



Deliverable D3.1

WP Implementation Plan from discussions at first GA

29.02.2024/v1.0



About this document

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Table of contents

1.	Abstract.....	4
2.	Introduction.....	4
2.1.	General description.....	4
2.2.	Deliverables and milestones.....	5
3.	WP3 implementation	6
3.1.	Task 3.1: Impacts of climate stressors on surface production of biogenic matter.....	6
3.2.	Task 3.2 Impacts of climate stressors on downward particle fluxes...	8
3.3.	Carbonate Pump and Alkalinity Budget.....	9
3.4.	Transfer knowledge to modeling	10
3.5.	Critical risks for implementation	10
3.6.	Expected results	12
3.7.	Gantt Chart.....	13
4.	WP3 management	14
4.1.	WP3 management structure and routines	14
4.2.	Key performance indicators (KPIs)	14
5.	Interactions with other WPs	14



1. Abstract

This report outlines the implementation plan of WP3, describing the task to fulfil the scientific objectives of WP3.

WP3 investigates the impact of climate change on the biological carbon pump focussing on ocean warming (temperature), acidification (pH) and deoxygenation (O_2), but also on expected changes in wildfire intensity, ash deposition and associated changes in atmospheric nutrient input. The work in WP3 involves data synthesis, fieldwork, habitat and resilience model development. The overarching goal is to generate new understanding and parameterizations of the impact of variability in climate multi-stressors (T, pH, O_2 , aerosol deposition) in the biological carbon pump. Key results will be introduced to models in collaboration with WP6.

1. Examine impacts of climate stressors and changing atmospheric micronutrient input on surface production of biogenic matter
2. Determine the role of temperature, pH and oxygen downward in controlling large-scale patterns of particle fluxes
3. Assess the fate of Carbonate and the Carbonate Pump in a Changing Ocean
4. Transfer the new knowledge generated in WP3 to modelling

2. Introduction

2.1. General description

Climate change is expected to substantially alter the functioning of pelagic ecosystems and the ocean carbon cycle. Research over the past two decades has demonstrated that many species of phyto- and zoo-plankton are sensitive to changes in environmental parameters such as temperature, oxygen or pH, and that these responses can lead to shifts in food-web structure and affect biogeochemical cycles. However, there is still a major knowledge gap regarding the large-scale influence of changing climate stressors on food-web structure and carbon fluxes, e.g. how this might alter spatial patterns of primary production or carbon export.

The aim of this WP is to examine the impact of ocean warming (temperature, T), acidification (pH) and deoxygenation (O_2) and wildfire deposition, collectively termed climate multi-stressors, on fluxes of particulate organic and inorganic C from the surface ocean and through the mesopelagic zone. An overarching objective will be to identify how these key multi-stressors impact future ocean C fluxes, particularly on regional to global scales. The new knowledge acquired in this WP will permit development of novel model parameterizations, as well as the assessment of existing ones.



Major knowledge gaps for this WP are how climate multi-stressors will alter: (a) surface productivity and the quality (stoichiometry) of biogenic matter produced (including interdependencies with changes in micronutrient limitation through changes in atmospheric deposition of dust or ashes); (b) the elemental composition of vertical particle fluxes (C:N:Si:P stoichiometry) and element-specific remineralization length scales, which control large-scale nutrient (re)distribution and biotic C export; (c) the global carbonate (CaCO_3) pump, which has diverse contributors in terms of ecology, trophic strategy and sensitivity to different stressors, and is a key (but poorly quantified) term in the oceanic C cycle through its control on air-sea CO_2 fluxes and the alkalinity budget.

To address these significant knowledge gaps, we will conduct global-scale data synthesis, and obtain new information from fieldwork and experimental activities, thereby generating novel understanding of the impact of multi-stressors on the key biological elements of the ocean C cycle. New insights will be utilized in new model parameterizations and sensitivity assessments of these and existing parameterisations of key biological elements of the ocean C cycle.

Specifically, we will determine the impact of changing T, pH and O_2 on surface ecosystem functioning, organic matter production and the response to micronutrient addition (T.3.1), vertical fluxes of organic matter (export) and their stoichiometry (T.3.2), the contribution and future fate of cold water coral ecosystems in the deep sea (T.3.3), and the relative contribution and sensitivity to abiotic multi-stressors of pelagic organisms involved in the carbonate pump (T.3.3).

This new knowledge will be used to develop and test model parameterisation of production, vertical fluxes, and remineralisation length scales of particulate organic material (C, N, P), including mineral ballasting (Si, CaCO_3) and remineralisation/dissolution of these biominerals, under changing T, pH and O_2 conditions. This will be achieved by joint workshops with OceanICU and external partners and thereby directly feed into related tasks in WP6.

