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UKSeaMap
The mapping of seabed and water column features of UK seas

October 2006

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The UKSeaMap project has been part-funded by the Interreg IIIB Programme and is a contribution to the MESH project.

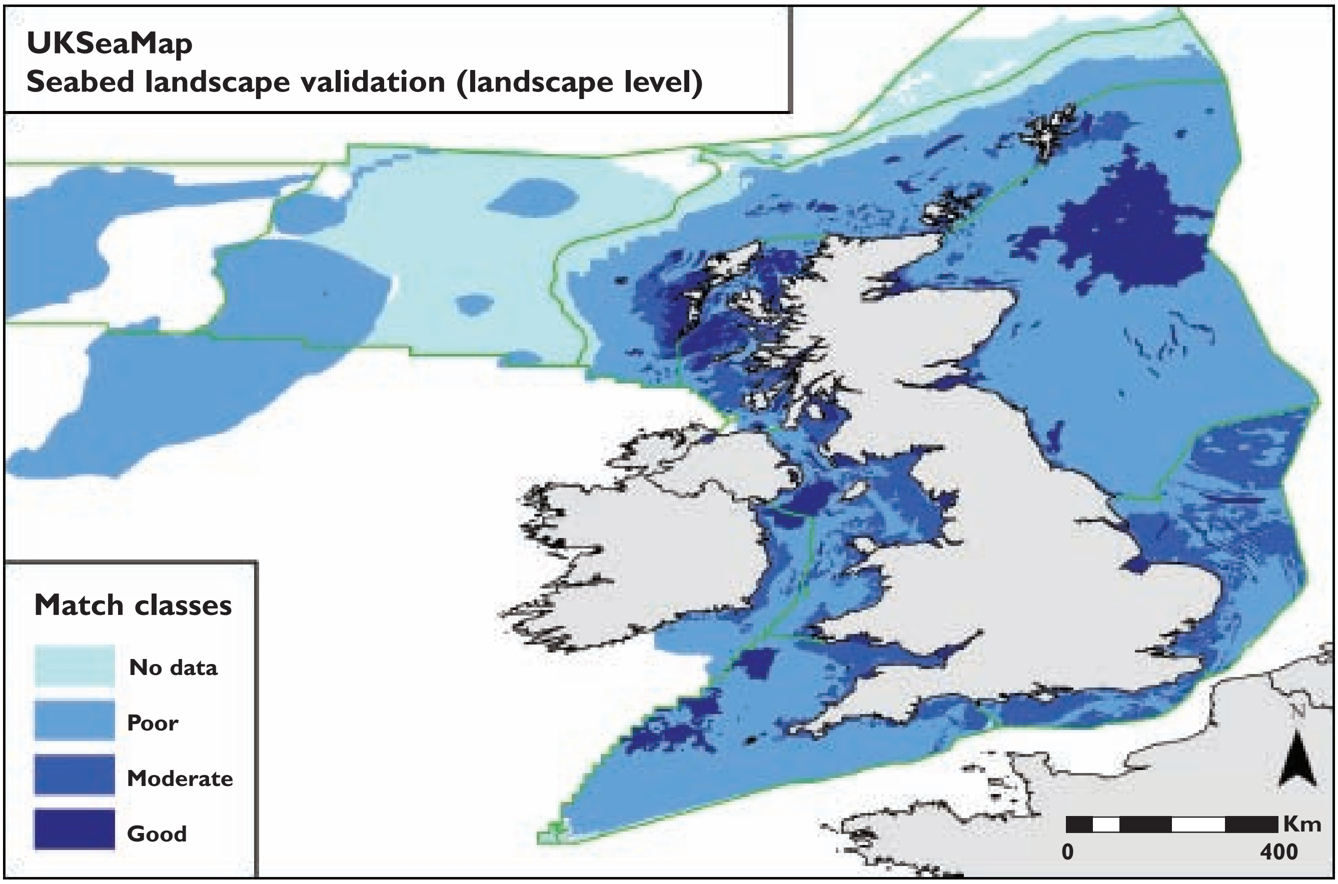

Figure 22: Map showing the degree to which the biological validation data, at the landscape level, supported the predicted character of the underlying landscape type (refer to text for full explanation and see also Table 7)

5.1 Overview

The general approach to development of maps to represent the ecological character of the water column or pelagic environment followed that for the seabed modelling, that is:

- Define a series of environmental data layers which are needed to characterise the water column;
- Source the required data sets, where possible to provide data layers covering the whole (or majority of) UK seas;
- Process the data into suitable GIS formats, including categorising each data set;
- Analyse the data sets in an integrated manner to produce classifications of the water column;
- Validate the resultant maps with ground-truth data (e.g. biological sample data);
- Characterise the final water column classifications according to both abiotic (physical, hydrographic) and biological characteristics;
- Present the underlying data layers and resultant maps in a web GIS application;
- Assess the level of confidence that can be placed in the resultant maps.

The key difference in methodology was that the data sets were processed and summarised according to four seasons to better reflect the highly mobile nature of the pelagic environment:

- Winter – December, January and February
- Spring – March, April and May
- Summer – June, July and August
- Autumn – September, October and November

In contrast to classifying the seabed features, the water column has a 3-dimensional aspect to its character, and is affected in particular by significant changes in temperature with depth. Within the timescale and resources available for the UKSeaMap project, it was only possible to consider the water column in a 2-dimensional perspective.

5.2 Water column data layers and their processing

A number of hydrographic data sets were obtained from the Proudman Oceanographic Laboratory (POL), and assessed for relevance to modelling water column types:

- Shelf surface salinity
- Atlantic surface salinity
- Sea surface temperature (remotely sensed data)
- Sea bottom temperature (modelled data)
- Surface to bed temperature difference (modelled data)
- Stratification probability (modelled data)
- Frontal probability (modelled data)
- Potential energy anomaly (modelled data)
- Shelf mixed layer depths (modelled data)
- Atlantic mixed layer depths (modelled data)
- Tidal stress (spatially referenced point values)
- Wave stress (spatially referenced point values)

After consideration of their potential role in defining water column types, and because some were effectively replicating other data sets (e.g. stratification probability and surface to seabed temperature difference), the data sets to be used in the final analysis were refined to the following:

- Surface salinity (shelf and Atlantic)
- Surface to bed temperature difference
- Frontal probability

Further details on those data sets which were not used in the analysis are provided in Annex 11.

5.2.1 Surface salinity

Salinity was selected as the initial classification parameter used for generating water column types, as it has a major role in determining biological character, varying from inshore estuarine and coastal conditions through to fully saline oceanic waters. The following categories in the salinity data were adopted:

- Estuarine (<30‰)
- Coastal or Region of Freshwater Influence (ROFI) (>30‰, but <34‰)
- Shelf (>34‰, but <35‰)
- Oceanic (>35‰)

Two separate data sets comprising shelf and beyond shelf (Atlantic) data were used to map surface salinity. Away from the shelf the data points used to create the raster layer were sparse but have enabled the North East Atlantic Approaches and the Rockall Trough and Bank regions to be mapped, as these were gaps in the shelf data set. Throughout the year surface salinity figures in the beyond shelf data set remain >35‰ and therefore fall within the Oceanic waters category. The resultant surface salinity maps are shown in Figures 23-26.

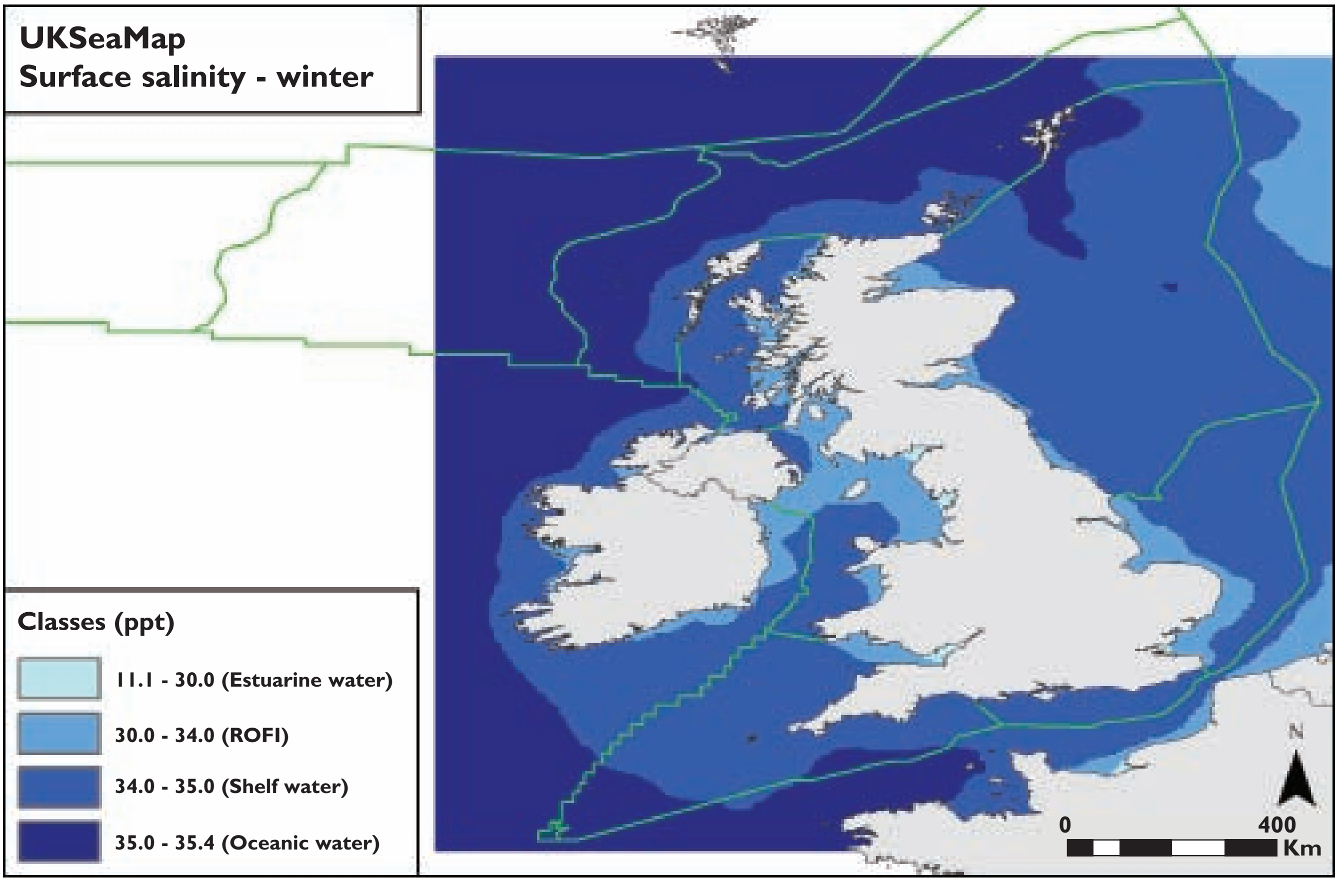

Figure 23. Winter sea surface salinity (source data from POL)

