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

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.

The scientific framework outlined below helps to determine the type of data that could be used for modelling of this service, and provides general guidance which indicators are likely to have a positive or negative impact on service provision.

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

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