2.2. Deliverables and milestones

Deliverable #	Deliverable Name	Lead Beneficiary	Type	Due Date (month)
D3.1	WP Implementation Plan from discussions at first GA	GEOMAR	Report	16
D3.2	Parameterisations	GEOMAR	Report	34

OceanICU | WP3 implementation plan from discussions at first GA



Deliverable #	Deliverable Name	Lead Beneficiary	Type	Due Date (month)
	delivered to WP6 from WP3			
D3.3	Main Science Outputs of WP	HW	Report	44
D3.4	Summary of WP outputs	HW	Report	54

Milestone #	Milestone Name	Lead Beneficiary	Means of verification	Due Date (month)
11	Data transfer #1 from W3 to WP6	GEOMAR	Data sets archived	21
12	Data transfer #2 from WP3 to WP6	GEOMAR	Data sets archived	33

3. WP3 implementation

3.1. Task 3.1: Impacts of climate stressors on surface production of biogenic matter (Lead: ULPGC; Contributors: GEOMAR, Heriot Watt, Liverpool)

We aim to assess the impact of aerosol inputs (dust, volcanic ash, wildfire/biomass burning ash) on surface biogeochemistry and plankton community composition in different biomes, also taking into account the influence of multi-stressors (T, pH, O₂).

As part of this task and to run atmospheric aerosol deposition bioassay experiments, a microcosm experiment was conducted to understand the nutrient limitation or co-limitation in the offshore Canary waters. Seawater, collected off the eastern coast of Gran Canaria, was randomly distributed in polycarbonate Nalgene bottles and replete with nutrients in the following concentrations: Fe: 2nM FeCl₃; N: 5 μM NO₃⁻; FeN: 2nM FeCl₃ + 5 μM NO₃⁻; FeNP: 2nM FeCl₃ + 5 μM NO₃⁻ + 0.29 μM PO₄³⁻.

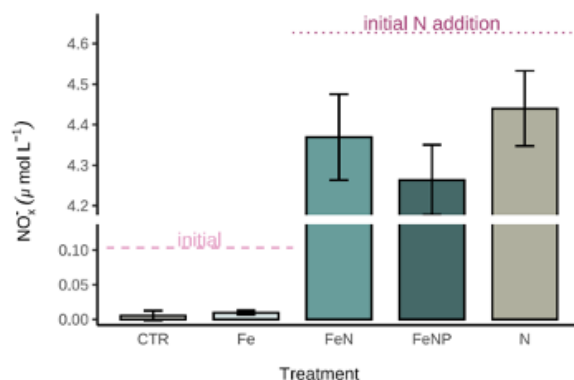


Figure 1. Nitrogen concentration (nitrate and nitrite) after 48-hour incubation in comparison to the initial seawater N concentration in treatments CTR, Fe (light pink line), and the initial N concentration added to treatments FeN, FeNP, N (dark pink line). After 48-hour incubation under natural irradiance and temperature regimes, plankton positively responded to macronutrient repletion while no change was observed upon iron addition (Fig. 1, Fig. 2). Bacteria and small phytoplankton benefited from nitrogen the most, increasing in abundance 1.5 and 2-fold, respectively.

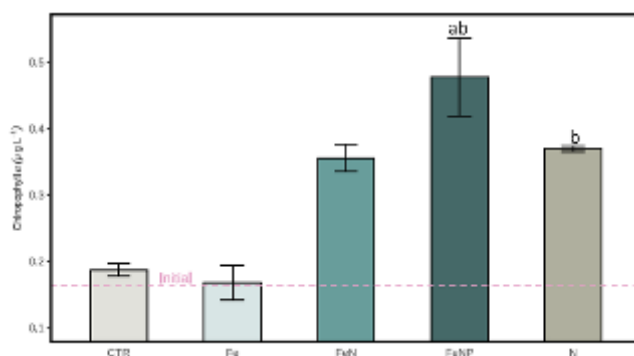


Figure 2. Photophysiological response in terms of chlorophyll-a concentration. The statistical significance of data was tested by Kruskal-Wallis test using Dunnet's test (a=significant to CTR; b=significant to Fe; c=significant to FeN; d=significant to FeNP; e=significant to N; or combined).

Based on this experimental outcome, it was decided to repeat the nutrient dissolution bio-assay experiments in four distinct periods of the year, of which the first will take place during the “spring bloom” of middle March 2024, thus obtaining detailed seasonal information of micro- and/or macronutrient limitation around the Canary Islands. Knowledge and experience acquired will serve to develop experimental work protocols to properly address how atmospheric deposition of aerosols (mineral dust, volcanic ash) impacts surface productivity and plankton community composition in biomes under climate multi-stressors (e.g. high T).