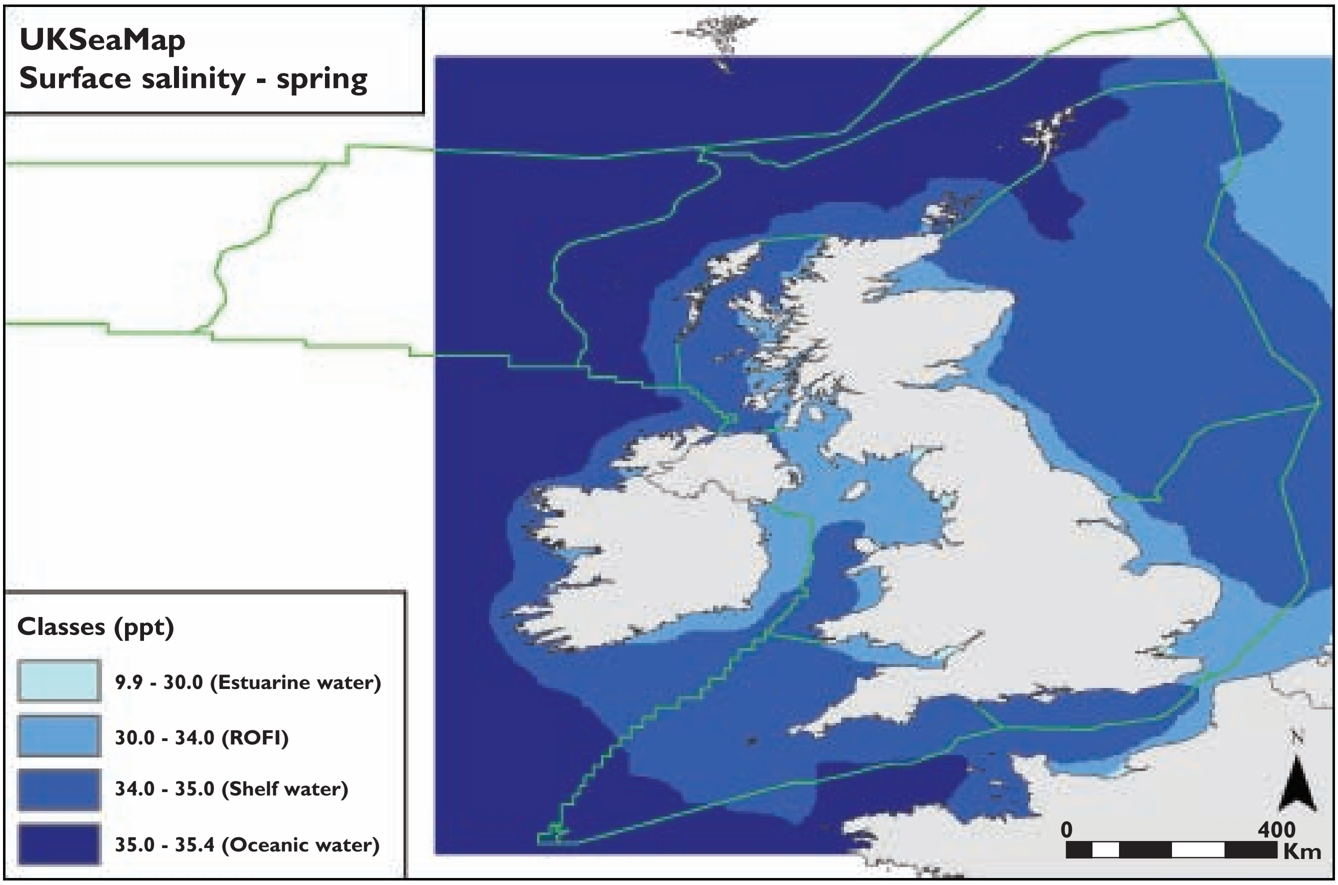

Figure 24. Spring sea surface salinity (source data from POL)

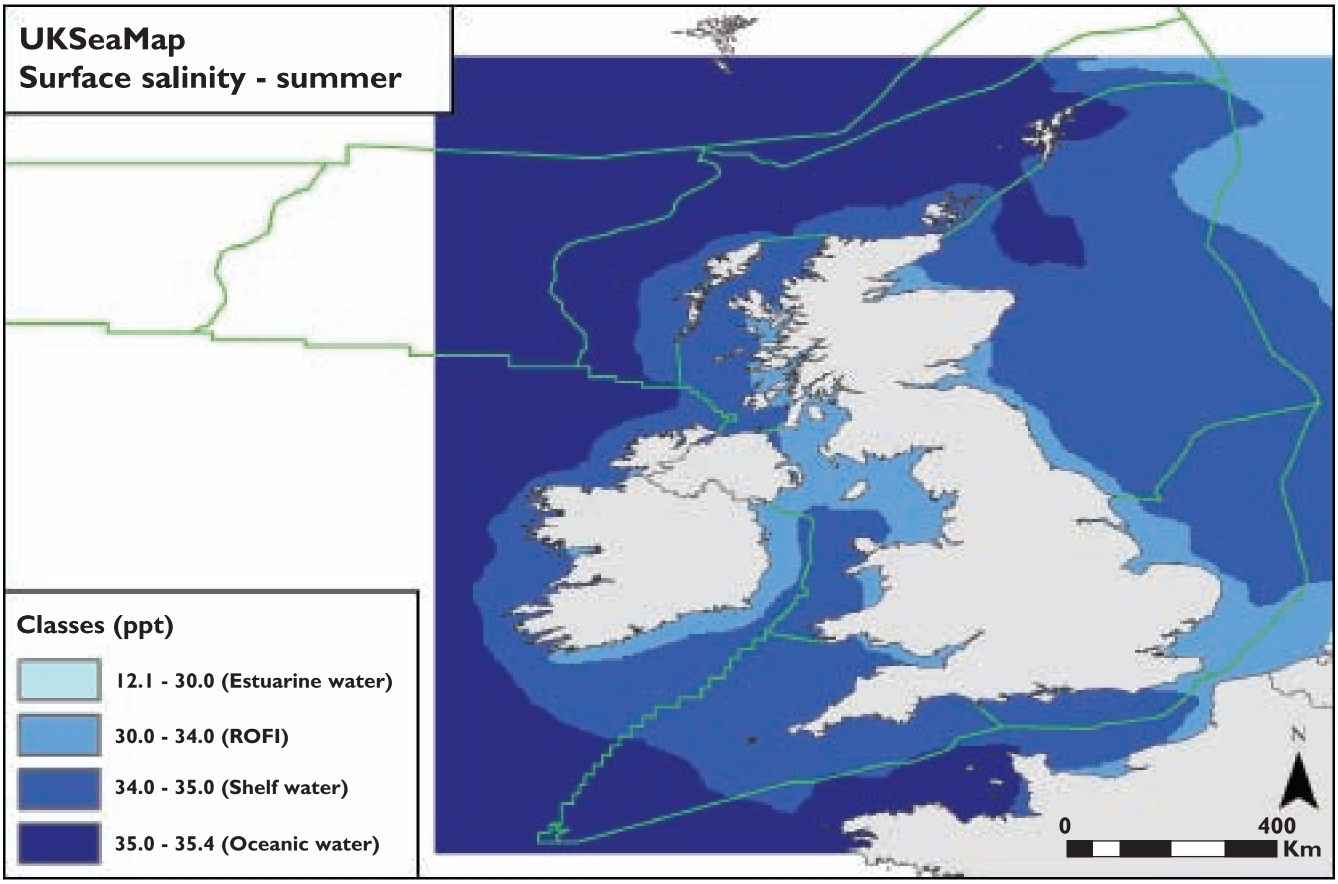

Figure 25. Summer sea surface salinity (source data from POL)

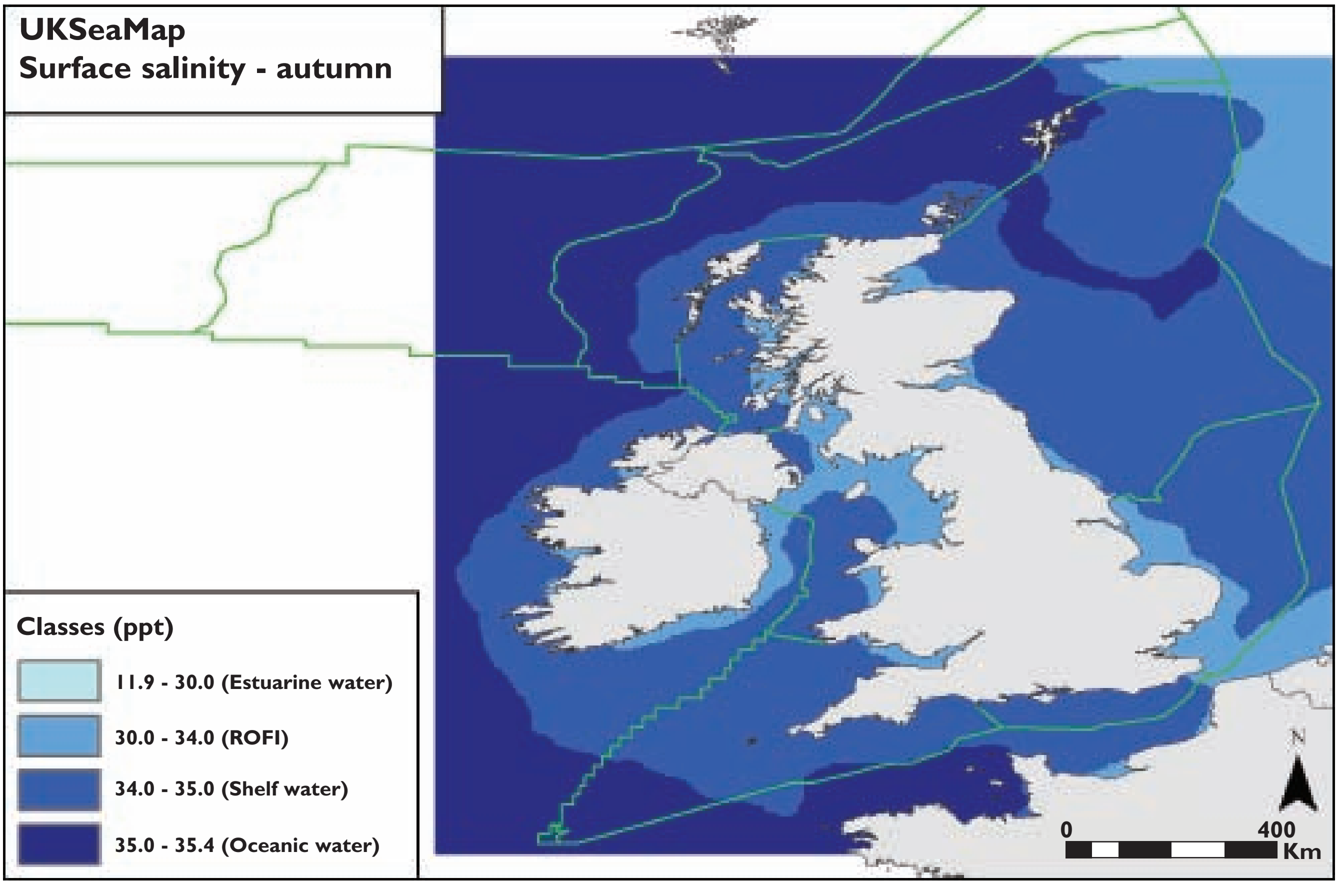

Figure 26. Autumn sea surface salinity (source data from POL)

5.2.2 Surface to seabed temperature difference

Surface to seabed temperature difference data has been used to distinguish three classes which reflect the degree of stability in the water column, namely thermally stratified and well-mixed waters on the continental shelf, together with an intermediate transition zone (shown as frontal on the maps) (Figures 27-30).

