Preliminary process assessment

The BRICS project was tasked with identifying key processes that significantly affect the biological influence on global ocean carbon storage in three areas: net primary production, interior remineralisation and the biological contributions to alkalinity. The assessments below were obtained from 1) an expert assessment by the BRICS team[(*1)] based on a detailed literature review, and 2) a community-wide survey.

1) Expert assessment

The BRICS team conducted a literature review to gather evidence derived from laboratory, observational and modelling studies for the importance of, and uncertainty in, each process (a total of 227 papers were reviewed). Consensus on the grading of each process as high, medium or low importance/uncertainty was reached by discussion within the BRICS team based on the assembled evidence. This assessment is necessarily subjective, but is supported by the list of surveyed literature (provided here); the detailed analysis by the BRICS team underpinning the assessment will form part of a future publication.

Basis for Importance ranking		Basis for Uncertainty ranking	
High importance	Has a substantial influence on determining the future biologically-mediated storage of C in the ocean	High uncertainty	Minimal supporting evidence and/or contrasting evidence with no consensus reached by the scientific community.
Medium importance	Has a moderate influence on determining the future biologically-mediated storage of C in the ocean	Medium uncertainty	Some supporting evidence with gaps in research or no clear consensus reached by the scientific community.
Low importance	Has a weak influence on determining the future biologically-mediated storage of C in the ocean	Low uncertainty	Strong supporting evidence from a range of studies. Consensus has been reached by the scientific community.

[(*1)] Stephanie Henson, Chelsey Baker, Stuart Painter (NOC), Paul Halloran (University of Exeter), Alessandro Tagliabue (University of Liverpool), Abigail McQuatters-Gollop (University of Plymouth), Alban Planchat (Ecole Normale Supérieure de Paris)

[(*2)] https://drive.google.com/drive/folders/1lTO1dEC_8wt60Dh1Whjz-x6_OyE6CP1-

Net Primary Production processes:

Process	Definition	Importance	Uncertainty
Resource limitation of growth	Limitation of phytoplankton growth by both major and micro nutrients and light.	High	Medium
Phytoplankton loss processes	All losses of phytoplankton biomass to grazing or mortality.	High	Medium
N2 fixation	Conversion of dinitrogen into fixed nitrogen by diazotrophs.	High	Medium
Zooplankton processes	Activity of zooplankton, encompassing grazing, nutrient recycling etc.	High	Medium
Phytoplankton adaptation, acclimation	Ability of phytoplankton to adjust their physiology in response to environmental changes.	Medium	High
Microbial loop	Turnover of organic nutrients and carbon by bacteria.	Medium	High
Response to thermal stress	How plankton are parameterised to respond to temperatures exceeding their thermal optimum.	Medium	High
Phytoplankton physiology	The cellular functioning of phytoplankton, including their photosynthesis, respiration and nutrient acquisition traits.	Medium	Medium
Plankton metabolism	Chemical processes that occur within individual organisms.	Medium	Medium
External nutrient inputs	Supply of nutrients into the ocean from rivers, sediments, atmosphere and hydrothermal venting.	Medium	Medium
Micronutrients	Nutrients typically present at low concentration - including iron, manganese, zinc, cobalt, nickel.	Medium	Medium
Organic matter cycling	Transformation of dissolved and particulate organic matter into inorganic forms, including acquisition of organic nutrients.	Low	High
Food web complexity	The number of groups in a food web (including plankton, bacteria, fish and viruses) and their interactions.	Low	High
Mixotrophy	Plankton that utilise both autotrophy and heterotrophy.	Low	High

Interior remineralisation processes:

Process	Definition	Importance	Uncertainty
Biotic fragmentation	Fragmentation of particles into smaller pieces by the action of zooplankton flux feeding or swimming.	High	Medium
Aggregation	Formation of larger particles by the aggregation of smaller particles. Transparent Exopolymer Particles (TEP) and other sticky exudates may increase the success rate of collisions.	High	Medium
Preferential remineralisation	Preferential remineralisation of elements relative to carbon of dissolved organic matter (DOM) and particulate organic matter (POM)	High	Medium
Microbial solubilisation	Microbial respiration of dissolved and particulate organic material. The rate of solubilisation may be impacted by the microbial community and metabolic rates and growth efficiencies. Pressure, temperature and oxygen concentration, and other factors will impact these rates.	High	Medium
Particle characteristics	The size, morphology, porosity and density of particles which can affect their sinking speed and susceptibility to remineralisation, fragmentation or (dis)aggregation (excluding the role of ballast).	High	Medium
Particle type	The type of particle (e.g. fecal pellet, aggregate, single cell, carcass, mucus web) will affect the sinking speed and susceptibility to remineralisation or fragmentation/aggregation.	High	Medium
Zooplankton vertical migration	Daily vertical migration of zooplankton between euphotic and mesopelagic depths. Also referred to as active flux, with excretion, egestion, respiration and mortality occurring in the mesopelagic.	Medium	High
Fish-mediated processes	Daily vertical migration of fish and their contribution to flux via fecal pellet production.	Medium	High
Ontogenetic migration	Seasonal migration of zooplankton to mesopelagic depths where they remain over winter (also referred to as the lipid pump).	Medium	High

