The potential for incorporating remote sensing methods in the national monitoring programme (NOVANA)

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Indhold

1 Resumé

Inddragelse af flere habitatnaturtyper i NOVANAs naturtypeovervågning stiller nye krav til overvågningen. For flere af disse naturtyper er det i mindre grad vegetationens artssammensætning og de kemiske parametre, der er centrale for at vurdere tilstand og udvikling, men i højere grad strukturelle forhold, såsom arealets udbredelse, geomorfologi, dækning af vedplanter, dværgbuske m.m., der er afgørende. Projektet omfatter 14 kystnære typer, herunder stenstrande og klittyper, hvor telemålingsdata i form af satellit- og/eller orthofotos er benyttet som supplement til den feltbaserede kontrolovervågning.

I den seksårige EU-rapportering af bevaringsstatus for habitatnaturtyperne indgår areal, udbredelse og naturtypernes struktur og funktion. Med telemåling (satellit- og flyfotos) vil det være muligt at overvåge hele den danske kystzone, mens traditionelle feltbaserede metoder kun dækker habitatområderne eller et stikprøvebaseret udsnit af kystzonen. Dette notat fremlægger resultaterne og konklusionerne af et toårigt projekt under NOVANAs naturtypeprogram, der har til hensigt at undersøge mulighederne for at udvikle egnede metoder til at understøtte overvågningen af kystnære habitatnaturtyper.

Metoden bygger på et avanceret analyseværktøj, der ud fra kortlagte strukturer i felten kan opbygge algoritmer til genkendelse af de samme strukturer i højopløselige orthofotos suppleret med satellitbilleder. Potentialet for anvendelse af telemåling i naturtypeovervågningen er størst i de kystnære naturtyper, fordi de spektralt er meget forskellige og dækker meget store områder, der er præget af en naturlig dynamik, som er vanskelig at beskrive alene ud fra overvågningsdata i felten. Metoden til genkendelse af strukturer er velkendt, men har endnu ikke været benyttet til så komplekse opgaver som erkendelse af terrestriske habitatnaturtyper. Metoden er derfor i første omgang benyttet til at kvantificere strukturelle aspekter som har stor betydning i en række naturtyper – eksempelvis vegetationens tæthed, udbredelsen af vedplanter, dværgbuske, bart sand og/eller vandflader.

Feltdata indsamlet af Naturstyrelsen i 2011-12 består af tilfældigt udlagte transekter hvor strukturelle elementer er indtegnet i de allerede kortlagte arealer i Habitatområderne. De objekt-baserede analyser benytter højopløselige ortofotos med pixelstørrelse på 0,16 x 0,16 m, suppleret med data fra en Digital Højdemodel, der tilsammen giver gode muligheder for at identificere de forskellige habitatstrukturer.

De foreløbige resultater er lovende i relation til:

- Kortlægning af kystnaturtyper. De rumlige og geografiske fordelinger af de strukturelle elementer giver gode muligheder for at identificere habitattyper. De foreløbige resultater viser en stærk korrelation mellem de identificerede strukturelementer og de kortlagte habitatarealer.
- De udviklede overvågningsmetoder er et vigtigt supplement til vurderingen af kysthabitatnaturtypernes struktur og funktion, der i væsentlig grad bygger på strukturelle elementer.
- Mulighederne for at identificere tilgroningen med *Rosa rugosa* og klit- og bjergfyr, såvel som andre af de udplantede klitdæmpende arter særligt i klittyperne.

- Udvikling af et bedre grundlag for opskalering af kortlægningsresultaterne til et nationalt og biogeografisk niveau baseret på vigtige strukturelle elementer, der også kan benyttes til de indenlandske habitattyper.

Projektet har vist at metoden er særdeles brugbar til at identificere og kortlægge strukturelle elementer. En endelig implementering af metoden i NOVANA overvågningen kræver yderligere udvikling baseret på de allerede indsamlede data, men allerede nu er der god grund til at være optimistisk for de fremtidige anvendelsesmuligheder.