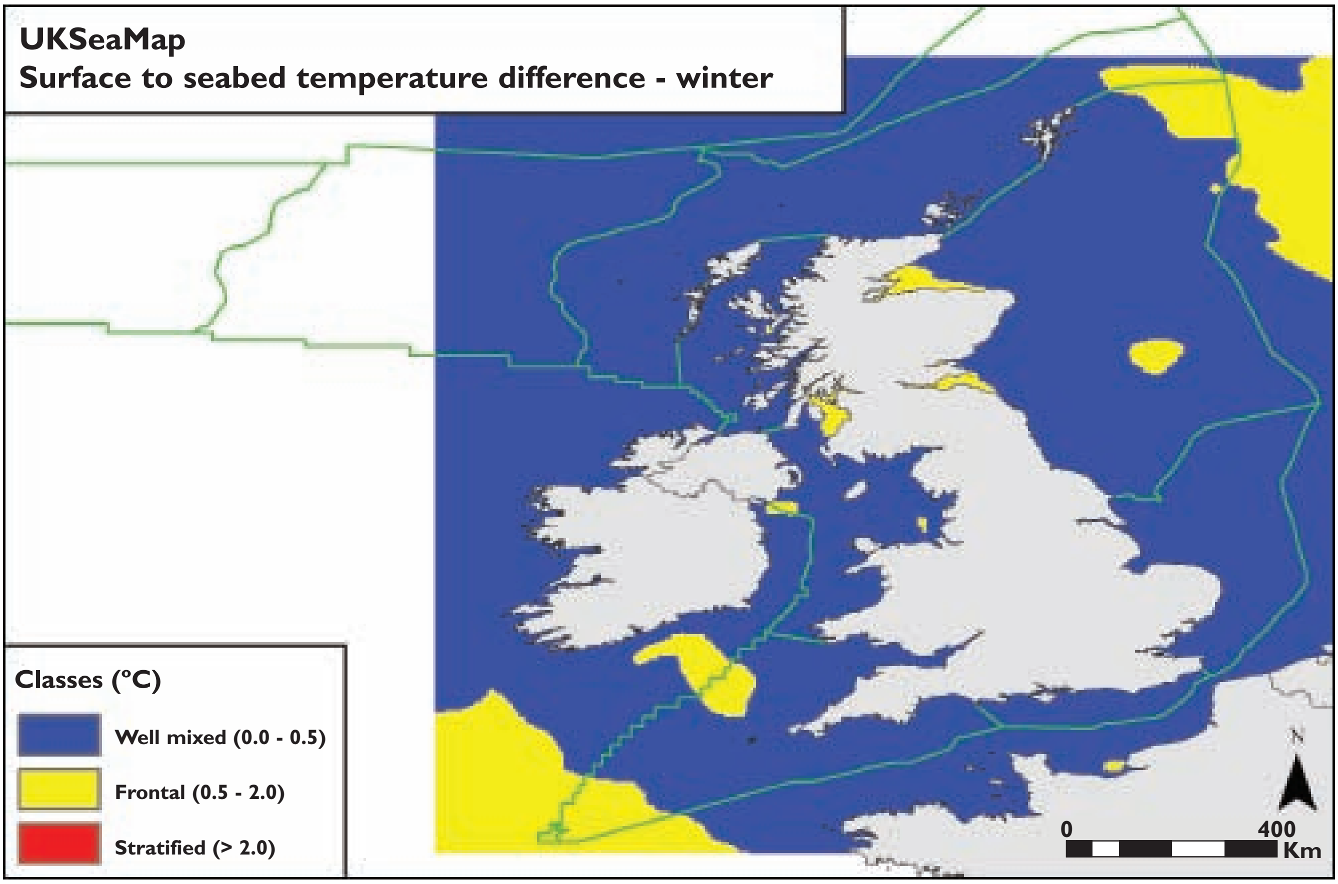

Figure 27. Winter surface to bed temperature difference (source data from POL)

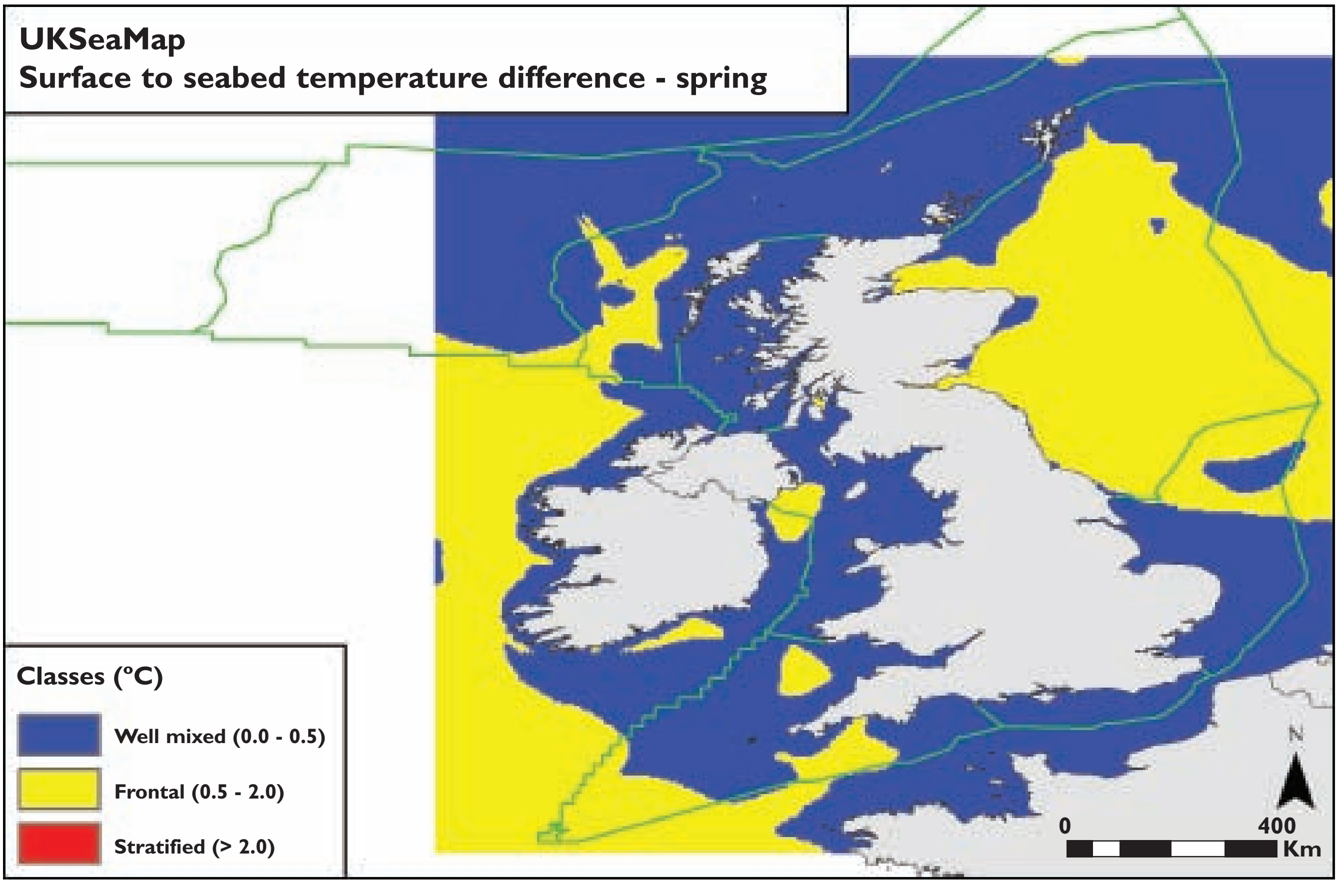

Figure 28. Spring surface to bed temperature difference (source data from POL)

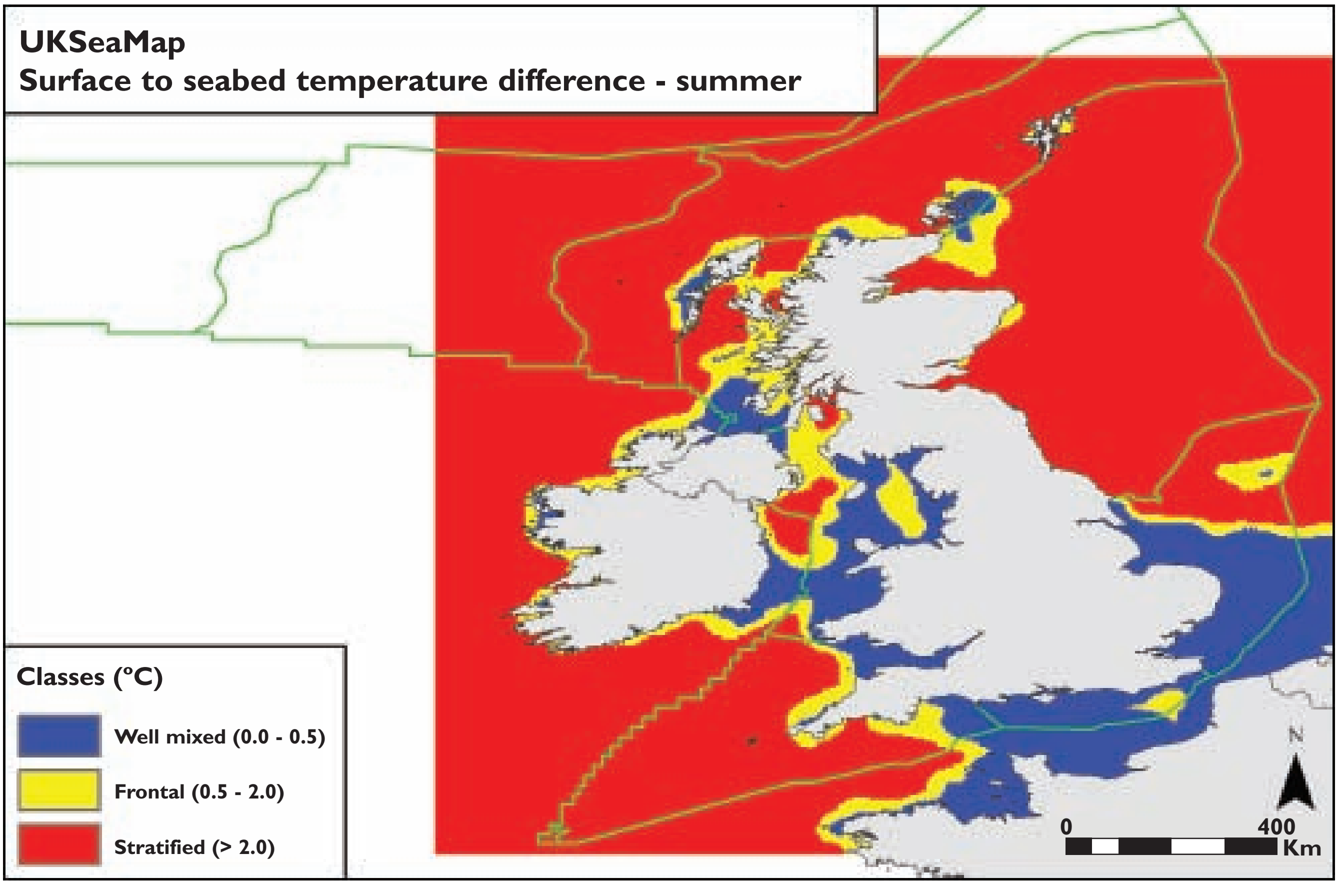

Figure 29. Summer surface to bed temperature difference (source data from POL)

