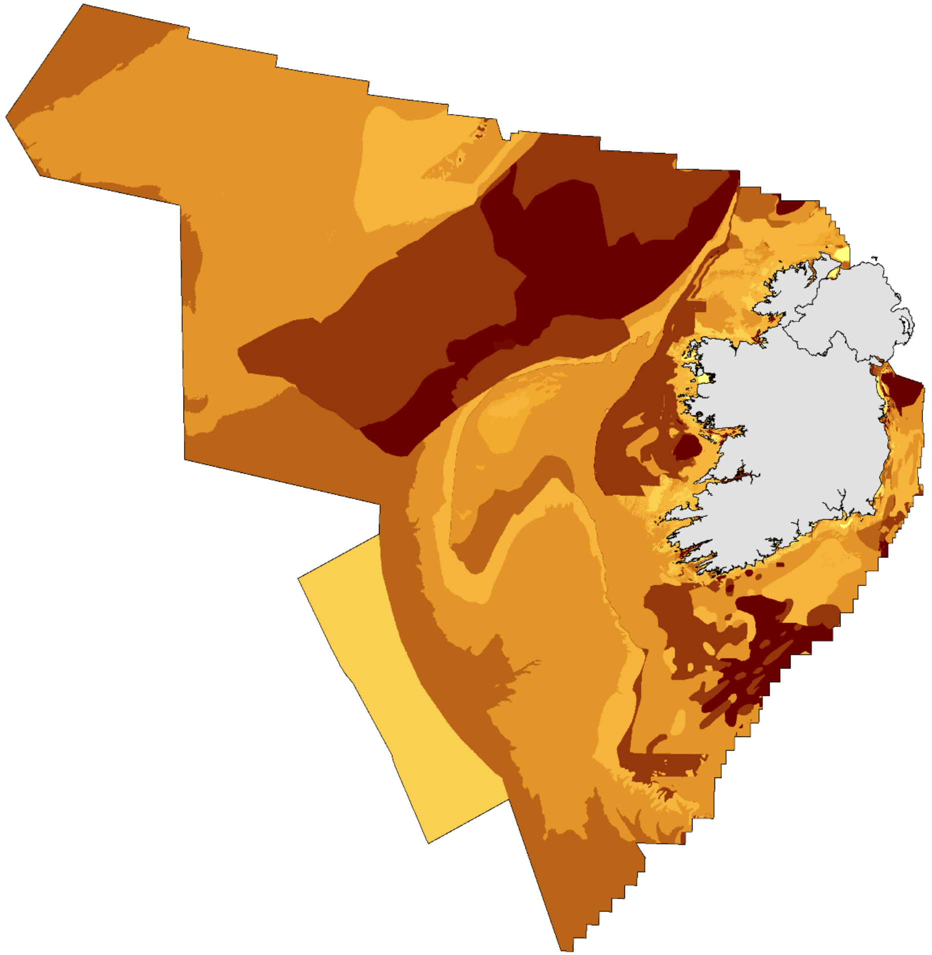
Marine Carbon: Indicator document - Ecosystem Service Modelling & Rule-base development

Marine Carbon

Ecosystem service: **Regulation of greenhouse gases (carbon)**

29/03/2016



Legend

Higher contribution to carbon sequestration
Moderate contribution to carbon sequestration
Lower contribution to carbon sequestration

How to interpret the map:
The darkest colours represent areas where there is more carbon storage in the marine environment. Lighter colours represent areas where the marine environment stores a lesser amount of carbon.

Ecosystem service:
Climate change (regulation) - storage of carbon within the marine environment.

What the service is:
Atmospheric carbon is sequestrated by and stored in the marine environment through the process of photosynthesis by phytoplankton with the resulting microbes passing into the food chain. The other main method is via dissolution and chemical reaction of carbon dioxide and water forming bicarbonate which is likely to be stored in marine sediments.