2 Introduction

Remotely sensed data represent a potential source of information to national programmes for nature monitoring such as NOVANA. From 2011 to 2013 studies have been made to develop and assess the use of remotely sensed image data for NOVANA related monitoring and mapping of coastal habitat types in Denmark. This briefing paper summarizes and discusses the implications of the results of that work for NOVANA. The objective of this briefing paper is to present and discuss operational possibilities for integration of the remote sensing method developed in the 2011-13 studies in the new monitoring programme (2016+).

The focus in this briefing note is a set of 14 out of the 15 EU Habitats Directive Annex-1 habitat types that are associated with coastal environments in Denmark (Table 1). Certain implications of the results relevant for other Danish habitat types are also noted.

Table 1. List of the 15 Annex-1 Habitat Types that are considered as coastal habitats in Denmark. Only the coastal cliffs have not been included in the presented study.

Annex-1 code	English name	Danish name
1210	Annual vegetation of stony banks	Strandvold med enårige planter
1220	Perennial vegetation of stony banks	Strandvold med flerårige planter
1230	Vegetated sea cliffs of the Atlantic and Baltic coasts	Kystklint/klippe
1310	*Salicornia* and other annuals colonizing mud and sand	Enårig strandengsvegetation
1320	*Spartina* swards	Vadegræssamfund
1330	Atlantic salt meadows	Strandeng
2110	Embryonic shifting dunes	Forklit
2120	Shifting dunes along the shoreline with *Ammophila arenaria*	Hvid klit
2130	Fixed dunes with herbaceous vegetation	Grå/grøn klit
2140	Decalcified fined dunes with *Empetrum nigrum*	Klithede
2160	Dunes with *Hippophae rhamnoides*	Havtornklit
2170	Dunes with *Salix repens* spp.	
2180	Wooded dunes of the Atlantic, Continental and Boreal region	Skovklit
2190	Humid dune slacks	Klitlavning
2250	Coastal dunes with *Juniperus* spp.	Enebærklit

NOVANA (in summary)

In order to meet EU Habitats Directive 6-yearly reporting requirements and the required management plans in the Natura 2000 programme, the NOVANA programme undertakes mapping and monitoring of the Danish Annex-1 habitat types. Every six years the habitat types are *mapped* in the Natura 2000 areas, and structural and biological indicators registered for each polygon to enable reporting of two of the four required aspects in the Article 17 report, Area and Range, as well as providing an assessment of the biological status of the individual areas for the Natura 2000 plans. Every six years the habitat types are *monitored* on randomly selected monitoring stations each with ten randomly distributed sample plots. The monitoring indicators encompass structural, chemical as well as biological indicators to enable reporting of the other two key required aspects in the Article 17 report: Structures and functions and Future prospects. In the first and the current NOVANA monitoring programmes:

- Area, for the coastal habitat types has been evaluated by a combination of methods:
    - For the Natura 2000 areas and designated examples of habitat types outside of the Natura 2000 areas, initial or update mapping of habitat type area has been undertaken by field survey; due to the widespread mosaic arrangement of habitat types, the mapping is made in a generalized way, with recording of the proportions of the habitat types present. Update mapping, such as for the second period of Habitat Directive reporting proceeds as checking of the existing mapping rather than fresh mapping.
    - For other areas, the extent of the coastal habitat types has been mapped by extrapolation, using where possible, other habitat mapping information (e.g. § 3-registrations)
    - The effort and costs involved in Area mapping is considerable for the coastal habitat types due to their complexity and dynamic nature.
- Range has been, for the coastal habitat types as for other habitat types, evaluated using the Area extent mappings and GIS operations (e.g. convex hull)
- Assessment of the Structure and function as well as Future prospects of the coastal habitat types has proceeded based on sample plot field based data collection in the monitoring programme, as a rolling three year process. Many of the relevant indicators collected in the field for this assessment are structural indicators and the effort involved in this data collection is considerable due to the complex and often scattered areal distribution.
- The biological status of the individual areas is based on a field data collection including vegetation structure, hydrology, habitat type specific structures, plant species composition and the influence of farming activities. These data form the basis for the status assessment and the management plans. The effort involved in this data collection is considerable, again related to the distribution pattern of the coastal habitat types and their associated sample plots.