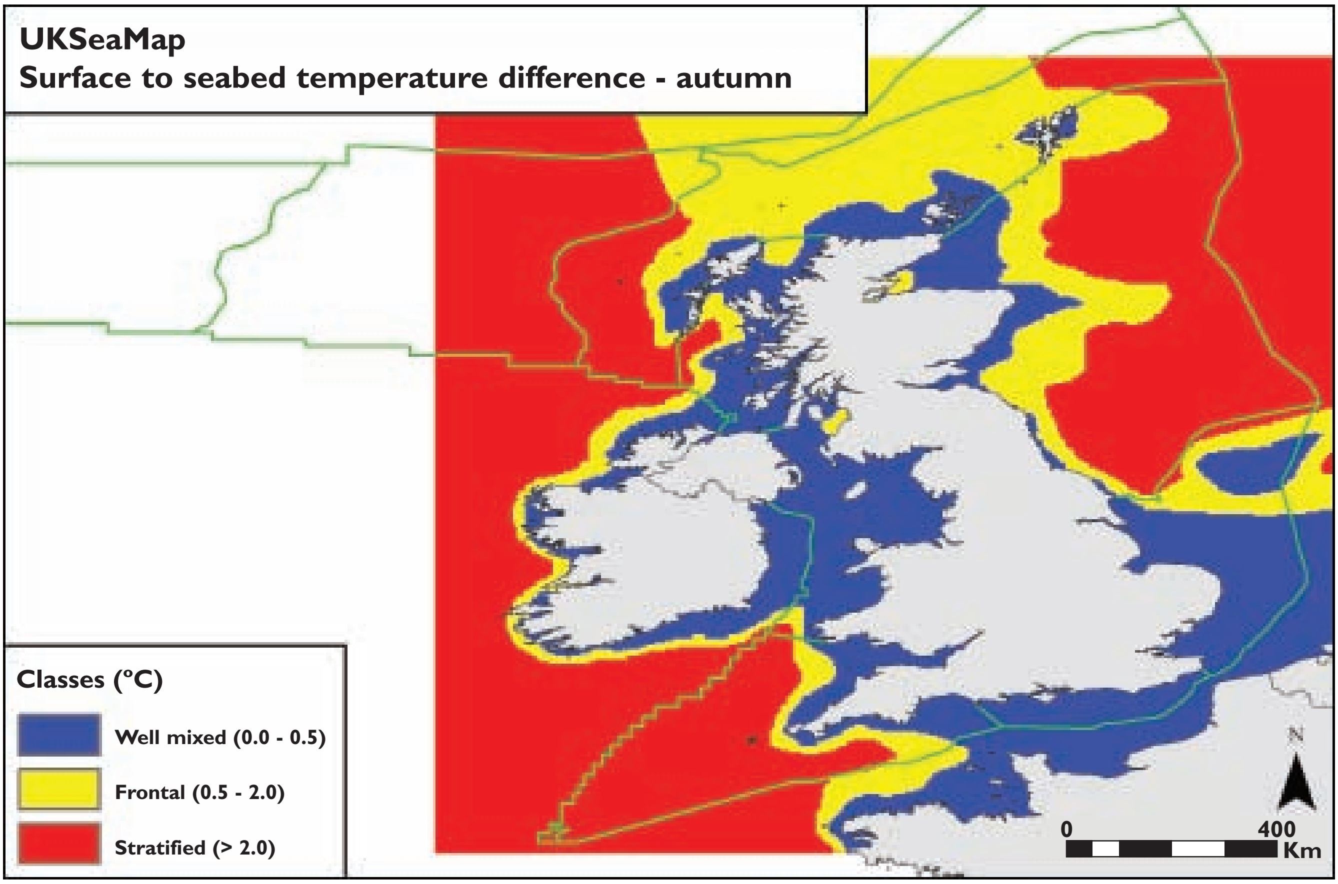

Figure 30. Autumn surface to bed temperature difference (source data from POL)

5.2.3 Front probability

Fronts are an important zone of rapid change in hydrographic and biological character, often separating shelf sea regions from the open ocean. Front probability data has therefore been included in the water column classification process to illustrate the likelihood of a front being present within a particular area.

The front probability density function is defined as the number of days the horizontal temperature difference between neighbouring modelled locations exceeds 0.5°C, divided by the number of days in this season over the 10-year run. Figures 31-34 illustrate the location of fronts in the UKSeaMap area.

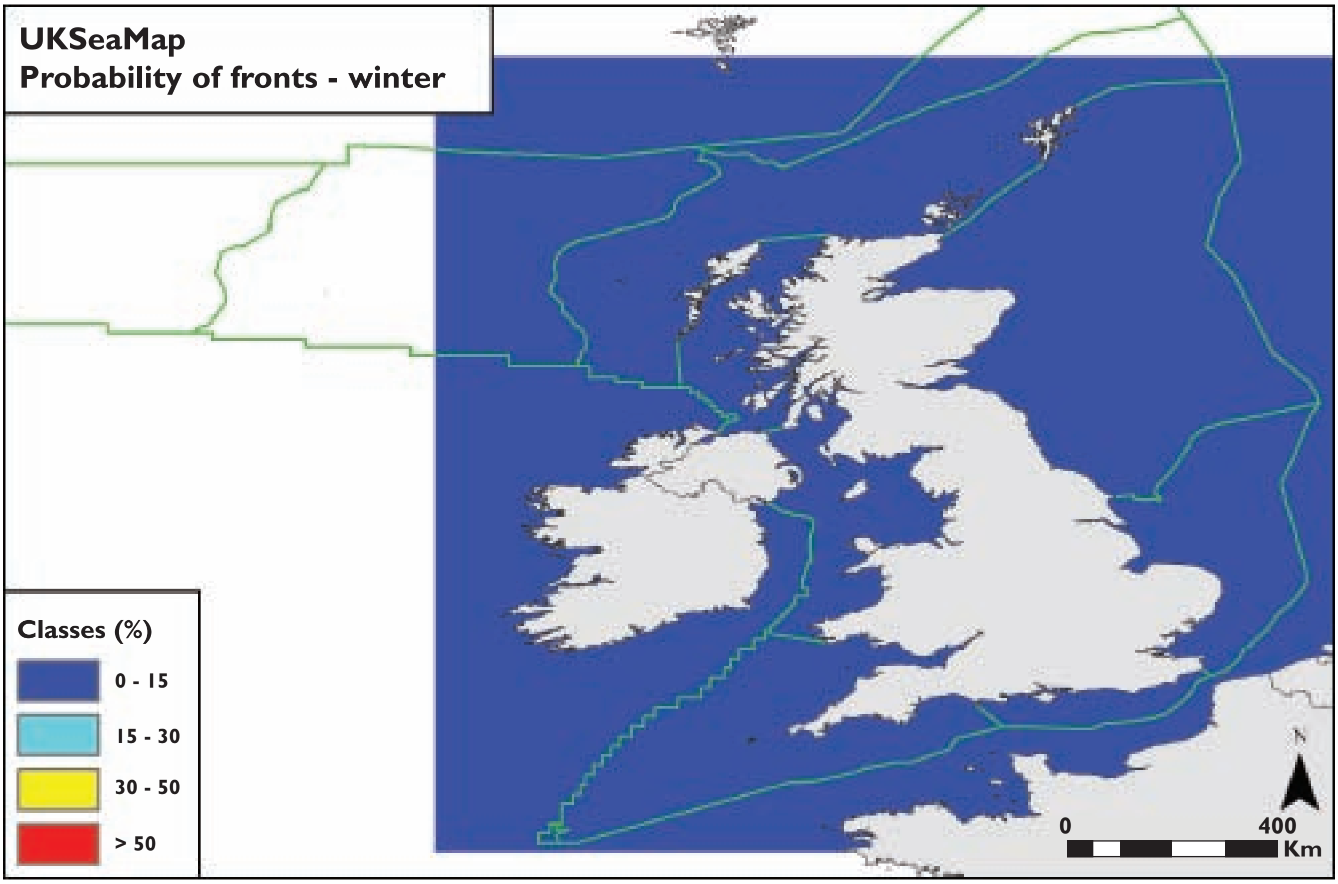

Figure 31. Winter front probability (source data from POL).

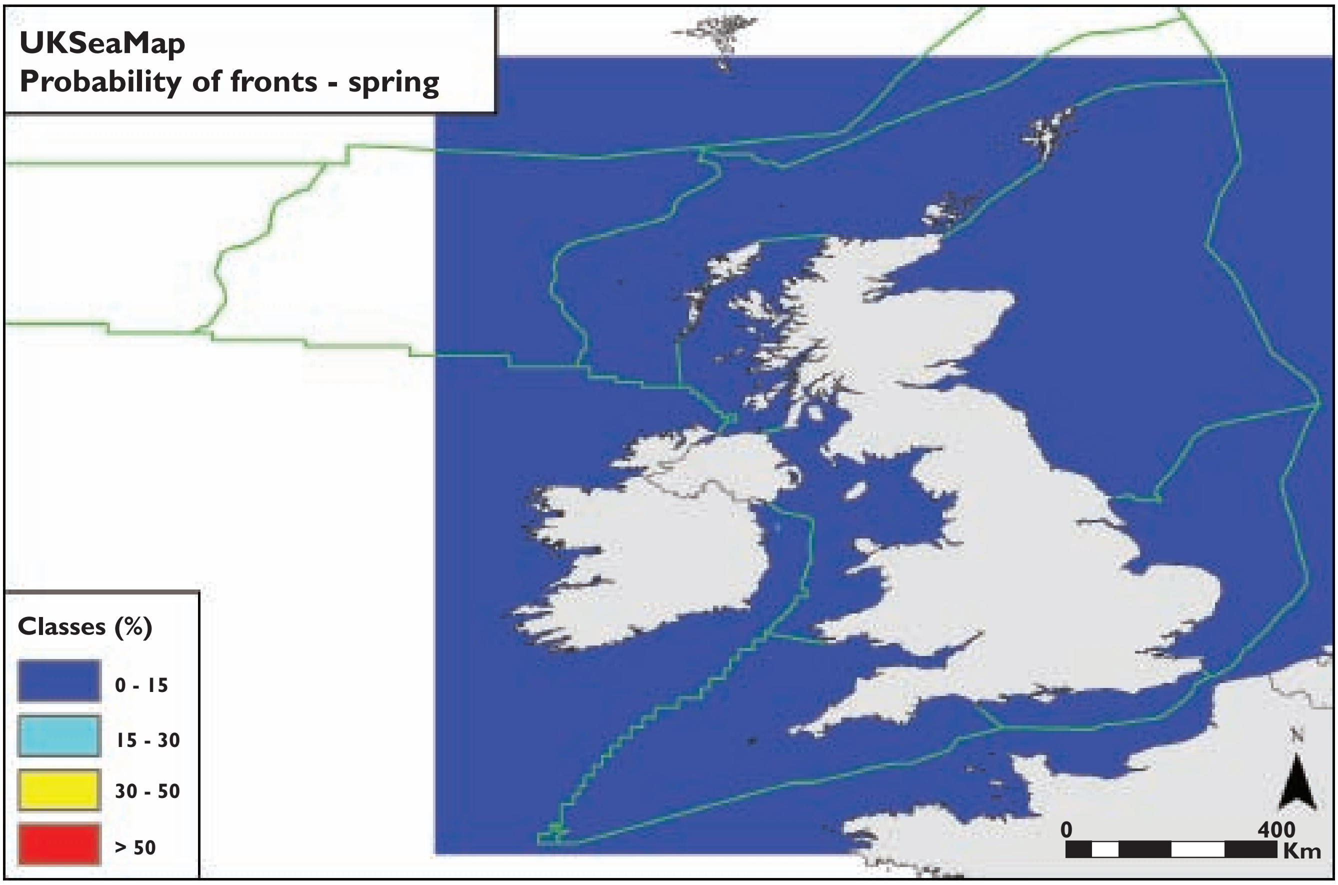

Figure 32. Spring front probability (source data from POL).