Why it is important:
The marine environment is one of the largest on Earth. The role the sea plays in storing carbon helps reduce atmospheric contributions as carbon dioxide and greenhouse gas concentrations.

How the map was created:
Data analysis identified areas of significant carbon storage in the seas surrounding Ireland. This included data from the EU Seamap (Atlantic Habitats) and collated seabed substrate. Attributes from each dataset were analysed and valued from high to low where circalittoral mud was considered to store more carbon and coarse sediments and sand likely to store less carbon. Attributes assigned with only rock or seabed were scored as neutral to negligible. The map should be interpreted as showing the best information using the data currently available.

Valuation example:

Ecosystem Service Typology	Significant effects	Data used	Example attributes	Indicative scoring
Marine carbon resource: how much carbon is stored in the sea	Presence of silts and sediments	Habitats	Deep sediment	High
			Bare rock	Low
	Sediment disturbance	Management	Undisturbed	High
			Dredged	Low

0 50 100 150 200 250
Kilometres

N

An Roinn Ealaíon, Oidhreachta agus Gaeltachta
Department of Arts, Heritage and the Gaeltacht

National Parks & Wildlife Service

Environment SYSTEMS evidence and insight

Indicator	**CICES classification**
MARINE CARBON STORAGE **Marine carbon (Regulation of greenhouse gases (carbon)**	**Section**: Regulation & Maintenance **Class:** Global climate regulation by reduction of greenhouse gas concentrations **CICES IE Sub-class:** Areas important for emissions reduction
Scale	**CICES Cascade Level** [1]
Strategic/National/~~Regional/Local~~	~~Structure/Function/~~Service/~~Benefit/Value~~

[1] Potschin, M. and R. Haines-Young (2016): Frameworks for ecosystem assessments. In: Potschin, M., Haines-Young, R., Fish, R. and Turner, R.K. (eds) Routledge Handbook of Ecosystem Services. Routledge, London and New York, pp 125-143.

What the service is

Atmospheric carbon is sequestrated by, and stored in, the marine environment through two main processes. The first is photosynthesis where CO_2 is used by phytoplankton and oxygen is realised. The resulting microbes that grow from the process pass into the food chain. The other main method is via dissolution and chemical reaction of carbon dioxide and water forming bicarbonate which is likely to be stored in marine sediments.

Service indicator(s) mapped

Substrate and management were the two main indicators used to map this ecosystem service.

The role of substrate type in marine carbon storage is related to the particle size distribution of the sediment. Coarse sandy sediments have large particles which allow water to flow freely through the upper part of the sediment, flushing the region with oxygen. Finer, tightly-packed sediments such as mud and clay allow less water penetration and so are less oxygenated. Higher levels of oxygenation promote greater microbial activity, leading to faster carbon cycling and lower levels of carbon retention within the sediment.

Datasets used	**Dataset requirement** [2]
Habitat Asset Register [3]	Beneficial
Conservation Designations	Beneficial
Collated Seabed Substrate	Essential
Predicted habitats – North Sea and Celtic Sea	Essential
Dumping at Sea Boundaries	Desirable
Dredge Fishing Activity	Essential

[2] 'Essential' datasets are needed to map the service, whilst 'beneficial' datasets will increase model accuracy but are not necessary requirements for mapping.

[3] The Habitat Asset Register only contains habitats suitable for national scale mapping; for details, please refer to the project report.

How the map was created

Data analysis identified areas of significant carbon storage in the seas surrounding Ireland. This included data from the 'Predicted habitats for North Sea and Celtic Sea' (EU Seamap) and collated seabed substrate. Attributes from each dataset were analysed and valued from high to low where circa-littoral mud was considered to store more carbon and coarse sediments and sand likely to store less carbon. Where only rock or seabed was mapped these were allocated as neutral to negligible carbon storage.

The map should be interpreted as showing ecosystem service information based on the data currently available; when new data become available the maps can be updated. The maps are intended for use at the strategic scale, and further information should be gathered before decisions are made regarding a particular location.