Assessment of the usefulness of remote sensing methods in the NOVANA monitoring and mapping of coastal habitat types is therefore understood in terms of this Habitats Directive reporting paradigm as well as the importance for the Natura 2000 planning process. This development and assessment of remote sensing methods also happens in the context of the current (i.e. end of the current programme in 2015) status of coastal habitat type data collection in NOVANA:

- For occurrences of six of the 14 coastal habitat types (1330, 2130, 2140, 2180, 2190, 2250) in the Natura 2000 designated localities and designated localities of these habitat types outside of the Natura 2000 areas, initial mapping was made during the first NOVANA programme (2004-09), and for the second NOVANA programme (2010-2015) has been undertaken based on the proscribed NOVANA mapping protocol (TA-N03)
- Over these mapped habitat occurrences monitoring data have been collected by field survey of a station-based point-plot sampling framework
- For these six habitat types there is as yet no NOVANA mapping of their extents outside of the designated areas other than in the designated localities outside of the Natura 2000 areas
- For the other eight habitat types the first mapping inside the Natura 2000 areas took place in 2010-12 and there is as yet no NOVANA mapping of their extents outside of the designated areas.

3 Remote sensing based classification of structural elements in coastal habitat types

The departure point of this briefing note is the results presented in Groom et al. (2015). That report relates to work undertaken between May 2011 and December 2013 to develop the use of remotely sensed image data for monitoring and mapping of the Danish coastal habitat types. That publication reports the results of the analysis of the field reference data collected as part of the remote sensing work, and it reports the initial results from establishment of algorithms to identify structural elements with the acquired image and field reference data.

Key methodological factors and applied principles

Taking into consideration in particular the more extensive coastal Habitat Types (e.g. 1330, 2130, 2140, 2180, 2190, 2250), there are two key factors that serve to contrast the coastal habitats from other open terrestrial habitats in Denmark: geography and anthropogenic influence. These factors represent principles for how the monitoring and mapping can be most effectively and efficiently undertaken for coastal habitat types, and how remote sensing methods can most appropriately be applied. Occurrences of coastal habitat types in Denmark often, each, cover relatively large extents, and occur at many locations around the Danish coast: this has two impacts that make both their monitoring and mapping for NOVANA more difficult than that for other habitat types:

- Considerable time is required in making the initial or update mapping by field survey, in particular in determining, in the field, the extent of habitat types, and in travel to habitat type locations.
- The station-based sample plot method for habitat monitoring that is applied for open habitat types in general, requires a larger network of stations (entailing additional cost) due to unpredictable spatial distribution of changes.

Anthropogenic influences (such as related to agricultural land use and urban development) play a relatively minor role in assessing conservation status of the coastal habitats, while the physical environmental influences (e.g. geomorphological processes) have a much greater significance than for other Danish open habitat types. An implication of this is that patterns in the life forms and related structures present can be expected to have a close relationship to patterns in the key abiotic conditions and processes. It is therefore meaningful, for these habitat types, to undertake monitoring and mapping in terms of life forms and related structures.