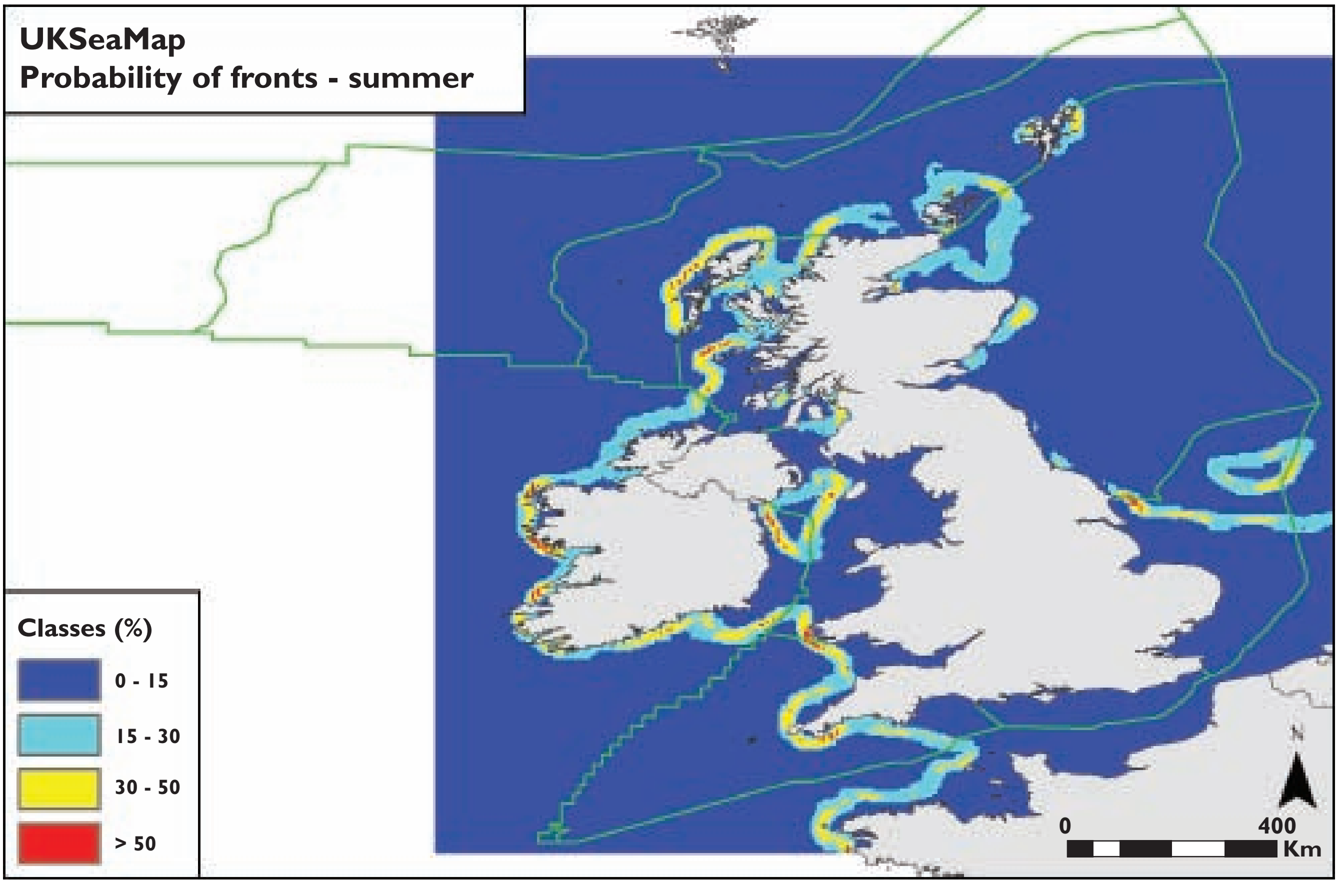

Figure 33. Summer front probability (source data from POL).

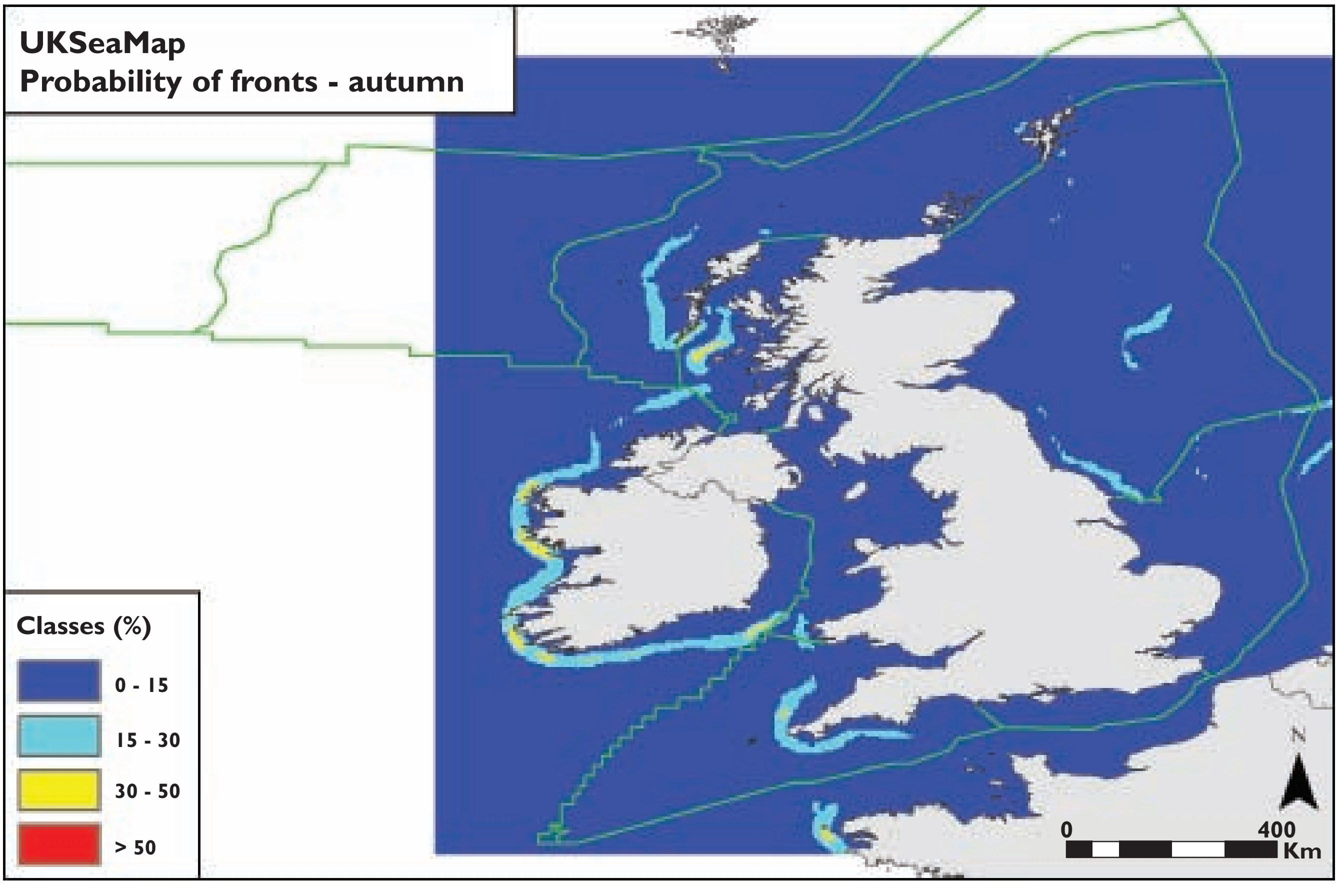

Figure 34. Autumn front probability (source data from POL).

5.3 Water column analysis

Using a similar methodology to that implemented for the seabed modelling (Section 4.3), a classification tree was developed, as shown in Table 9, to enable a supervised classification of the water column data sets to be undertaken. The analysis used data sets on salinity, surface to bed temperature difference and the probability of fronts.

Surface to bed temperature difference was used to distinguish between well mixed, frontal and temperature stratified areas. Areas identified as frontal from the surface to bed temperature difference data were then subdivided using the front probability data.

Four maps were produced (winter, spring, summer, autumn) to illustrate the seasonal variability in the pelagic environment (Figures 35-38).

Table 9. Water column features analysis

Salinity (‰)	Surface to seabed temperature difference (°C)	Fronts (% probability)	Water column type
Estuarine (<=30)			Estuarine water
ROFI (>30 and <=34)	Well-mixed (<=0.5)		Well-mixed ROFI
	Frontal (>0.5 and <=2.0)	No Front (<15%)	Weakly-stratified ROFI
		Front (>15%)	Frontal ROFI
	Stratified (>2.0)		Stratified ROFI
Shelf (>34 and <=35)	Well-mixed (<=0.5)	0	Well-mixed shelf water
	Frontal (>0.5 and <=2.0)	No Front (<15%)	Weakly-stratified shelf water
		Front (>15%)	Frontal shelf water
	Stratified (>2.0)		Stratified shelf water
Oceanic (>35)	Well-mixed (<=0.5)	0	Well-mixed oceanic water
	Frontal (>0.5 and <=2.0)	No Front (<15%)	Weakly-stratified oceanic water
		Front (>15%)	Frontal oceanic water
	Stratified (>2.0)		Stratified oceanic water

5.4 Water column classification and maps

The classification of water column features, resulting from the supervised analysis, is presented in Table 10 and illustrated, by season, in Figures 35-38.

Table 10. Classification of water column features and their main characteristics

Water column type	Salinity (‰)	Surface to seabed temperature difference (°C)	Fronts (% probability)
Estuarine water	Estuarine (<=30)		
Well-mixed ROFI	ROFI (>30 and <=34)	Well-mixed (<=0.5)	
Weakly-stratified ROFI	ROFI (>30 and <=34)	Frontal (>0.5 and <=2.0)	No Front (<=0.15)
Frontal ROFI	ROFI (>30 and <=34)	Frontal (>0.5 and <=2.0)	Front (>0.15)
Stratified ROFI	ROFI (>30 and <=34)	Stratified (>2.0)	
Well-mixed shelf water	Shelf (>34 and <=35)	Well-mixed (<=0.5)	0

Water column type	Salinity (‰)	Surface to seabed temperature difference (°C)	Fronts (% probability)
Weakly-stratified shelf water	Shelf (>34 and <=35)	Frontal (>0.5 and <=2.0)	No Front (<=0.15)
Frontal shelf water	Shelf (>34 and <=35)	Frontal (>0.5 and <=2.0)	Front (>0.15)
Stratified shelf water	Shelf (>34 and <=35)	Stratified (>2.0)	
Well-mixed oceanic water	Oceanic (>35)	Well mixed (<=0.5)	0
Weakly-stratified oceanic water	Oceanic (>35)	Frontal (>0.5 and <=2.0)	No Front (<=0.15)
Frontal oceanic water	Oceanic (>35)	Frontal (>0.5 and <=2.0)	Front (>0.15)
Stratified oceanic water	Oceanic (>35)	Stratified (>2.0)	

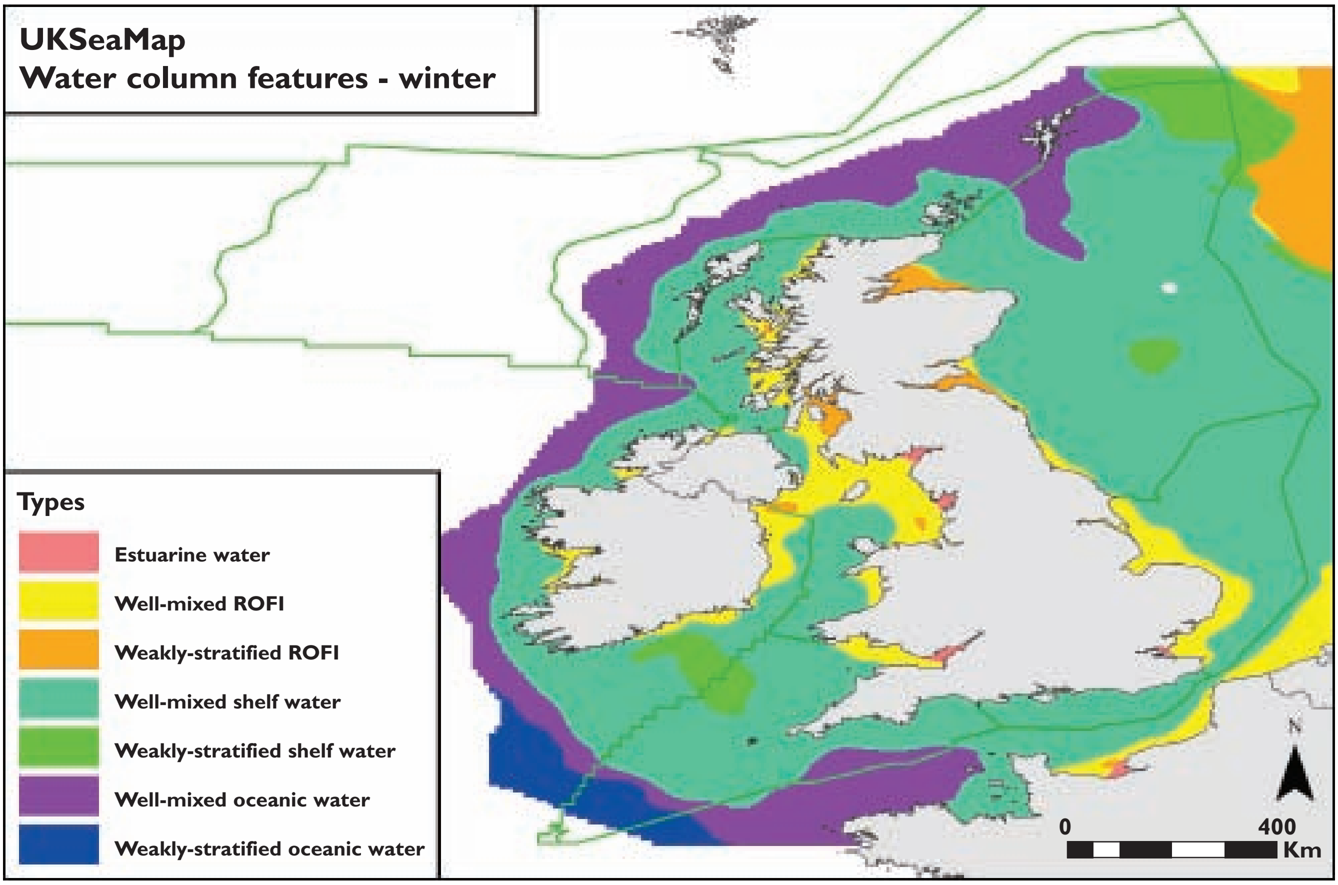

Figure 35. Winter water column features.