Scoring

Significant Effects	Datasets used	Example attributes	Indicative scoring [4]
Deep habitats are more likely to store carbon long term; re-suspension is more likely in high energy environments	Collated Seabed Substrate	Deep Circalittoral mud	High
		Deep Circalittoral sand	Medium
		Circalittoral rock	Low
Deep habitats are more likely to store carbon long term; re-suspension is more likely in high energy environments	Predicted habitats – North Sea and Celtic Sea	Mud to sandy mud, A5:37: Deep circalittoral mud	High
		Coarse sediment, A5.13: Infralittoral coarse sediment	Medium
		Seabed, High energy Circalittoral seabed	Low
Input of organic materials adds carbon to the seabed	Dumping at Sea Boundaries	None	High
		Fish waste	Medium
		Dredged Material	Low
Disturbance of loose sediment and/or biogenic reefs; release of stored carbon back into the water column	Dredge Fishing Activity	None	High
		None	Medium
		None	Low
		[whole layer]	Disbenefit

[4] The indicative scoring in this table gives overview-type information on how the individual data layers were incorporated into the ES maps. For full scoring, please refer to the spreadsheet containing the full rules-base.

Data gaps associated with this map during the pilot project

Depth and substrate are only used as general proxy indicators for marine carbon storage as a whole. Biomass within the sediment, for example, will differ based on how well oxygenated the area is, which could form an additional indicator. Similarly, removal of carbon from the sediment back into the water column will be higher in high energy/high disturbance environments and greater clarity in attributed data could provide a solution to this.

The map does not incorporate processes occurring within the water column, where factors such as depth of light penetration, presence of fronts, currents or eddies, as well as the depth of thermocline and halocline can affect the overall productivity of the marine carbon pump. It does also not consider the efficiency of chemical exchange of carbon at the air-water interface.

Scientific framework for modelling 'marine carbon storage'

Overview	Substrate, particularly the depth at which it occurs and how stable it is likely to be, and management were the two main indicators used to map this ecosystem service. There is a good amount of evidence regarding the effect of habitat and substrate on carbon sequestration, as well as regarding processes occurring within the water column (though the latter can be difficult to map).
Water	Existing carbon stocks are considered to be greater in deeper parts of the ocean and are likely to be better at maintaining carbon storage in the longer term. When considering sequestration of carbon dioxide, residence time in the water column will be extended below the thermocline (depths of >1000-1500 m) (Tsouris et al., 2004). However, the sequestration potential of the deep oceans is limited by the exposure of the deep ocean water to the atmosphere. The "solubility pump", where C transfers as Dissolved Inorganic Carbon (DIC) due to under-saturation, occurs in surface waters. Once the DIC has been absorbed into the mixing of ocean waters, it sinks into the deep water formations and is subsequently sequestered into the ocean floor (Hessen et al., 2004). Marine snow (aggregate particles of >0.5 mm) plays an important role in oceanic biochemical cycles (Lampitt et al., 1993). Marine snow is one of the important factors in the flux of C from surface waters to deep oceanic waters (Hessen et al. 2004), where they are sequestered once below the oceanic thermocline. However, Hessen et al. (2004) states that biological processes, such as the sinking of particles and dissolved organic matter, cannot sequester anthropogenic carbon dioxide from the atmosphere directly, though ocean warming associated with climate change may change nutrient availability in surface waters.
Biochemical Processes	Biochemical processes contribute to the uptake and storage of C in the oceans. This includes the uptake of organic C through primary production and photosynthesis, and the uptake of dissolved inorganic C through the construction of seashells or reef structures by shellfish and corals. Net primary production (NPP) is an important factor governing C sinks in the