Mineral ballasting	Biomineral (biogenic silica, calcium carbonate) or lithogenic (dust) material which increases the specific density and sinking speed of particles.	Medium	Medium
Organic matter lability	Particulate organic matter and dissolved organic matter is composed of compounds of varying lability, with some more readily remineralised than others.	Medium	Medium
Zooplankton processes	Zooplankton particle interactions (e.g. grazing, fecal pellet production, coprophagy) excluding biotic fragmentation and diel vertical migration.	Medium	Medium
Ectoenzymatic hydrolosis	Microbial excretion of extracellular enzymes to degrade complex organic compounds.	Low	High
Viral infection	Viral infection of cells can lead to cell lysis. This may lead to the viral shuttle, i.e. increased secretion of sticky material promoting aggregation, or to the viral shunt, i.e. increased DOC production and a reduction in transfer of carbon to higher trophic levels.	Low	High
Abiotic fragmentation	Fragmentation of particles into smaller pieces by turbulence or shear.	Low	Medium

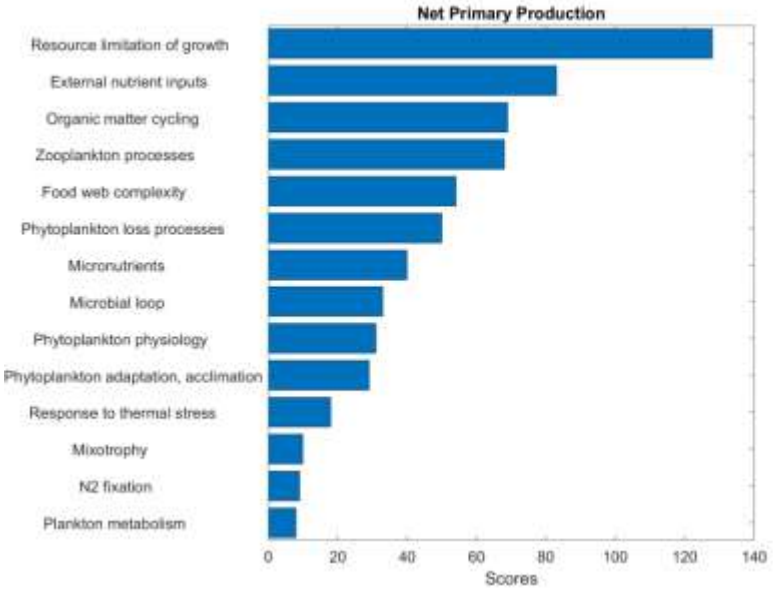
Biological contributions to alkalinity processes:

Process	Definition	Importance	Uncertainty
High level understanding of calcium carbonate production	e.g. the amount and distribution of biological CaCO3 production and its sensitivity to future environmental change.	High	Medium
Rain ratio	High-level controls on Particulate Inorganic Carbon to Particulate Organic Carbon (PIC:POC) ratio of export.	High	Medium
Mineralogy of calcium carbonate production	Production of calcium carbonates such as aragonite and high magnesium calcite which have higher solubilities than standard calcite.	Medium	High
Plankton community	Our understanding of and ability to represent calcifiers within the planktonic ecosystem models.	Medium	High
Fish derived carbonates	Carbonates produced in the guts of bony fish.	Medium	High
Biotically mediated dissolution	Dissolution of CaCO3 in zooplankton/fish guts and within fecal pellets and aggregates.	Medium	Medium
Abiotic dissolution	Dissolution of CaCO3 in undersaturated waters.	Medium	Medium

