

<b>Institution:</b> University of Essex		
<b>Unit of Assessment:</b> 5 - Biological Sciences		
<b>Title of case study:</b> Developing new natural capital approaches to incorporate ecosystem service provision into national coastal policy		
<b>Period when the underpinning research was undertaken:</b> 2000 - 2020		
<b>Details of staff conducting the underpinning research from the submitting unit:</b>		
<b>Name(s):</b>	<b>Role(s) (e.g. job title):</b>	<b>Period(s) employed by submitting HEI:</b>
Graham J C Underwood	Professor, School of Life Sciences	1992 - present
<b>Period when the claimed impact occurred:</b> 2017- 2020		
<b>Is this case study continued from a case study submitted in 2014?</b> N		
<b>1. Summary of the impact</b>		
<p>Enhancing natural capital is at the core of the UK Government's approach to protecting the environment, and reversing decades of degradation (The 25 Year Environment Plan). Essex research <b>provided essential evidence</b> on salt marsh carbon sinks, food supply, biodiversity and flood protection <b>and methodologies for the UK Government Defra-funded Suffolk Marine Pioneer, enabling the development of key tools for Government to quantify salt marsh NC, and shaping the Pioneer's policy recommendations. These recommendations are now adopted nationally by the Marine Maritime Organisation (MMO) and Defra in delivering the 25 Year Environment Plan (25 YEP).</b> Essex research also identified success factors for enhancing biodiversity when incorporating salt marsh into sea defence infrastructure; this 'green-grey' approach was <b>adopted by the Environment Agency (EA) and Natural Resources Wales, enhancing natural capital in coastal defence policy.</b></p>		
<b>2. Underpinning research</b>		
<p>Natural Capital (NC) is the environmental assets that directly or indirectly produce value (ecosystems services) to society. To produce a sustainable 'flow' of benefits requires NC to be maintained or enhanced. A NC approach therefore requires evidence of the condition of NC assets, and how they will change with time.</p> <p>Research led by Professor Underwood at Essex since 2000 on the ecology and biogeochemistry of estuaries and coastal habitats has quantified the primary production, carbon stocks and flows, and associated ecosystem services such as provisioning (fish nurseries, oyster beds), diversity, salt marsh and sediment stability (coastal defence), water quality (eutrophication) and habitat connectivity. Research funded by NERC identified factors determining the rates of biogeochemical processes in estuaries, and the production, retention and transformation of carbon and nitrogen related to microbial diversity (bacteria, micro-algae), allowing the quantification of the stocks and dynamics of organic carbon and nitrogen species in N.W. European coastal salt marsh and mudflat habitats [R1, R2]. These findings were used as underpinning evidence to determine carbon stocks of salt marshes and mudflats across NW Europe [R2]. Separate NERC funded research revealed that the fish nursery-function of salt marshes in the coastal seascape is modulated by characteristics of salt marsh area and saltmarsh health, seasonality, fish larvae behaviour, and salt marsh geospatial distribution [R3, R4]. This knowledge was used to both determine the degree of internal erosion and loss of vegetated area within salt marshes, against a baseline of "healthy" marsh, and, in conjunction with biogeochemical data, the potential for carbon storage if habitat restoration was adopted.</p>		

The research on larval fish use of salt marsh [R3, R4] permitted the calculation of areal values for sea bass fish larval use of salt marsh. Underwood and Essex were asked to contribute to the Suffolk Pioneer based on this previous research experience in measuring natural capital. The Suffolk Pioneer in their final report [S4] identified that '*The most pressing gap identified through the process of baselining and that could not be addressed by wider literature review was an understanding of the condition of the salt marsh*'. This was addressed using research from the University of Essex [R3, R5, R2] and is summarised in Box 3 of the technical annex'.

Increasing sea levels and salt marsh loss threatens coastal defence sea walls with increased erosion and damage. The Environment Agency has a programme of repairs and sought to incorporate elements of salt marsh restoration in these new structures to enhance natural capital. Essex research funded by the Environment Agency established the important engineering, sedimentological and environmental factors necessary in determining successful salt marsh restoration and to enhance biodiversity, when incorporating "green" infrastructure into building sea wall flood defences [R6]. This research provides scientific support for inclusion of "nature-based solutions" in engineered coastal defence projects [R7].

