there are several factors that could not be taken into account in this analysis, such as exposure to waves and the drifting of ice, currents and bed type. There can therefore be a substantial variation even in the areas that appear to be very suitable, and local knowledge of the water will probably play an important role for where the mussel farming can be the most successful. Anyone who wishes to invest in developing mussel farms himself is therefore encouraged to discuss things with people who know the local conditions in the area and with the municipality.

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Map appendices

(obtainable as pdf)

Appendix A. Figure 1. A3, vertical.
Appendix B. Figure 2. A3, vertical.
Appendix C. Figure 3. A3, vertical.
Appendix D. Suitable mussel areas Borgholm Mun. A3, horizontal.
Appendix E. Suitable mussel areas Kalmar Mun. A3, horizontal.
Appendix F. Suitable mussel areas Mönsterås Mun. A3, horizontal.
Appendix G. Suitable mussel areas Mörbylånga Mun. A3, horizontal.
Appendix H. Suitable mussel areas Oskarshamn Mun. A3, horizontal.
Appendix I. Suitable mussel areas Västervik Mun. A3, horizontal.
Appendix J. Suitable mussel areas Torsås Mun. A3, horizontal.

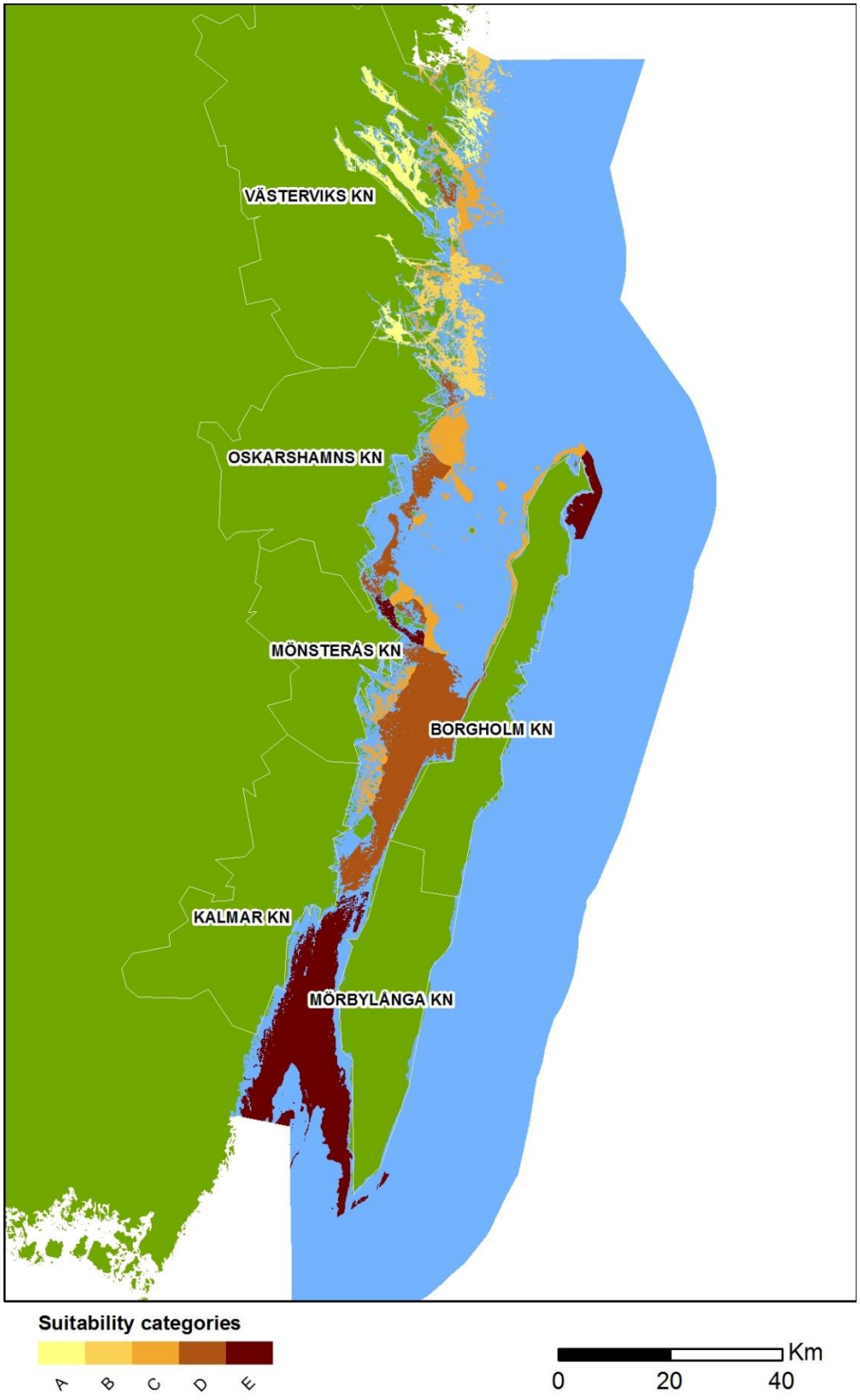

Figure 1. Suitability categories for the establishment of mussel farms. The darker the areas, the greater the suitability and the paler the areas, the less suitable they are, according to the grading from the algorithm. KN = municipality.

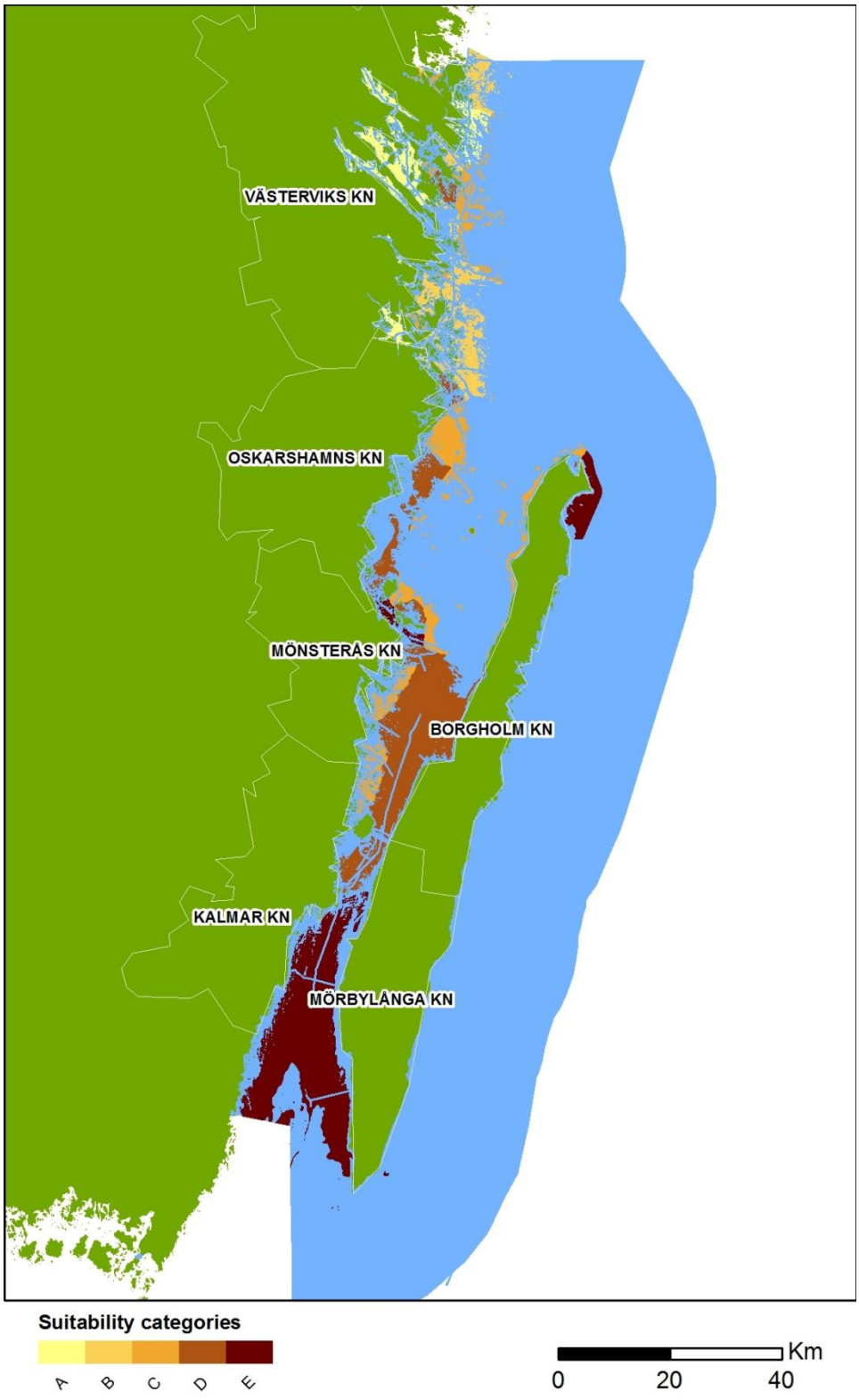

Figure 2. Suitability categories for the establishment of mussel farms, excluding the areas that disappear when observing the conflicts of interest according to scenario 2: Consideration. (Compare with Figure 1). KN = municipality.