Riverine supply of alkalinity	Alkalinity input to the ocean via rivers.	Medium	Medium
Physiology of CaCO3 production	How CaCO3 is produced by different organisms.	Low	High
Sedimentary processes	Alkalinity fluxes across the sediment-water interface, in response to processes such as anaerobic sulphate reduction.	Low	High
Calcium carbonate within sea ice	Formation and dissolution of carbonates changing the total alkalinity to dissolved inorganic carbon ratio within sea ice	Low	High
Nutrient cycling	Processes beyond primary production and remineralisation such as nitrification/denitrification.	Low	Medium
Organic alkalinity	Contribution of weakly acidic functional groups present in Dissolved Organic Matter.	Low	Medium
Primary production and remineralisation	Assimilation and release of nutrients that contribute to total alkalinity.	Low	Low

2) Community survey results

A survey was circulated throughout the international community via newsletters, social media, direct emails etc. 120 responses were received. Respondents were asked to select their top three processes within each of the three focus areas on the basis of "importance", which was defined in the survey question as how significant these processes are likely to be for determining the future biologically-mediated storage of carbon in the ocean. The respondents were asked to focus on the global and centennial scales relevant to coupled climate models. Respondents were not required to answer all 3 sections if they felt their expertise wasn't sufficiently high. A total of 105, 88 and 61 respondents completed the sections on net primary production, interior remineralisation and biological contributions to alkalinity, respectively. In the charts below responses are weighted so that the 1st ranked choice = 3 points, 2nd ranked = 2 points, and 3rd ranked = 1 point.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N2 fixation
Plankton metabolism
0
20
40
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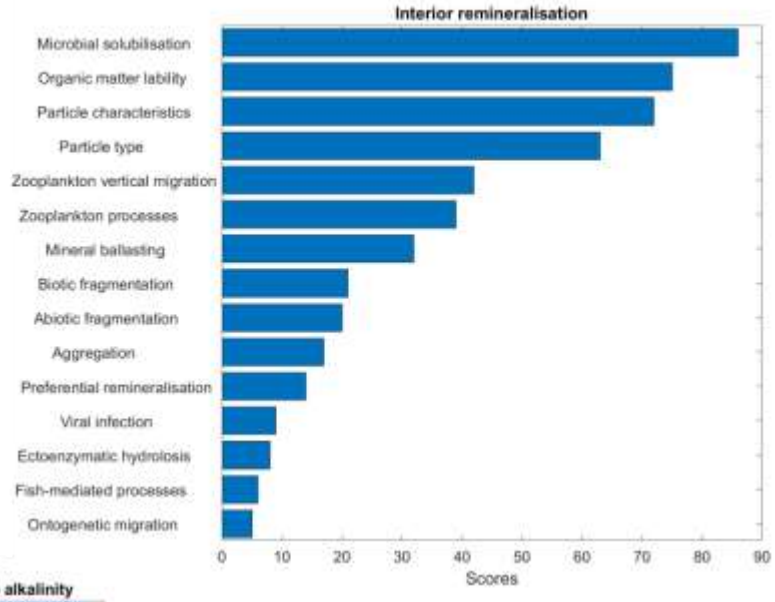
140
Scores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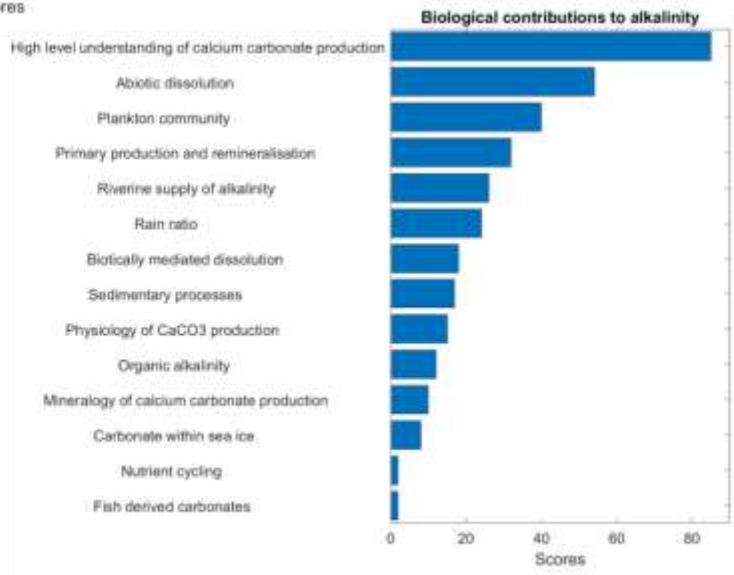
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