### 3. References to the research [can be supplied by HEI on request]

**R1** Thornton, D.C.O., Dong, L.F., Underwood, G.J.C. and Nedwell, D.B. (2002) Factors affecting microphytobenthic biomass, species composition and production in the Colne estuary (UK) *Aquatic Microbial Ecology*. 27: 285-300.

<http://www.int-res.com/articles/ame/27/a027p285.pdf>

**R2** Legge O., Johnson M., Hicks N., Jickells T., Diesing M., Aldridge J., Andrews J., Artioli Y., Bakker D.C.E., Burrows M. T., Carr N., Cripps G., Felgate S., Fernand L., Greenwood N., Hartman S., Kröger S., Lessin G., Mahaffey C., Mayor D. J., Parker R., Queiros A.M., Shutler J.D., Silva T., Stahl H., Tinker J., Underwood G.J.C., Van Der Molen J., Wakelin S., Weston K. and Williamson P. (2020) Carbon on the Northwest European Shelf: Contemporary Budget and Future Influences. *Frontiers in Marine Science*, 7, 1-23.

<https://www.frontiersin.org/article/10.3389/fmars.2020.00143>

**R3** Green, B.C., Smith, D.J., Earley, S.E., Hepburn, L.J. and Underwood, G.J.C. (2009) Seasonal changes in community composition and trophic structure of fish populations of five salt marshes along the Essex coastline, United Kingdom. *Estuarine and Coastal Shelf Science*. 85: 247-256. <https://doi.org/10.1016/j.ecss.2009.08.008>

**R4** Green, B.C., Smith, D. J., Grey J., Underwood G.J.C. (2012). High site fidelity and low site connectivity in temperate salt marsh fish populations: a stable isotope approach. *Oecologia*. 168, 245-255. DOI: 10.1007/s00442-011-2077-y.

**R5** Slee, N. J. D., Parris, A., Underwood, G.J.C. (2018). *Deben Estuary salt marsh status: extent, carbon stocks and Sea Bass nursery values, and the potential gain in these natural capital assets from successful restoration*. Report to Suffolk Marine Pioneer

<https://www.suffolkcoastandheaths.org/wp-content/uploads/2020/03/Slee-2018.pdf>

**R6** Cousins, L. J., Cousins, M.S., Gardner, T., Underwood, G.J.C. (2017) Factors influencing the initial establishment of salt marsh vegetation on engineered sea wall terraces in south east England. *Ocean and Coastal Management*. 143: 96-104.

<http://dx.doi.org/10.1016/j.ocecoaman.2016.11.010>

**R7** Naylor, L.A., Coomber, M.A., Kippen, H., Horton, B., Gardiner, T., Cordell, M.R., Simm, J., Underwood, G.J.C. (2018). Developing a business case for greening hard coastal and estuarine infrastructure: preliminary results. In *Coasts, Marine Structures and Breakwaters 2017: Realising the Potential*, p 801-811, Institute of Civil Engineers ICE Publishing, 2018. <https://doi.org/10.1680/cmsb.63174.0801>

**G1 NERC Shelf Seas Biogeochemistry thematic programme:** Data Synthesis and Management of Marine and Coastal Carbon (DSMMACC) The *Blue Carbon module*, 2014 – 2018. University of Essex subcontract with CEFAS GBP20,000 (PI: Underwood)

**G2 Environment Agency (EA). Survey of Essex saltmarsh berms.** 2013 – 2018, GBP6,100 (PI: Underwood)

**G3 NERC, A hierarchical approach to the examination of the relationship between biodiversity and ecosystem service flows across coastal margins - CBESS** Feb 2012 - Mar 2016. GBP392,843, GBP312,210, plus GBP86,000 NERC facilities costs (PI: Underwood)

#### 4. Details of the impact

Essex research provided the evidence and approach critical to the UK Defra Suffolk Marine Pioneer recommendations for the application of natural capital approaches to salt marsh. The Pioneer outcomes are contributing to key lessons for Government and Defra agencies as they implement the 25 Year Environment Plan (25 YEP). Essex research has also shaped UK coastal defence policy by supporting the development of “green-grey” infrastructure, incorporating salt marsh into coastal defence structures by the Environment Agency and Natural Resources Wales.

