DEFINING TRANSITIONAL AND COASTAL WATER TYPOLOGIES FOR THE EU WATER FRAMEWORK DIRECTIVE USING GIS AND MULTIVARIATE STATISTICS

by C. M. Mills [1], S. I. Rogers [1], B. O'Connor [2], P. Balson [3], M. Elliott [4], D. Connor [5]

CEFAS
The Centre for Environment, Fisheries & Aquaculture Science

Introduction

The Water Framework Directive (WFD) requires Member States to differentiate transitional waters (TWs) and coastal waters (CWs) according to type. Differentiation must use a predefined set of physical descriptors and must ensure that biological comparisons can be made between similar physical types of water bodies. Typology is one of the first stages in the implementation of the Directive. Draft typologies for England, Wales, Scotland and Ireland were prepared for SNIFFER by a consortium of marine research organisations. The typologies were derived by (i) populating vector grid cells (ii) summarising the data to generate proportional scores, and (iii) utilising multivariate analysis to generate groups with similar physical characteristics. The final set of typologies provides a basis upon which reference conditions required by the WFD can be applied.

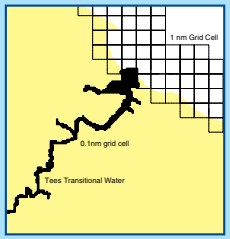

Figure 1: Example of the gridding system used to populate transitional and coastal waters around the UK and Ireland

Grid Creation

Querying Cells

Over half a million cells were created to cover; 180 transitional waters with 0.1nm square cells and the entire coastline of the UK and Ireland within the 3nm baseline with 1nm square cells (Figure 1). Using GIS, the correct number of cells within the transitional and coastal water polygons were selected by following a series of predefined spatial rules.

Projection

The more familiar British National Grid (BNG) and Irish National Grid (ING) were used to project the grid cells as opposed to an equal area projection. This produced minimal latitudinal area deviation errors (0.00002%).

Coastlines

Due to availability and cost, it was necessary to use a number of coastlines. The Ordnance Survey coastline of the British Isles (UK), UKHO vector charts (Ireland), and the US Defence Mapping Agency World Vector Shoreline. The World Vector Shoreline uses Mean High Water (MHW) as it's vertical datum while the UKHO vector bathymetry uses chart datum.

Population of Cells

Each cell of the coastal and transitional waters was populated with information from 9 factors (Table 1). All factors had a range of categories and any one cell could only be allocated to a single category. For each factor, '1' identified the category membership of each cell in the corresponding cell of the GIS.

Table 1. Physical factors and categories used for populating cells in TWs and CWs (Inter-tidal Area was used only for TW's)

Factor	Category					
Salinity	Freshwater	Oligohaline	Mesohaline	Polyhaline	Euhaline	
Mean Tidal Range	Micro-tidal	Meso-tidal	Macro-tidal			
Substratum	Mosaic	Hard	Sand	Gravel	Mud	Mixed
Depth	0-10 m	10-30 m	> 30 m			
Inter-tidal Area	< 50%	> 50%				
Exposure	Exposed	Moderate	Sheltered			
Mixing	Fully mixed	Partly mixed	Stratified			
Residence Time	Days	Weeks	Months			
Current Velocity	Weak	Moderate	Strong			

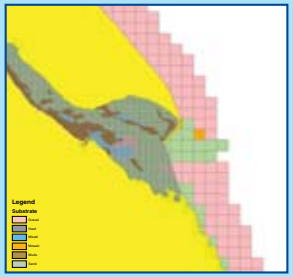

Figure 2a: The geographical distribution of substrate at the mouth of the Humber Estuary based on 1nm (CW) and 0.1nm (TW) grid cells

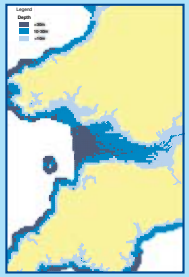

Figure 2b: The geographical distribution of depth based on 1nm populated grid cells in the Bristol Channel region

Analysis

Transitional Waters

The physical data matrix for each of the Transitional waters (often containing many thousands of cells) was reduced to a single row describing the proportions of each category of a factor in an entire TW (Table 2). This was repeated for all 9 factors and all 180 TWs. These fuzzy scores were subjected to Cluster Analysis supported by Fuzzy Multiple Correspondence Analysis to show which groups of TWs had similar proportions of physical factors and so could be grouped together.