A remote sensing method has therefore been developed (Groom et al., 2015) as one that represents a basis for the required coverage and one that represents a basis for monitoring and mapping in terms of the structural elements of the coastal habitats. For a remote sensing method to improve upon the methods currently applied in NOVANA without additional costs, the selection of the method was constrained in that it should represent a basis for national coverage, enable mapping with sufficient spatial detail and be low cost. Thus, the method was developed around use of summer and spring national aerial orthophoto image mosaic datasets, as the only source of image data that met these conditions. The main image dataset used has pixels that represent land units of 0.16 x 0.16 m. These image data are seen as particularly meaningful to the work in that they express a wealth of fine scale spatial detail, such as is highly relevant with respect to habitat structure elements. The image data have in the method development been supplemented by national coverage fine spatial resolution (1.6 m) digital elevation model (DEM) data, which are also seen as representing important details of habitat structure elements. A data analysis approach was developed that actively exploits the spatial detail present in the image and DEM data. This is an object-based analysis, which is seen as most ably enabling use of the spectral detail present in the individual image pixels and the spatial detail present as texture and context of sets of pixels. Sets of pixels were therefore seen as representations of the structural elements. Field based collection of reference data for a set of reference transects, undertaken by the Danish Nature Agency in 2012, has been a key input to interpretation of the image data and development of the method.

Expectations and Constraints

Moving from a field survey based set of methods for coastal habitat monitoring and mapping to one based on use of remote sensing methods is a considerable undertaking. Thus the current situation of this work in Denmark, compared to that found in several other European countries (e.g. The Netherlands, Wales, Sweden), is relatively modest. Similar works have elsewhere been undertaken by teams of researchers engaged on the activities for many years. It is important to recognize therefore that the work undertaken in Denmark to date is only a first step in establishing remote sensing methods for coastal habitat monitoring and mapping in NOVANA. Moreover, as the first such activities in NOVANA in this direction, considerable time has been used in acquiring and preparing the necessary data for use in the analysis work. In addition, the key field reference data were delivered only relatively late (winter – summer 2013) in the work period, and the analysis has been made with the data for just those 55 reference transects for which field reference data was delivered in winter 2013. The steps beyond the first stage the work has currently reached are discussed below.

4 The potential for incorporating remote sensing methods in NOVANA

Four key aspects of the potential for incorporating remote sensing methods in the national monitoring programme (NOVANA) are identified and addressed here:

- Which needs under NOVANA habitat monitoring can the remote sensing methods help to fulfill?
- What are the possibilities of repeatability and change detection?
- Which reference data are needed for repeatability?
- Present and future data use: what are the possibilities of improving and expanding the structure mappings?

Which needs under NOVANA habitat monitoring can the remote sensing methods help to fulfill?

As reported in Groom et al. (2015), with various subsets of the independent image and DEM data variables, it has, in the local area of the field references, been possible to correctly label objects to most field classes (i.e. structural elements) with error rates of 11 – 14% for cases where the field reference data records that the same structure covers at least 75% of the object's extent. Lowest error rates (around 11% for most combinations of variables) have been achieved for the high tree, high dwarf bush, high herb, low herb, lichen, sand, stone/gravel and water field classes. Error rates of between 13 – 14 % have been achieved for the clay/mud, and low tree field classes, with slightly higher (18%) error associated with the non-built-up class. The highest error rates, of between 30% and 35% have occurred for the built-up and low dwarf bush classes, which are two thematically difficult classes associated with a small number of reference samples.

The results achieved to date, and reported in Groom et al. (2015) are initial results. There are still many aspects of the data and the analysis method to investigate further in order to better understand the use and usability of the image and DEM data for identification of the structural indicators of the coastal habitat types. However, the prospects with this method for integration in NOVANA appear promising for:

Mapping of the extent of coastal habitat types: The spatial and geographic arrangements of the structure elements represent the basis for their interpretation as required target classes, such as habitat types. This stage of the method has yet to be developed. The work undertaken to date has assessed the possibility for using a remote sensing based method for identifying structural elements within reference transects. However, one aim for developing a remote sensing method is to reduce the cost associated with initial or update habitat type mapping by providing a basis for the mapping of habitat types over the extensive parts of the Danish coastal areas that have not yet been mapped. The basis for that is to apply the image and DEM data patterns that have been successively applied for classification of the structure elements in the reference transects for classification of image data objects elsewhere. Initial results (Table 2) indicate, for the reference transects, a strong pattern of association between the structure element mapping results and habitat type mappings. This extension of the current work to areas beyond the reference transects is still to be undertaken.