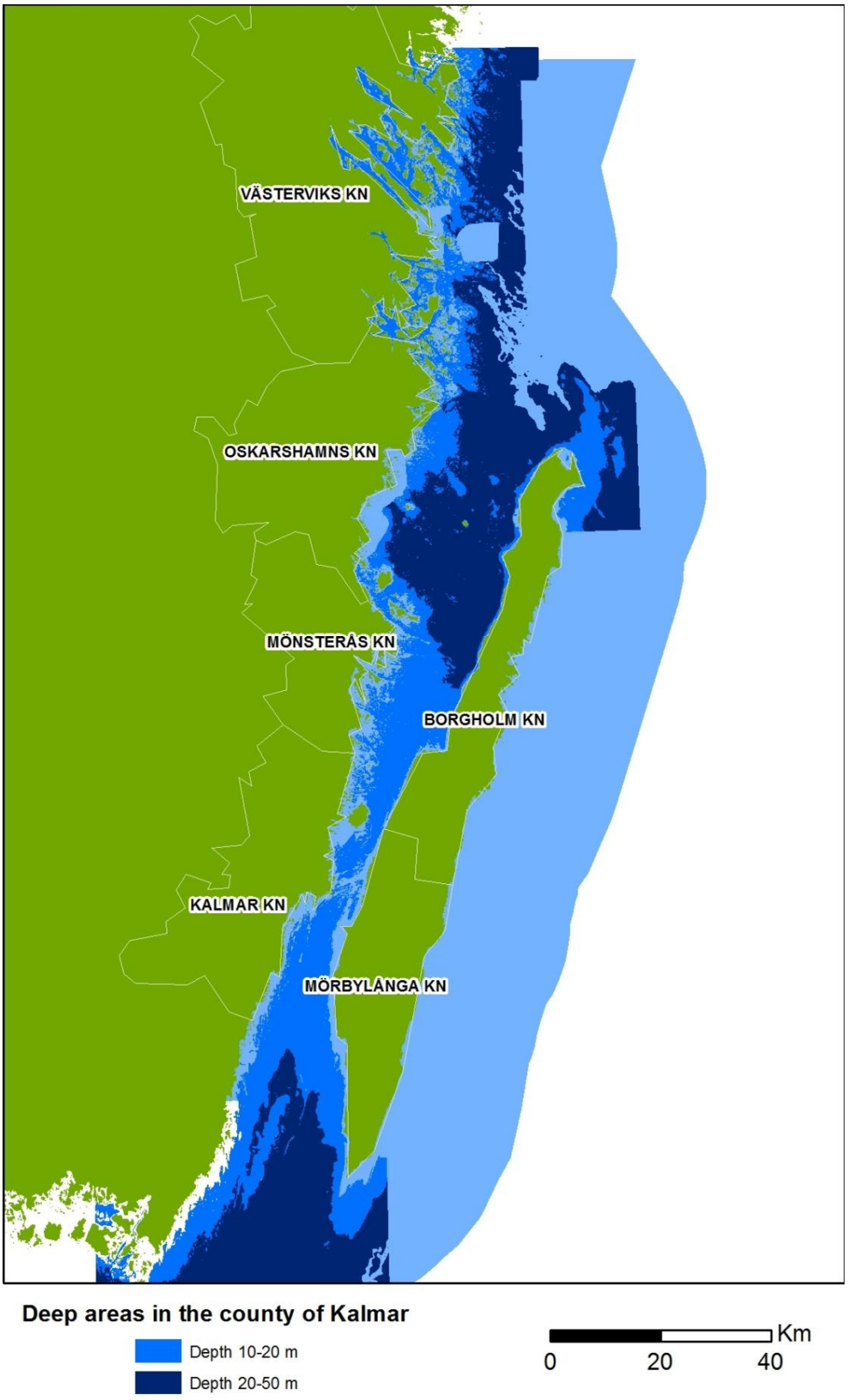

Figure 3. Map of the deep areas in the county of Kalmar. The range of 10-20 metres is suitable for mussel farming and constituted the basis for selecting the suitable areas (Figs. 1 and 2). However, the 20-50 metres range may include additional areas that could possibly be used for mussel farming. KN = municipality.