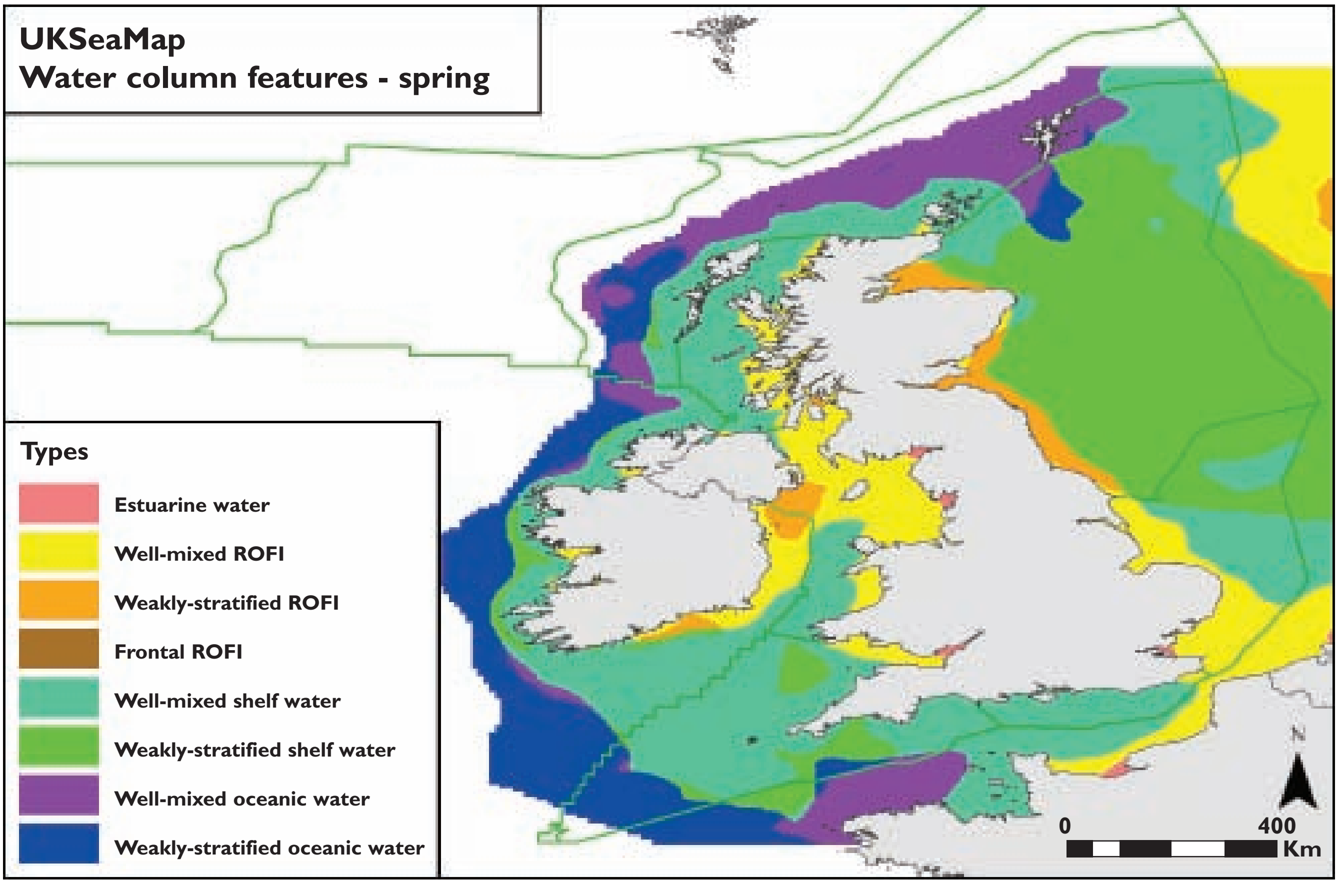

Figure 36. Spring water column features.

5.5 Biological validation

5.5.1 Data used

The water column maps were compared with plankton distribution data prepared by SAHFOS (Sir Alister Hardy Foundation for Ocean Science). These data showed the annual mean distribution of the following plankton taxa in the north-east Atlantic: the copepods *Calanus finmarchicus, Calanus helgolandicus* and *Metridia lucens*, decapod larvae and total dinoflagellate abundance. The data for these five plankton indicators were supplied as log transformed abundance per sample (per $3m^3$). Phytoplankton colour as an index of total phytoplankton biomass was also provided. Further information on the origin and development of these data sets, and their use in helping to classify and delineate water column features can be found in Edwards and Johns (2005). In contrast to the biological validation of the seabed landscapes, where it was possible to define the expected biological character of each type (in terms of its expected habitat composition), this was not possible for the water column as a detailed habitat classification for the water column is not available for UK waters.

5.5.2 Data analysis

The plankton distribution data were interfaced with the seasonal water column maps in a GIS using Spatial Analyst to determine a mean abundance of each plankton indicator for each water column type on a season by season basis.

5.5.3 Results – validity and characterisation of water column types

The results from the water column biological validation are shown in Tables 11-15. The grey shaded rows indicate the water column features which were not indicated in the analysis as being present during that particular season. In the 'relative contribution' tables, the figures given show the highest mean annual abundance as 100, with the remaining figures represented as a proportion of that highest figure (e.g. for Spring data, *Calanus finmarchicus* has its highest abundance as 0.458 per $3m^3$ for *Well-mixed oceanic waters*. The value of 0.254 per $3m^3$ for *Weakly-stratified oceanic waters* represents 55% of this maximum value. The relative contribution figures enable easier comparison of relationship of each taxon to one or more water column types.

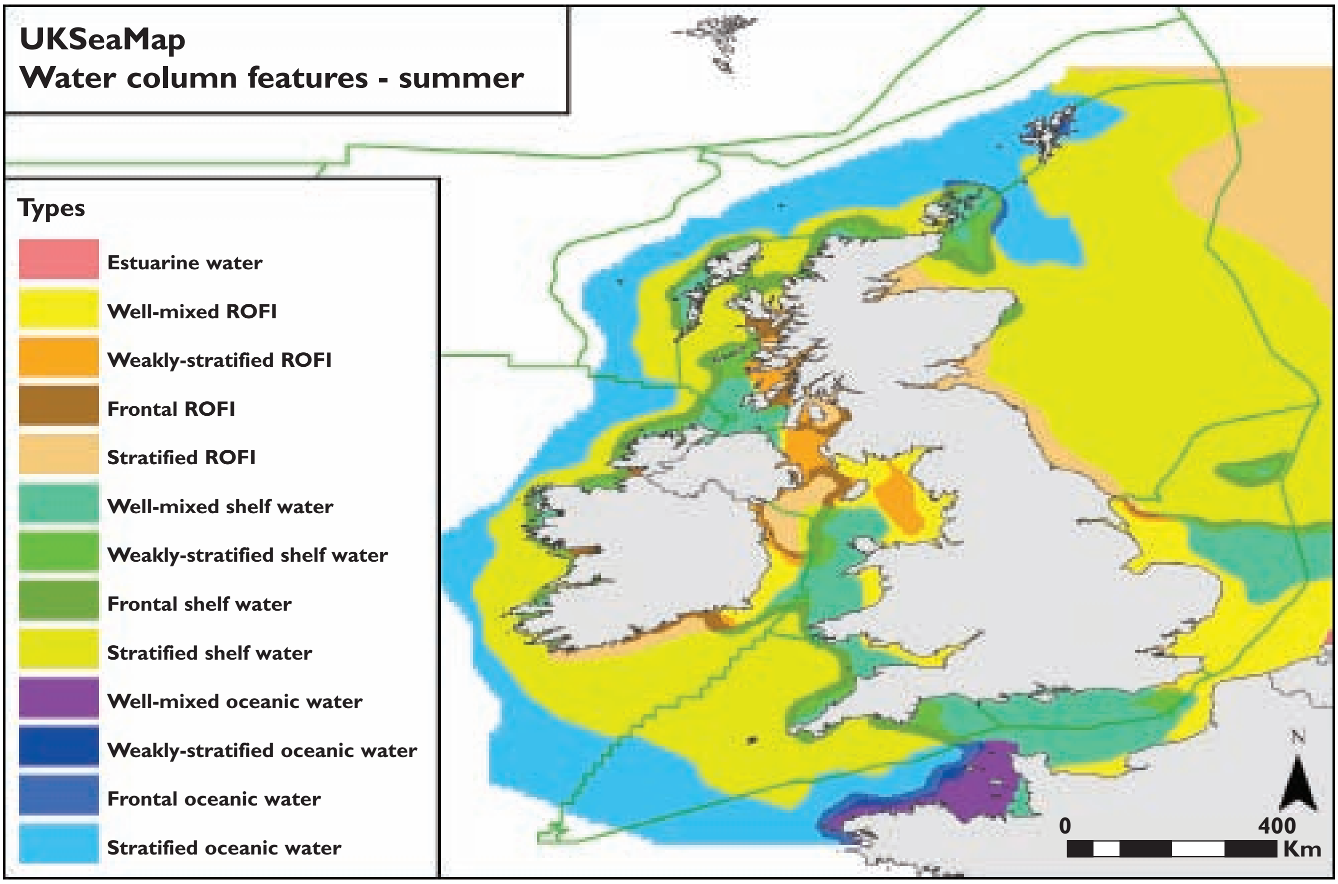

Figure 37. Summer water column features.