Monitoring of structure and function: The developed remote sensing method is seen as representing a major contribution to future monitoring of the coastal habitat types given the relatively greater role played by abiotic factors and the lesser role played by anthropogenic factors, and the problems of detecting patterns of change with a relatively low density field station based method alone. Interpretation of image and DEM data in terms of structure elements, as representations of key factors and processes, is seen as coherent with monitoring of structure and function. Several of the indicators that have been identified as important for assessment of the conservation status of coastal habitat types (Nygaard et al, 2014) relate directly to aspects of the structural elements. For example, for habitat type 1330 the height of the vegetation, for 2130 the coverage of lichens, and for 2140 and 2190 the coverage of woody vegetation over 1 m high are noted by Nygaard et al. (2014) as being important indicators of the conservation status. These indicators can be directly related to structure elements addressed by the developed remote sensing method.

Table 2. The correspondence between habitat types (rows) and structure elements (columns). Polygons of pure habitat type as registered in reference transects by NST in the 2012 reference data fieldwork are presented in terms of their structure elements composition as was recorded by NST in the 2012 reference data fieldwork. Values represent pooled data with respect to 55 reference transects. The table also records the structure element composition of six habitat types other than 13 out of the set of 14 coastal habitat type, which were also recorded by NST as present within the reference transects.

	Clay mud	High dwarf	High herb	High tree	Lichen	Low dwarf	Low herb	Low tree	Sand	Shadow	Stone/gravel	Water
1150			.27				.02					.71
1220			.51	.03			.12	.01	.13		.19	
1230	.70		.08							.23		
1310							.43					.57
1320			.73									.27
1330	.01		.56				.32	.01				.09
2110			.27						.73			
2120			.58			.01	.04	.06	.28	.01	.01	
2130		.19	.35	.04	.06		.21	.11	.02			.02
2140		.76	.15	.04		.03	.01			.01		
2160			.10					.87	.03			
2180				.96	.02				.01	.01		
2190		.37	.47				.05	.09				.02
2250				.30				.19		.51		
4010			.78	.02						.10		.10
6210			.44	.03			.51			.02		
6230			.07	.09			.64	.15	.01	.03		
6410			.89	.04								.07
7230	.01		.94	.03								.02

The coverages of mountain pine and other species of special interest. Taken together with earlier Danish remote sensing work with coarser spatial resolution image data (Nielsen et al. 2000), the project has shown that mountain pine is also associated with image data signatures that can enable mapping of its extent. In the current project, no single species mappings have been produced from the image and DEM data to date, but with the collected field reference data, and good structure classification results, there are some prospects of mapping distinct species such as *Rosa rugosa, Phragmites australis*, *Hippophaë rhamnoides* and *Spartina spp*. Such species mapping would not only form a contribution to assessing structure and function, but also to the mapping of the species defined habitats such as 1320, 2160 and 2170. Further work could also include classifications into broadleaved/evergreen trees and shrubs, e.g. feeding into the classification of habitat types 2180 and 2250. Other indicators of the conservation status of coastal habitat types that are noted by Nygaard et al. (2014) relate to aspects of nutrient status and species composition. The possibilities for monitoring of such indicators with the developed remote sensing method are less fully understood, but could, in the case of nutrient status in coastal habitat, for example relate to the geomorphological processes present that could be modelled in terms of the structure elements present. The relationships of species composition and structure elements have also been identified as a significant line of enquiry.

Development of a monitoring and mapping programme with high levels of transparency, objectivity and synopsis: Transparency, in that it is possible to review and examine the entire process by which every item in the structural element identification has been made, and following the further development of the method, the delineation and labelling to a habitat type of each mapping unit. Objectivity, in that the same method has been applied to all parts of Denmark, without any systematic processes that represent subjectivity, such as the skills of different field survey teams. The application of equivalent data and the same analysis method for all Danish coastal areas gives the remote sensing method its synoptic meaning and value, making possible the analysis of structural indicator related patterns upon different spatial scales.