	ocean but is primarily limited by the availability of nutrients in the water column to support biologically mediated C storage (Field et al., 1998). Oceanic carbon sequestration also includes seashell production and limestone-reef building, through the chemical incorporation of CO32- ions (Carbonate) from the water column to form CaCO3 limestone structures. The dissolution of biogenic marine carbonates (magnesian calcites from coralline algae, aragonite from corals and pteropods, and calcite from coccolithophorids and formainifera) reduces anthropogenic carbon dioxide and increases total alkalinity (Feely et al., 2004). Processes that increase total alkalinity in the upper oceans increase the uptake rate of anthropogenic carbon dioxide (Feely et al., 2004).
Benthic Sediment	Burial of organic matter in sediments leads to the long-term reduction of atmospheric carbon dioxide, therefore sediment properties are considered an important factor of oceanic carbon sequestration (Burdige, 2007).
Atmosphere-Ocean Interface	Wind driven upwelling is an important factor for marine carbon storage. Upwelling brings nutrient rich, dissolved organic carbon poor waters to the surface, where carbon dioxide uptake can occur by dissolution (the solubility pump) and primary production (the biological pump). Carbon dioxide dissolution potential is proportional to the length of time the surface waters have been exposed to the atmosphere and the buffer capacity (or Revelle Factor) – which relates to the ratio between dissolved inorganic concentration in the water and carbon dioxide concentrations in the atmosphere. If DIC concentration is lower than atmospheric carbon dioxide, C uptake can theoretically take place (Sabine et al., 2004).
Management	Management leading to reduced carbon storage and sequestration includes: • Reef-sourced aggregates • “Carbon Capture and Storage” has the short term benefit of anthropogenic carbon dioxide removal from the atmosphere, but the longer timescales (of hundreds or thousands of years) associated with ocean mixing and ventilation results in its release back into the carbon cycle.

	Positive management, leading to increased biodiversity includes: • Conservation of high C storage ecosystems and habitats by primary production – Mangroves, seagrass meadows, tidal salt marshes, kelp forests, coral reefs (though, arguably, coral reefs could be considered slight C sources rather than C sinks due to chemical interactions on a local scale (Laffoley and Grimsditch, 2009).

Supporting evidence: References

Burdige, D.J., 2007. Preservation of organic matter in marine sediments: controls, mechanisms, and an imbalance in sediment organic carbon budgets? Chemical reviews, 107(2), pp.467-485.

Feely, R.A., Sabine, C.L., Lee, K., Berelson, W., Kleypas, J., Fabry, V.J. and Millero, F.J., 2004. Impact of anthropogenic CARBON DIOXIDE on the CaCO3 system in the oceans. Science, 305(5682), pp.362-366.

Field, C.B., Behrenfeld, M.J., Randerson, J.T. and Falkowski, P., 1998. Primary production of the biosphere: integrating terrestrial and oceanic components. Science, 281(5374), pp.237-240.

Hessen, D.O., Ågren, G.I., Anderson, T.R., Elser, J.J. and de Ruiter, P.C., 2004. Carbon sequestration in ecosystems: the role of stoichiometry. Ecology, 85(5), pp.1179-1192.

Laffoley, D., Grimsditch, G., 2009. The Management of Natural Coastal Carbon Sinks. IUCN.

Lampitt, R.S., Hillier, W.R. and Challenor, P.G., 1993. Seasonal and diel variation in the open ocean concentration of marine snow aggregates. Letters to Nature, 362, pp.737-739.

Sabine, C.L., Feely, R.A., Gruber, N., Key, R.M., Lee, K., Bullister, J.L., Wanninkhof, R., Wong, C., Wallace, D.W., Tilbrook, B. and Millero, F.J., 2004. The oceanic sink for anthropogenic carbon dioxide. Science, 305(5682), pp.367-371.

Tsouris, C., Brewer, P., Peltzer, E., Walz, P., Riestenberg, D., Liang, L. and West, O.R., 2004. Hydrate composite particles for ocean carbon sequestration: field verification. Environmental science & technology, 38(8), pp.2470-2475.