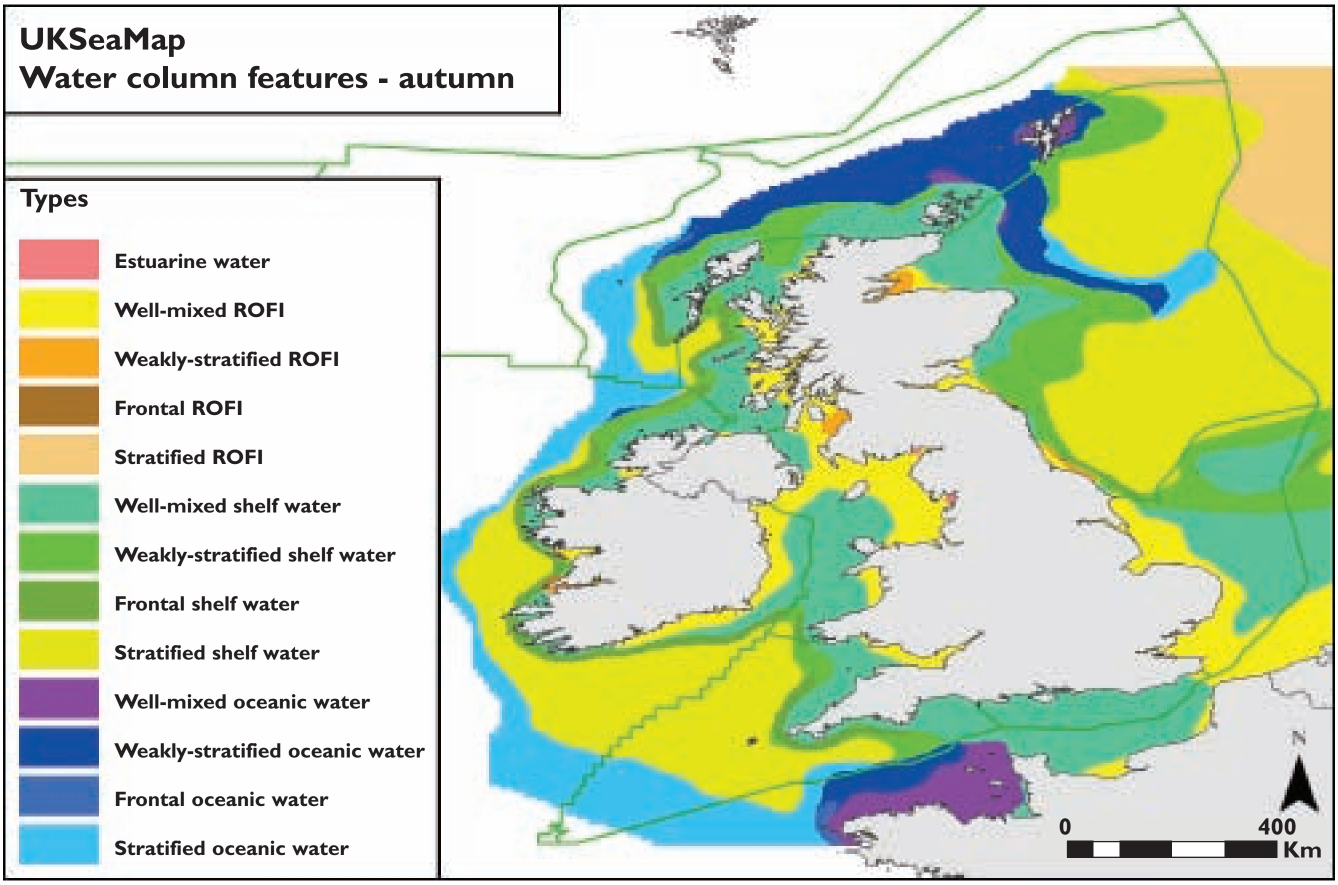

Figure 38. Autumn water column features.

Table 11. Water column features for Spring showing mean annual abundance (per 3m³) of the six plankton indicators and their relative contribution across the features for each indicator.

Mean annual abundance:

Water column feature	*Calanus finmarchicus*	*Calanus helgolandicus*	Decapod larvae	*Metridia lucens*	Total dinoflagellate	Phytoplankton colour index
Frontal ROFI						
Stratified ROFI						
Weakly stratified ROFI	0.194	0.307	0.246	0.093	1.570	0.911
Well mixed ROFI	0.118	0.297	0.320	0.070	1.558	1.060
Shelf frontal water						
Shelf stratified water						
Weakly stratified shelf water	0.401	0.302	0.182	0.100	1.856	1.030
Well-mixed shelf water	0.266	0.423	0.261	0.147	1.669	0.978
Oceanic stratified water						
Weakly stratified oceanic water	0.254	0.466	0.161	0.229	1.642	0.867
Well-mixed oceanic water	0.458	0.283	0.146	0.182	1.646	0.980

Relative contribution across water column features for each taxon:

Water column feature	*Calanus finmarchicus*	*Calanus helgolandicus*	Decapod larvae	*Metridia lucens*	Total dinoflagellate	Phytoplankton colour index
Frontal ROFI						
Stratified ROFI						
Weakly stratified ROFI	42	66	77	41	85	86
Well mixed ROFI	26	64	100	31	84	100
Shelf frontal water						
Shelf stratified water						
Weakly stratified shelf water	88	65	57	44	100	97
Well-mixed shelf water	58	91	82	64	90	92
Oceanic stratified water						
Weakly stratified oceanic water	55	100	50	100	88	82
Well-mixed oceanic water	100	61	46	79	89	92

Table 12. Water column features for Summer showing mean annual abundance (per 3m³) of the six plankton indicators and their relative contribution across the features for each indicator.

Mean annual abundance:

Water column feature	*Calanus finmarchicus*	*Calanus helgolandicus*	Decapod larvae	*Metridia lucens*	Total dinoflagellate	Phytoplankton colour index
Frontal ROFI	0.223	0.334	0.254	0.132	1.510	0.862
Stratified ROFI	0.440	0.258	0.164	0.121	1.705	0.821
Weakly stratified ROFI	0.187	0.262	0.306	0.089	1.525	0.960
Well mixed ROFI	0.081	0.287	0.339	0.052	1.587	1.171
Shelf frontal water	0.200	0.418	0.310	0.113	1.701	1.091
Shelf stratified water	0.380	0.362	0.188	0.134	1.794	0.980
Weakly stratified shelf water	0.213	0.295	0.360	0.061	1.861	1.403
Well-mixed shelf water	0.111	0.353	0.375	0.069	1.568	1.078
Oceanic stratified water	0.372	0.358	0.147	0.199	1.634	0.903
Weakly stratified oceanic water						
Well-mixed oceanic water						

Relative contribution across water column features for each taxon:

Water column feature	*Calanus finmarchicus*	*Calanus helgolandicus*	Decapod larvae	*Metridia lucens*	Total dinoflagellate	Phytoplankton colour index
Frontal ROFI	51	80	68	67	81	61
Stratified ROFI	100	62	44	61	92	59
Weakly stratified ROFI	43	63	82	45	82	68
Well mixed ROFI	18	69	90	26	85	83
Shelf frontal water	45	100	83	57	91	78
Shelf stratified water	86	87	50	68	96	70
Weakly stratified shelf water	48	71	96	30	100	100
Well-mixed shelf water	25	84	100	35	84	77
Oceanic stratified water	84	86	39	100	88	64
Weakly stratified oceanic water						
Well-mixed oceanic water						

Table 13. Water column features for Autumn showing mean annual abundance (per 3m³) of the six plankton indicators and their relative contribution across the features for each indicator.

Mean annual abundance:

Water column feature	*Calanus finmarchicus*	*Calanus helgolandicus*	Decapod larvae	*Metridia lucens*	Total dinoflagellate	Phytoplankton colour index
Frontal ROFI						
Stratified ROFI	0.702	0.223	0.084	0.201	1.807	0.769
Weakly stratified ROFI						
Well-mixed ROFI	0.122	0.293	0.320	0.072	1.547	1.033
Shelf frontal water	0.143	0.514	0.317	0.118	1.693	0.987
Shelf stratified water	0.397	0.394	0.173	0.145	1.792	0.922
Weakly stratified shelf water	0.360	0.274	0.203	0.111	1.807	1.094
Well-mixed shelf water	0.176	0.349	0.323	0.089	1.643	1.110
Oceanic stratified water	0.295	0.452	0.156	0.215	1.670	0.852
Weakly stratified oceanic water	0.473	0.261	0.139	0.174	1.650	0.973
Well-mixed oceanic water	0.463	0.300	0.159	0.159	1.594	1.005

Relative contribution across water column features for each taxon:

Water column feature	*Calanus finmarchicus*	*Calanus helgolandicus*	Decapod larvae	*Metridia lucens*	Total dinoflagellate	Phytoplankton colour index
Frontal ROFI						
Stratified ROFI	100	43	26	93	100	69
Weakly stratified ROFI						
Well-mixed ROFI	17	57	99	33	86	93
Shelf frontal water	20	100	98	55	94	89
Shelf stratified water	57	77	54	68	99	83
Weakly stratified shelf water	51	53	63	51	100	99
Well-mixed shelf water	25	68	100	41	91	100
Oceanic stratified water	42	88	48	100	92	77
Weakly stratified oceanic water	67	51	43	81	91	88
Well-mixed oceanic water	66	58	49	74	88	91

Table 14. Water column features for Winter showing mean annual abundance (per 3m³) of the six plankton indicators and their relative contribution across the features for each indicator.

Mean annual abundance:

Water column feature	*Calanus finmarchicus*	*Calanus helgolandicus*	Decapod larvae	*Metridia lucens*	Total dinoflagellate	Phytoplankton colour index
Frontal ROFI						
Stratified ROFI						
Weakly stratified ROFI						
Well-mixed ROFI	0.127	0.300	0.311	0.076	1.540	0.962
Shelf frontal water						
Shelf stratified water						
Weakly stratified shelf water	0.575	0.302	0.107	0.175	1.797	0.805
Well-mixed shelf water	0.309	0.360	0.230	0.120	1.742	1.022
Oceanic stratified water						
Weakly stratified oceanic water	0.095	0.603	0.165	0.235	1.523	0.682
Well-mixed oceanic water	0.427	0.309	0.161	0.187	1.680	0.992

Relative contribution across water column features for each taxon:

Water column feature	*Calanus finmarchicus*	*Calanus helgolandicus*	Decapod larvae	*Metridia lucens*	Total dinoflagellate	Phytoplankton colour index
Frontal ROFI						
Stratified ROFI						
Weakly stratified ROFI						
Well-mixed ROFI	22	50	100	32	86	94
Shelf frontal water						
Shelf stratified water						
Weakly stratified shelf water	100	50	34	75	100	79
Well-mixed shelf water	54	60	74	51	97	100
Oceanic stratified water						
Weakly stratified oceanic water	17	100	53	100	85	67
Well-mixed oceanic water	74	51	52	80	94	97

The copepod *Metridia lucens* appears to correlate well with the oceanic water column features; although it occurred in all water column features, it was recorded at highest abundance in the oceanic water column features such as *Weakly stratified oceanic water* (its relative contribution value to oceanic features was >70, whilst for shelf and ROFI features it was nearly always <70). This concurs with the use of *M. lucens* as a salinity indicator, indicating areas of high salinity.

The copepod *Calanus finmarchicus* is predominantly a boreal (cold-water) species whereas the copepod *Calanus helgolandicus* is predominantly a temperate (warm-water) species. These two plankton taxa were used to examine the distribution of bio-geographical boundaries and whether they coincided with water column feature boundaries. While *C. finmarchicus* generally occurred at higher abundances in stratified water column features, there were no clear patterns evident linking these two taxa with particular water column types. This may be due to the fact that a direct measurement of sea temperature was not used in UKSeaMap to develop the water column features.

A difference between summer stratified waters and tidally mixed waters was observed in the densities of decapod larvae, which were used as an indicator to represent the meroplanktonic fauna. This correlation was reflected in certain water column features across all seasons, where decapod larvae were recorded in their highest abundances in *Well mixed shelf water* but particularly in the *Well mixed ROFI* type.

Phytoplankton colour index (PCI) was consistently highest in well-mixed water column features, likely due to the increased availability of nutrients which tend to be limiting under stratified conditions.

The *total dinoflagellate* group occurred at the highest abundance of all six plankton indicators used across all four seasonal water column maps. The *Well mixed ROFI* in particular consistently contained the highest abundance of *total dinoflagellate* compared to all other water column types. Again, this may be due to the increased availability of nutrients in a well mixed water column.