A basis for inter-comparison: The developed method, with its strong reliance on similar image data for all areas, and one analysis method represents a strong basis for inter-comparison between the field survey based data from different parts of Denmark, and the patterns that characterize the two Biogeographic regions that are present in Denmark.

It is anticipated that the developed remote sensing method can be applied for monitoring and mapping of most of the coastal habitat types. At the same time it is recognized that it may not be possible to apply it fully for certain coastal habitat types; that might for example include habitat types 2170 (Dunes with *salix repens ssp. argentea*).

What are the possibilities of repeatability and change detection?

The developed remote sensing method is seen as being directly relevant to issues of repeatability and change detection on two primary counts:

- The method addresses issues that are related as much to the monitoring as to the mapping
- The method is based upon data that can be expected to themselves be updated regularly in the future.

Repeatability relates to the future, whereas change detection can also relate to both the past and the future, i.e. it can also be understood in terms of how developments in the conditions associated with coastal habitat types have progressed up to their current status. Similar image data to those now being used for development of the remote sensing method exist and are available, for all areas, for several years since at least 1995:

- Summer aerial orthophoto image data: 1995, 1999, 2002, 2004, 2006, 2008, 2010, 1012
- Spring aerial orthophoto image data: in digital form back to 2002, and as analogue form back to the early 1960s on a rolling 5 year coverage.
- High spatial resolution height model data are generally available just for 2005-06; however, a second national lidar data acquisition is currently underway (2014-15).

For many of the coastal habitat types, there is an ongoing process of local level changes that relates to the natural dynamics of the abiotic factors and processes that play key roles in coastal habitats. Therefore relatively frequent and widespread localized natural changes are often observed, such as in dune habitats. Evolutions between habitat types on relatively short time frames are also part of the natural dynamics of coastal habitat areas. The developed remote sensing method, with its basis in the structural elements of the coastal habitats, which represent responses to the abiotic factors and processes, will provide data on these natural change patterns as part of its monitoring role. Changes in the sets of structure elements associated with habitat types will serve to indicate situations in which habitat type is changing, or where non-abiotic, more anthropogenic factors and processes are also involved in habitat change.

The developed remote sensing methods can make contributions to the process of updating the mappings for each successive reporting period in a number of ways, which will be developed and assessed more fully in the subsequent work. Given the established method, assessment of habitat type changes can be made in the following ways:

- Changes in the mapped extents of the habitat types
- Changes in the mapped extents of structure elements
- Changes in the image data characteristics of structure elements.

Which reference data are needed for repeatability?

The field referenced data collected by NST in 2012 according to the Technical Manual TA-N04 (Feltmetode til telemålingsbaseret overvågning af kysthabitatnaturtyper) have had a key role in development and establishment of the remote sensing method. As well as providing the necessary field data for the image and DEM data analyses, the involvement of NST in the field data collection has represented an important process for discussion and feedback on the methods.

In principle, once undertaken, the collected field reference data represent a strong basis for establishment of a library of the various image and DEM data signatures associated with different structure elements, i.e. that further reference data collection is not needed. There are two ways in which that principle can be relevant for NOVANA:

- For the assessment of change as part of the NOVANA monitoring of coastal habitats: the developed method associates each structure elements with patterns in a specific set of image data signatures. Changes in the assemblages of signatures associated with an individual case of a struc-

ture element will indicate how the ground characteristics of that parcel of land have changed.
- For the extension of the work from the reference transects to otherwise unmapped areas, such as the other parts of the habitat areas. This is seen as a core basis for developing a remote sensing method, i.e. to reduce the cost associated with initial habitat type mapping, as is required for extensive parts of the Danish coastal areas, and has been discussed above.