In parallel, bio-assay experiments of desert dust and volcanic ash addition under increasing temperatures, simulating the IPCC Representative Concentration Pathways (RCP) 6.0 (+1.5°C) and 8.5 (+3°C) predicted for 2100, will be conducted in the laboratory between the months of May and November of 2024.

Atmospheric aerosol addition experiments will also be carried out during the fieldwork on board of the R/V Sarmiento de Gamboa in the frame of the OceanICU oceanographic cruise from Walvis Bay (Namib) to Las Palmas de Gran Canaria (Spain), that will start on the 20th of March and end on the 18th of April of 2025.

3.2. Task 3.2 Impacts of climate stressors on downward particle fluxes (Lead: GEOMAR; Contributors: Heriot Watt)

We will quantify the influence of T, O₂, pH on vertical particle fluxes, their stoichiometry (C:N:P, including ballasting by CaCO₃ and bSiO₂) and element-specific remineralisation length scales.

To achieve this goal, we will examine the influence of T, O₂, pH on particulate C export, its efficiency (e-ratio) and flux attenuation using a global image-based dataset of particle fluxes from the Underwater Vision Profiler 5 (UVP5; Kiko et al. 2021). Machine learning tools will allow us to extrapolate identified relationships of T, O₂, pH and C fluxes to larger spatial and temporal scales.

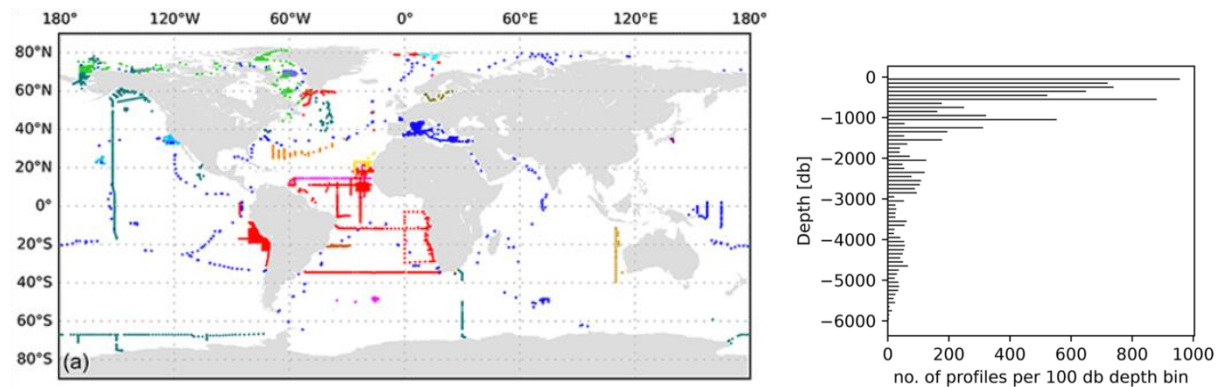


Figure 3. Spatial and vertical coverage of the UVP5 database. Particle profiles range from the surface to a maximum of 6000m depth.



Besides the magnitude of carbon flux and its attenuation, a second focus is the assessment of the stoichiometry (C:N:Si:P) of vertical particle fluxes and how this is controlled by T, pH and O₂. Therefore, we will analyze existing global compilations of sediment trap data (e.g. Mouw et al. 2016).

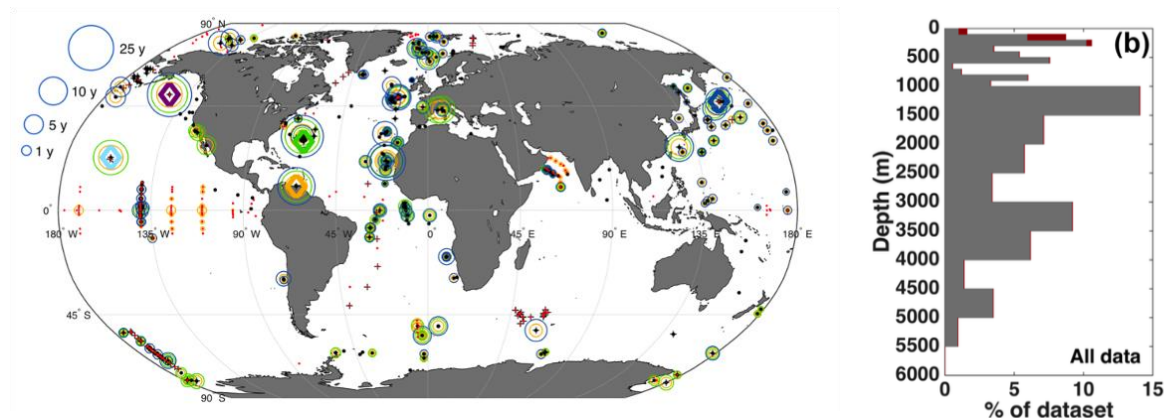


Figure 4. Spatial and vertical coverage of the sediment trap data compilation by Mouw et al., (2016).