#### **Shaping UK Defra Suffolk Marine Pioneer policy recommendations for the application of natural capital approaches to salt marsh**

The UK Government established the Pioneer Programme in 2017 to inform iteration and implementation of the Government’s 25 YEP [S1]. It consisted of four national projects to test natural capital approaches in urban, river, landscape and marine environments respectively. The Marine Pioneer ran in only two UK locations, North Devon and Suffolk. The Suffolk Marine Pioneer (‘the Pioneer’ hereafter) tested NC approaches as a means of delivering the 25 YEP, through demonstration projects in the Deben estuary. The Pioneer’s focus was on determining the natural capital value of salt marsh [S2, p3]. The Pioneer undertook a natural capital assessment for salt marsh restoration and other ecosystem services, including fisheries. Underwood was invited to work directly with the Pioneer team from 2017 to 2020 to build the natural capital work programme [S3]. The Pioneer required a method to calculate “asset extent” and “asset condition” which non-technical specialists could use. The crucial contribution Essex’s work made [S3] was in developing a tool to determine salt marsh carbon stocks and potential carbon storage and enhanced fish nursery provision through salt marsh restoration, identified by the Pioneer as a key method ‘*to define asset condition in relation to ecosystem service provision*’ [S4, key learning, p17-18, *key lessons – methods*, p 30, and Boxes 3-5 Tech annex, p42-47]. These approaches were used by the Pioneer to estimate carbon value and fish value using a ‘*natural capital approach*’ [S4].

The Essex research, developing methods for evidencing baseline quality and potential enhancement of saltmarsh natural capital [S2 p5], which were key outcomes of the Pioneer,

shaped the recommendations of the final report published in May 2020 [S4] [S2]. This report directly draws on [R1, R2, R3, R5, R6] [S4, p40-41] and brings together the work to produce tools to assist in natural capital assessments, calculating carbon, fish and coastal defence potentials for three areas of the Deben estuary. This research contributed significantly to the main report and to Technical Annex boxes 3, 4, and 5 [S4]. The Defra Suffolk Marine Pioneer manager acknowledges the significance of Underwood's contribution to the development of the natural capital assessment stating "*The evidence from the Essex team was crucial; a method for valuing the natural environment was essential and Underwood's work at Essex provided scientific validity for the numbers*" and "**Objective, rigorous evidence of environmental functions and services is required to affect positive improvements to the environment [...] Underwood's research provided this and has enabled the Defra's Suffolk Marine Pioneer to address these issues by demonstrating the natural capital approach**". [S3]. The Pioneer Manager concludes that the Essex research was '*the cornerstone of the Suffolk Pioneer's success. Without the methods and evidence provided by Essex, a key objective of the Pioneer, and the subsequent benefits to environmental policy, could not have been delivered*' [S3]. Beyond the Pioneer project Underwood's research has "*contributed to the Deben Estuary Partnership integrating natural capital in the revised estuary plan and Suffolk County Council's initiative to partner with New Anglia LEP and Norfolk County Council to establish a natural capital baseline for East Anglia.*" [S3].

#### **Informing the UK Government and Defra agencies' implementation of England's new Environment Policy: the 25 Year Environment Plan (25 YEP)**

Underwood's research [R2, R3, R4, R5], through shaping the Pioneer recommendations, is used more widely by the UK Government and Defra agencies including the Marine Management Organisation (MMO) in the development of advice and policy for delivering the UK Government's aspirations set out in the 25 Year Environment Plan and the Environment Bill. The Lead for the Marine Pioneer and Head of Evidence for the MMO [S5] verifies that "*Natural Capital approaches need baselines against which to measure capital gains and losses.... Underwood's group developed methods, based on their earlier published work, to allow the calculation of carbon, fish natural capital values for three areas of the Deben estuary. Objective, rigorous evidence of environmental functions and services is required to affect positive improvements to the environment. Professor Underwood's research provided this and has enabled the DEFRA's Suffolk Marine Pioneer to address these issues by demonstrating the natural capital approach. Research at Essex enabled the Suffolk Marine Pioneer to provide new cost effective and deliverable methods on how the natural capital approach can succeed in practice.*" The research has influenced the overall UK Pioneer programme outcomes produced by the MMO. The Lead for the Marine Pioneer and Head of Evidence for the MMO confirms that "*The Suffolk Pioneer final report delivered clear recommendations for natural capital approaches required by the UK 25YEP. The "lessons learned" by the Pioneer programme are being published on the gov.uk website by the Marine Management Organisation (MMO). This natural capital approach developed by the Suffolk and North Devon Marine Pioneer is being used to train and advise people working in the Environment Agency and Natural England on conservation, protection and restoration of habitats and is being held in a central knowledge sharing platform*" [S5]. The Lead for the Marine Pioneer and Head of Evidence for the MMO concludes by stating that "*Underwood's research at Essex enabled the Suffolk Marine Pioneer to provide new cost effective and deliverable methods on how the natural capital approach can succeed in practice. Now that Defra and MMO have a better understanding of how to generate and apply the natural capital approach they have used this evidence to generate funding and support for larger scale evidence production*". [S5].