Coastal Waters

To ensure that coastal typologies were regionally coherent, and that the entire CW dataset (30,000 by 30,000 cell matrix) could be included in the analysis, all the 1nm cell data were combined into larger 10 by 10nm cells. One disadvantage of combining cells into larger spatial units was that bigger cells tended to be less than 100% full (Figure 3a). These data were analysed using the same statistical techniques as for TWs.

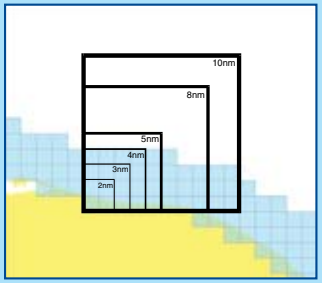

Figure 3a: The use of different cell sizes to aggregate the 1nm populated cells

Table 2: Section of table describing the proportional scores for each transitional water

Estuary	Region	Freshwater	Oligohaline	SALINITY Mesohaline	Polyhaline	Euhaline
Adur	ESW	0.02	0.43	0.18	0.25	0.13
Aeron	ESW	0.00	0.29	0.14	0.43	0.14
Afan	ESW	0.05	0.08	0.05	0.08	0.74
Alaw	ESW	0.00	0.00	0.19	0.47	0.35
Alde & Ore	ESW	0.00	0.00	0.35	0.65	0.00
Allonby	ESW	0.00	0.00	0.00	0.00	1.00
Aln	ESW	0.02	0.17	0.31	0.40	0.10
Alt	ESW	0.00	0.00	0.00	0.24	0.76
Arun	ESW	0.40	0.31	0.25	0.04	0.00
Asheldham Brook	ESW	0.00	0.00	0.00	0.00	1.00
Atro	ESW	0.00	0.15	0.21	0.65	0.00
Auchencairn Bay	ESW	0.02	0.03	0.10	0.41	0.43
Avon	ESW	0.03	0.18	0.19	0.26	0.34

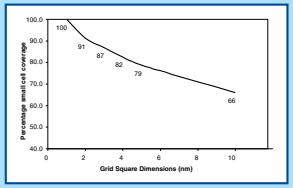

Figure 3b: The numbers of 1x1nm CW cells in larger cells of varying dimensions expressed as a proportion

Results

From the cluster analysis, it was apparent that within-site variability was high and so most TWs formed part of a largely undifferentiated continuum of data describing the full range of estuary types (Figure 5). Within this continuum the TWs were split into two major groups as shown in Table 3. Transitional Lagoons, Sea Lochs, and Embayments were classified independently.

The simplified analysis of the CW cells produced five groups described in Table 4. Groups one and two were by far the most widespread with groups three, five and eight covering much more specific stretches of coastline. Coastal lagoons were classified independently.

Table 3: Physical characteristics of transitional water types

Type	Name	Mixing Character-istics	Salinity	Mean Tidal Range	Exposure	Depth	Substratum	Example
Group 1		Partly mixed/ stratified	Mesohaline/ polyhaline	Strongly mesotidal	Sheltered	Intertidal/ shallow sub-tidal	Sand and mud	Tees Estuary Dart Estuary
Group 2		Fully mixed	Polyhaline/ euhaline	Mesotidal or macrotidal	Sheltered	Extensive intertidal	Sand or mud	Mersey Estuary Humber Estuary
	Transitional lagoon	Partly mixed/ stratified	Oligohaline - polyhaline	N/A	Sheltered	Shallow	Mud	
	Sea Loch							
	Embayment	N/A	Euhaline		Sheltered	Shallow	Sand	Hamshire Harbours Outer Wash Budle Bay