Any extension of the current NOVANA station based field data collection could provide future field reference data for the remote sensing method, to serve as control and adjustment data in application of the remote sensing methods.

Present and future data use: what are the possibilities of improving and expanding the structure mappings?

As noted above, a new approach to monitoring, for the coastal habitat types, based on remote sensing, requires more resources and time than have been applied to it in Denmark to date, and therefore the present results represent just the first steps towards full operational implementation. Towards that goal, there is need for (a) further development and testing of the current basic methods, and (b) extension of the basic methods to expand the scope of the method and develop its complementarity to other NOVANA methods.

The developed approach, based on a concept of structure elements and using appropriate image data and analysis methods, is seen as sound for meaningful monitoring of the coastal habitat types in the context of NOVANA. Many significant aspects of the habitats for assessment of their conservation status can be monitored via remote sensing based analysis of structural elements. The work also supports the possibilities for mapping of habitat type extents. As noted above, it is likely that mapping of the extent of certain habitat types will be more successful than that of others. Future work should aim to develop possibilities for improving the possibilities for mapping of such classes. In some cases that could involve greater application of DEM data, or also the raw lidar data used to generate the DEM data. A second direction for that work would be to integrate the high spatial, low spectral detail of the aerial orthophoto image data with less spatially detailed, but more spectrally detailed satellite image data.

There are considerably more levels to which this work can be taken:
- Integration of field based species data with the remote sensing methods is merited, for improved structure element identification, habitat type mapping and modelling of the processes operating in the coastal habitats. There is a wealth of species composition field data of the coastal habitats that is available through NOVANA and other activities for such investigation and method development work.
- Interpretation and analysis of older (pre 2010) image data should also be undertaken, integrating that with the current analyses to establish change patterns and remote sensing based models relating to the processes of changes in the coastal habitats.
- Extension of the methods developed for the coastal habitats to non-coastal habitat occurrences that have similar extent and low levels of abiotic influence characteristics.

5 Conclusions

The work to date has been successful, indicating that a remote sensing based monitoring and mapping of some coastal habitat types for NOVANA reporting requirements is possible.

The developed remote sensing approach does not simply replace the existing methods for NOVANA monitoring and mapping of coastal habitat types but instead represents an alternative approach that relates more closely to the overall spatial and temporal patterns of the driving processes, and can replace some of the cost associated with field survey for mapping and some of the cost of field survey for monitoring.

The basis for the remote sensing method has been partially demonstrated, but its full implementation requires further development work. However, we do not anticipate that remote sensing methods will wholly replace the need for field based data collection, and indeed, remote sensing methods also require field data such as for verification.

6 References

Fredshavn, J.R., Ejrnæs, R., Nygaard, B. (2011). Kortlægning af terrestriske naturtyper. (Teknisk anvisning N03). Fagdatacenter for Biodiversitet og Terrestriske Naturdata, AU-DMU.

Juel, A., Groom, G., Ejrnæs, R., Fredshavn, J.R. (2012). Feltmetode til telemålingsbaseret overvågning af kyst-habitatstruktur. (Teknisk anvisning N04). Aarhus University, DCE – National center for miljø og energi.

Groom, G., Juel, A. & Ejrnæs, R. (2015). Remote sensing based classification of structural elements of coastal habitats. Aarhus University, DCE – Danish Centre for Environment and Energy, 44 pp. Scientific Report from DCE – Danish Centre for Environment and Energy No. 144.

Nygaard, B., Nielsen, K.E., Damgaard, C., Bladt, J., Ejrnæs, R. (2014). Fagligt grundlag for vurdering af bevaringsstatus for terrestriske naturtyper. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 142 s. - Videnskabelig rapport fra DCE – Nationalt Center for Miljø og Energi nr. 118

Nielsen, K. et al. (2000) Areal Informations Systemet- AIS. Miljø- og Energiministeriet, Danmarks Miljøundersøgelser.