In order to assess further the validity of the water column features using plankton data, it would be necessary to use plankton data split according to the same seasonal categories as used in the water column feature maps. The use of annual mean biological data appears to have reduced the ability to discriminate and validate trends occurring within each seasonal water column map. Nevertheless, certain plankton taxa, such as *Metridia lucens,* displayed trends in distributional abundance which was observed within the water column feature maps. Validation of the water column features on a cell by cell basis, rather than at a water column feature scale, could also be of merit. This may highlight more subtle trends across the water column features which were lost during the amalgamation process.

6 Web-based dissemination of the maps

A web-based GIS mapping facility has been developed to disseminate the underlying data sets and the resultant maps. The application was developed as part of the MESH programme (**www.searchMESH.net**), but the UKSeaMap results are made available as a separate output, via the JNCC web site at **www.jncc.gov.uk/UKSeaMap**.

7 Relationships to other 'habitat' schemes and data sources

In using the outputs of UKSeaMap, and when considering them in more technical discussions, readers should be aware of the relationship to other ways of classifying the marine environment. There are differences between these, such as the way in which the same feature might be classified or the scale at which classifications operate. Such differences do not necessarily mean any one classification is preferred over another, but rather they reflect the different purpose behind each classification. It is thus important to be aware of these differences when trying to interpret them individually and collectively. The following sections outline key differences between UKSeaMap and a number of other classifications that are currently of importance to marine management and protection.

7.1 Relationship to Habitats Directive Annex I types

The relationship between Annex I habitats and the marine landscape types is given in Table 15.

Table 15. Relationship between Annex I habitat types and marine landscape types.

Annex I habitat type	Equivalence	Marine landscape type
Sandbanks which are slightly covered by sea water all the time	Includes some of	Subtidal sediment banks
Estuaries	Equals	Estuary
Mudflats and sandflats not covered by seawater at low tide	Included within	Shallow sand plains, or Shallow mud plains
Lagoons	Equals	Lagoons
Large shallow inlets and bays	Includes some of	The following, where the specific site meets the EC definition: Rias Sealochs Embayments Bays
Reefs	Includes some of	Photic rocks, and Aphotic rocks
Submerged or partially submerged sea caves	Occur within	Photic rocks, and Aphotic rocks

Where possible the landscape types have been directly linked with Annex I features; the landscape maps therefore provide an initial overview of Annex I distribution in the UK. However, as the Annex I habitats are specifically defined in EC guidance (European Commission 1999), and are subject to modification, the landscape maps should not be taken to encompass all areas that might qualify as Annex I habitat. For instance, the areas of *Reef* habitat are significantly under represented in the maps (due to the lack of coastal rock in the substratum data set). Conversely only a portion of the sealochs, embayments and bays in the landscape map will meet the EC definition (which is interpreted in the UK to have a particular depth limit).

7.2 Relationship to OSPAR habitats

Most of the habitats on the OSPAR List are at a finer level of detail than marine landscape types and are better equated to habitats within the EUNIS classification (see correlation table at **www.jncc.gov.uk/page-3365**). However, the OSPAR habitat *Seamounts* equates to the marine landscape type *Deep ocean rise* and *Carbonate mounds* are also a marine landscape type.

7.3 Relationship to EUNIS habitat classification

The relationship to the habitat classification scheme of EUNIS is given in Annex 7. Broadly, the modelled seabed and water column types can be directly related to one or more EUNIS broad habitat types. The seabed types, defined by sediment type and depth, are most readily equated to particular EUNIS types. However, as these features may occur within some of the topographically-defined marine landscape types, there may not always be a simple 1:1 relationship to EUNIS.

7.4 Access to more detailed habitat and species data

The UKSeaMap project is intended to provide only a broadscale suite of seabed and water column types for UK seas; more detailed maps on marine habitats can be found at **www.searchMESH.net**. These data are primarily presented as polygon data, but point sample biological data referenced to the national habitat classification are also presented. The National Biodiversity Network Gateway (**www.searchNBN.net**) holds a similar set of point sample biological data, with facilities to search and map at the species level.

8 Limitations and lessons learned

Some overall limitations of the maps developed within the project are outlined in Section 2.6. These and further considerations are outlined below:

- The relative coarseness of the grid used, particularly for the areas beyond the Continental Slope, means that the maps are not suitable for fine-scale management and advisory uses. The associated MESH project is collating fine-scale data, where this is available, and is thus better suited to fine-scale management issues.
- Some areas have no data or insufficient data and remain unmapped.
- In view of the need to use relatively coarse DEMs which provide full UK coverage, it has not been possible to identify more fine-scale topographic and bed-form features which are known or likely to be present throughout the area. The resultant map of topographic features (Figure 4) should therefore be considered to represent only the most prominent features.
- In some coastal areas there is considerable under representation of rock in the seabed substratum data set, which has had a significant effect on the biological validation and confidence assessment in the coastal zone (see Section 4.8).
- Section 4.6.6 highlights further aspects resulting from the biological validation process that have indicated areas of uncertainty in either the seabed landscape map or in the biological validation data.
- There is generally a paucity of biological validation data for offshore and deep-water habitats which has led to insufficient data to validate the landscape types for these regions. Additionally limitations in the modelling data for these regions, particularly for deep-water, and the lack of a detailed deep-water habitat classification, yield a lower level of confidence in the maps for these areas.

Despite having gained the practical experience of developing a marine landscape map for the Irish Sea Pilot, undertaking the UKSeaMap project has provided a number of additional challenges which were not anticipated at the start of the project. The highlighting of these issues may provide guidance to others wishing to embark on a similar modelling process, as well as to those with a strategic interest in such issues, such as government:

- The scale of the area to be mapped and its variation in character from small coastal features, such as lagoons, through to the extensive deep-water zones beyond the continental shelf, requires significant additional effort to coordinate the data required at this scale. With multiple options for data storage, manipulation and processing, the final data and methodology used were the result of a significant number of trials, each of which had to be evaluated within the context of the available data, technical expertise and time.
- Acquisition of suitable data sets which covered the entirety (or majority) of the UK waters. The data sets for physical and hydrographic parameters often had limitations in terms of geographical coverage, resolution or format, and the final data sets used were sometimes a compromise of these aspects (for instance, the best data may not have had sufficiently wide geographical coverage).
- Where suitable data were available, they often required considerable additional processing to get them into a suitable GIS format and to define categories which related directly to ecological character.
- Whilst the physical and hydrographic data sets used were mostly sourced from single organisations able to provide a UK-wide data set, access to biological seabed sample data was via a wide range of organisations. As was encountered with the Irish Sea Pilot, acquiring such data proved very time consuming as many organisations do not yet have the data fully archived to facilitate its rapid provision.
- Overall, the project has raised considerable interest amongst stakeholders who wish to use the final maps and the web-GIS. Stakeholder expectations have sometimes needed to be managed in relation to the level of detail achievable, or the amount of data that could be acquired for certain parts of the project. This has necessarily led to lowering their expectations as to how much the project could achieve in the time available or its suitability for their intended use.

9 Future development of UKSeaMap

The maps resulting from the UKSeaMap project have started to be used by others who have developed some aspects of the uses identified in Section 2.5. For example, a Defra-funded project by the University of Wales at Bangor has undertaken a preliminary scoping study to identify a network of marine protected areas that represent the range of marine landscapes defined by UKSeaMap (Richardson *et al*. 2006). Ongoing work at CEFAS is examining the relationship between the marine landscape types and the distribution of human activities, such as fishing (see Eastwood *et al*. in prep.).

The work undertaken to produce the seabed and water column maps and to validate them with biological data has led to maps with varying levels of quality or confidence, as might be expected from a methodology using data over this scale and complexity. To ensure the maps remain useful into the future there is a need to work towards improving and maintaining their overall quality (confidence). This work can be achieved under a number of themes:

- Quality and completeness of the underlying data sets
  - Incorporation of data on substratum type from the ground-truth data – this is particularly important for rock habitats close to the coast.
  - Use of higher resolution substratum data, where available, such as the coastal characterisation data being produced by BGS.
  - Addition of finer-scale data where available, such as for rocky mounds and outcrops from SEA surveys, additional pockmark and carbonate features in the Irish Sea, diapers in the Faroe-Shetland Channel, moraines, drowned cliff lines and peat beds.
  - Improvement in the modelled data set for near-bed stress to take account of known areas of strong tidal currents, particularly around Scotland.
  - Development of a Data Management Plan – to improve documentation of each data set used, and track updates as they become available.
- Modifications to the models
  - Consideration of using temperature for the water column model, further differentiation of bottom temperature (e.g. below 0°C in Faroe-Shetland Channel), and consideration of the importance of annual variation of bottom temperatures.
  - Consideration of modelling the water column in 3D to reflect known differences in water mass with depth (e.g. because of temperature).
  - Validation of the water column features on a cell by cell basis, rather than at a water column feature scale, may highlight subtle trends across the water column features which are lost in the present analysis.
  - Consideration of the use of internal wave data which is known to have a significant influence on ecological character of the seabed in some areas (e.g. slope west of Shetland).
  - Assessment of whether oxygenation (anoxia, hypoxia) and nutrient loading (oligotrophic, eutrophic) should be added to the seabed model (both parameters are important in determining ecological character at various scales).
- Quality and completeness of the biological validation data
  - The seabed biological validation for offshore areas needs further analysis to confirm the habitat types identified using the Habitat Matching Program, as the habitat standards are limited in this area; additionally more detailed assessment of the mis-matches between seabed substrata and biological validation data for the modelled landscape types are needed, as well as further assessment of the validity of the bed-stress sub-types. This work should help improve the validation for the relevant landscape types.
  - There remain significant offshore areas for which validation has not been possible. Of particular note is the use of SEA data for deep water, which needs classification (into habitat types) before assessment against the landscape map.
  - Use of plankton data at the seasonal level rather than annual averages, to better coincide with the seasonal water column maps.
- Refinement of the landscape classification, through more detailed analysis
  - Some coastal physiographic types, in particular sealochs, estuaries and lagoons, are quite broad in character, and a more in-depth analysis would lead to a more refined classification of these features. Whilst there are existing classifications available, these are mostly based on their physical characteristics; an analysis of their ecological character is required to produce more ecologically relevant classifications of these features.
- Maintenance of the webGIS facility
  - The UKSeaMap webGIS data sets will be uploaded to the MESH web site, but both projects will run for a limited period and consideration needs to be given as to how both the MESH and UKSeaMap data sets can be maintained, and where possible added to and improved, beyond the end of the two projects.
  - Development of a 3D 'fly through' bathymetric model for UK waters over which the landscape types are draped, to provide a much more powerful visual display of the maps for end-users.

- Integration of the UKSeaMap broadscale maps with finer scale habitat maps
  - UKSeaMap provides a broadscale modelled characterisation of the UK seas based on a series of thematic data sets, often at relatively course resolution. Ultimately, it should be the intention to improve the quality of the maps with improved data; this can be achieved through integration of more high resolution data as it becomes available. For instance, using high quality multibeam acoustic data and other more detailed habitat maps to update the present landscape maps (i.e. replace the broader scale modelled landscape types with real data) so that confidence in the map can be further improved. Consideration needs to be given here to both the classification system used (landscapes versus habitats) and the scale at which the maps are presented (aggregation of finer scale data).
- Assessment of the relationship between water column and seabed types
  - Assessment of the relationship between the seabed types and the water column types would be valuable as the character of seabed communities relies heavily on the influences of the water column, both in relation to its hydrographic properties (salinity, temperature, water quality), and its plankton (many benthic species have planktonic larval stages). Additionally, pelagic and demersal fish species might be expected to show a relationship to seabed types, which could be useful both in fisheries management and environmental protection.
- Development of a strategy and process for incorporating new data
  - Further new information will become available over time and a process is needed to enable it to be incorporated so that the underlying data sets and resultant landscape maps can be periodically updated.
- Re-evaluation of the regional seas boundaries
  - The collation of information on a series of physical and hydrographic data layers provides the relevant information to assess the appropriateness of the current (draft) regional seas boundaries and to recommend modifications if appropriate.

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