Table 4: Physical characteristics of coastal water types

Type	Name	Salinity	Mean Tidal Range	Exposure	Current Velocity	Example
Group 1		Euhaline	Mesotidal	Exposed	Weak	Northumberland Coast
Group 2		Euhaline	Generally mesotidal	Sheltered	Weak	Liverpool Bay Cardigan Bay
Group 3		Euhaline	Generally mesotidal	Moderately exposed or exposed	Moderate or strong	Essex Coast North Cornwall Coast
Group 5				Sheltered	Weak	Galway Bay Sligo Bay
Group 8				Very exposed	Moderate to strong	Small area off Pembroke Coast
	Coastal lagoon	Euhaline	N/A	Sheltered	Weak	

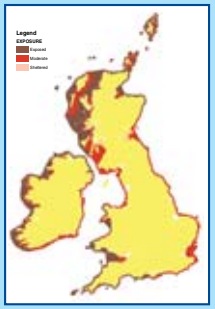

Figure 4: The geographical distribution of exposure based on 1nm populated grid cells in CW

Figure 6: The distribution of inter-tidal areas based on 0.1nm grid cells in the Solway

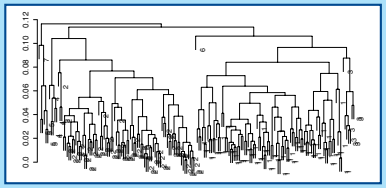

Figure 5: Dendrogram illustrating the continuum shown from the analysis of all TW fuzzy data

Biological Validation

Biological data, collected throughout Britain and Ireland by the JNCC as part of their Marine Nature Conservation Review, was used to validate the physical types found. A basic assumption throughout the validation process was that the distribution of biological communities would reflect the physical characteristics of each water body. Thus the physical typology was tested by superimposing the physical types onto the biological data set.

The biological validation showed that there were no significant differences in the biotope complex composition of the major physical types identified for TWs and CWs. However, it was possible to give a biological characterisation/description of the two main physical types in TWs. As a result of the lack of validation of the physical typology, an alternative biological typology was developed for TWs. It was based on a cluster analysis using a comprehensive biological dataset, combined with expert judgment based on the detailed scrutiny of the data and relevant literature. This approach identified 5 to 6 distinct biological types for TWs, which also benefited from some geographical coherence.

Conclusions

Although the relatively large number of physical factors described the characteristics of TWs and CWs well, they did not help to generate a simple physical typology.

- The major physical types of CW and TW could not easily be biologically validated.
- Estuarine assemblages are influenced by localised environmental conditions and biogeography. So, averaging the physical properties of estuaries as undertaken here is not likely to explain the biological structure of estuaries.
- An alternative biological typology of TW was prepared, and different analytical techniques were also recommended.
- Lack of physical and biological data in some regions prevented the population of all cells using direct observations. Interpolation was necessary in a number of areas.

This poster is based on work undertaken during a UK project to deliver a common typology for the UK and Ireland's transitional and coastal waters, funded jointly through SNIFFER (Scotland and N. Ireland Forum for Environmental Research), the Environment Agency of England and Wales and the Irish Environmental Protection Agency. UKHO vector charts for inshore waters of the British Isles were purchased under single user Data Licence Agreement No. 072002/004.

[1] The Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft Laboratory, Pakefield Road, Lowestoft, Suffolk NR33 0HT, UK. http://www.cefas.co.uk
[2] Aquafact International Services Ltd, 12 Kilkerrin Park, Liosbaun, Galway, Ireland
[3] British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, UK NG12 5GG
[4] Institute of Estuarine and Coastal Studies (IECS), University of Hull, Hull HU6 7RX, UK
[5] Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 1JY