### Shaping coastal defence policy through the adoption of “green-grey” infrastructure in England and Wales

Underwood's research on salt marsh and mudflat ecosystems led to him being directly approached in 2012 by the Environment Agency to assess their programme of repairs of coastal defence sea walls. By identifying the factors for successfully incorporating salt marsh habitat into repairs of coastal defence infrastructure and associated natural capital, this research [R6, R7], published 2017 and 2018 resp., '*provided essential scientific evidence for the success criteria of these schemes*' '*evidence of its success rested on the research outputs provided by the University of Essex*' Biodiversity Officer, EA [S6]. The EA adds that the research '*provided confidence to the Agency that this approach to sea wall repair could enhance salt marsh development and biodiversity, and the soft-engineered structures would not structurally fail. This has led the Agency to install a further 900 m of these structures in wall repairs, enhancing natural capital by adding 0.2 ha of salt marsh habitat in another 14 locations in Essex. This habitat creation has contributed to the Agency's obligation to provide statutory habitat compensation associated with Flood and Coastal Risk Management activity.*' [S6]. They conclude that Underwood's work '*played a key role in the EA's adoption of a “greening-the-grey” solution to an essential element of the Agency's mission, namely to provide sea defence from tidal flooding*'. [S6]. The work [R6, R7] is highlighted as one of 8 case studies in 'Greening the Grey: A Framework for Integrated Green Grey Infrastructure (IGGI)' (NERC collaborative project with the University of Glasgow, University of Oxford, Government agencies and UK businesses), which presents innovations from academia and practice designed to green grey infrastructure assets [S7]. This “green-grey” approach for seawalls is also recommended by Natural Resources Wales [S8 report p59] as a part of their Welsh flood policy and has been promoted by a key industry stakeholder, the Institute for Civil Engineers [R7] [S8].

#### 5. Sources to corroborate the impact

**S1** Evaluation of the 25 Year Environment Plan Pioneers. Final Report 25 Year Environment Plan. Defra, HM Government.

[http://randd.defra.gov.uk/Document.aspx?Document=14438\\_BE0144\\_FinalReport.pdf](http://randd.defra.gov.uk/Document.aspx?Document=14438_BE0144_FinalReport.pdf)

**S2** Suffolk Marine Pioneer: Policy Brief Applying the natural capital approach in England <https://www.suffolkcoastandheaths.org/wp-content/uploads/2020/04/Suffolk-Marine-Pioneer-lessons-.pdf>

**S3** Testimonial, Suffolk Marine Pioneer Manager, Suffolk Coast & Heaths AONB

**S4** Suffolk Marine Pioneer: Lessons & recommendations for applying the natural capital approach in England, Suffolk Coast & Heaths Area of Outstanding Natural Beauty, Dock Lane, Melton 58pp. 2020 <https://www.suffolkcoastandheaths.org/managing/projects/marine-pioneer/> <https://www.suffolkcoastandheaths.org/wp-content/uploads/2020/04/2020-SMP-Applying-Nat-Cap-Guidance-.pdf>

**S5** Testimonial, Marine Management Organisation Lead for the Marine Pioneer and Head of Evidence MMO.

**S6** Testimonial, Biodiversity Officer, Environment Agency.

**S7** Naylor et al. Greening the Grey: 2017 A Framework for Integrated Green Grey Infrastructure (IGGI). Case Study 1: <http://eprints.gla.ac.uk/150672/37/150672Full.pdf> Appendix 4 Coastal: <http://eprints.gla.ac.uk/150672/42/150672Appendix4.pdf>

**S8** Armstrong S et al. 2019 Supporting the implementation of the Welsh National Marine plan: Enhancing marine ecosystems 106 pp. NRW Bangor. <https://cdn.naturalresources.wales/media/689255/nrw-evidence-report-no-357-supporting-the-implementation-of-the-welsh-national-marine-plan-enhancing-marine-ecosystems.pdf>