This will permit the assessment of the influence of T, pH and O₂ on the change in stoichiometry of particle fluxes during sinking, including organic (C:N:P) matter and inorganic ballast (Si, CaCO₃). The associated enrichment of C due to differential remineralization of elements is a key factor determining the efficiency of the biological carbon pump on large spatiotemporal scales.

3.3. Carbonate Pump and Alkalinity Budget (Lead: Heriot Watt; Contributors: NUI Galway, Exeter, LSCE)

3.3.1 Benthic Carbonate Stores: Cold Water Corals (Lead: NUI Galway)

Assess and model the as yet poorly quantified standing stock of carbonate-forming deep-sea coral reefs/mounds in terms of contribution to the carbonate pump and resilience to multi-stressors including climate change. We will develop regional habitat suitability models using existing and new data to examine the global distribution of deep-water carbonate production in current and predicted future conditions

3.3.2 Carbonate Pump: Diverse responses to abiotic stressors (Lead: Heriot Watt)

Recognizing the biological diversity that underpins carbonate production and alkalinity cycling is essential for an assessment of the sensitivity of the carbonate pump in the future ocean (see Task 2.2 in WP2). This work will use literature synthesis, data compilation, expert workshops and meta-analysis approaches to assess the relative sensitivities of different pelagic calcifiers



(plankton to fish) to multi-stressors (temperature, oxygen, pH). Combined with an inventory of the relative contribution and roles of different pelagic calcifiers in the carbonate pump (Task 2.2), we will use this relative sensitivity information to run a ‘risk assessment’ of the carbonate pump under future climate change scenarios.

3.4. Transfer knowledge to modeling (Lead: ULIV; Contributors: GEOMAR, ULPGC, Heriot Watt, NUI Galway)

We will use the observations and data synthesis from T3.1 to T3.3 to develop model parameterisations linking production, vertical fluxes, and remineralisation length scales of particulate organic material (C, N, P), including mineral ballasting (SiO_2 , CaCO_3), to T, pH, O_2 and changing aerosol dust conditions for use in WP6. Activity will include an assessment of the contribution of wildfire deposition of iron to the carbon cycle and the provision of parameterisations to WP6. This will be achieved by joint workshops with partners in WP6, and thereby directly feed into related tasks T.6.3.

Modelling work on the modelling as part of T3.4 will use the NEMO PISCES-Quota-Fe model following the protocols of the Global Carbon project and will benefit from interactions with T3.1 around aerosol impacts and T3.2 and T3.3 for the testing of parameterisations of key processes in an initial NEMO-PISCES test bed.

The transfer of knowledge to modelers will occur in 2 steps - one early in the project (Milestone 11, month 21) and one towards the end of the project (Milestone 12, month 33). In addition, our data syntheses, new knowledge and parameterisations will be documented in Deliverables 3.2 (month 34) and 3.3 (month 44).

3.5. Critical risks for implementation

Risk number	Description	Proposed mitigation measures	Likelihood	Severity	Specific partners exposed
1	Cruise programme fails to occur due to COVID or increases in fuel prices (Low risk, low severity). Impact is no new	Fallback position of using extant data sets identified in plan, risk spread by	Low	Low	ULPGC GEOMAR HW



Risk number	Description	Proposed mitigation measures	Likelihood	Severity	Specific partners exposed
	<p>information regarding how key processes operate. Low severity as multiple datasets exist already, low risk as cruises mainly postponed not cancelled and we are not reliant on a single campaign.</p>	<p>operating on multiple vessels from different nations.</p>			
2	<p>Transfer of Information between WPs breaks down (low risk, high severity) due to COVID induced lockdowns preventing face to face meetings. Severity is high, efficient comms between experimentalists, modellers and data scientists is key to delivering the complex workflow. Low risk as project partners have worked together before and we will manage the transfer of information very carefully and monitor it very strongly.</p>	<p>Devote considerable resource in WP1 to monitoring the interactions between WPs. Staged approach to data transfer between WPs to ensure that there is some flex in the system and it is resilient to a milestone being delayed. Use VC based technologies for meetings if required.</p>	Low	High	<p>GEOMAR HW ULPGC NUI ULIV</p>



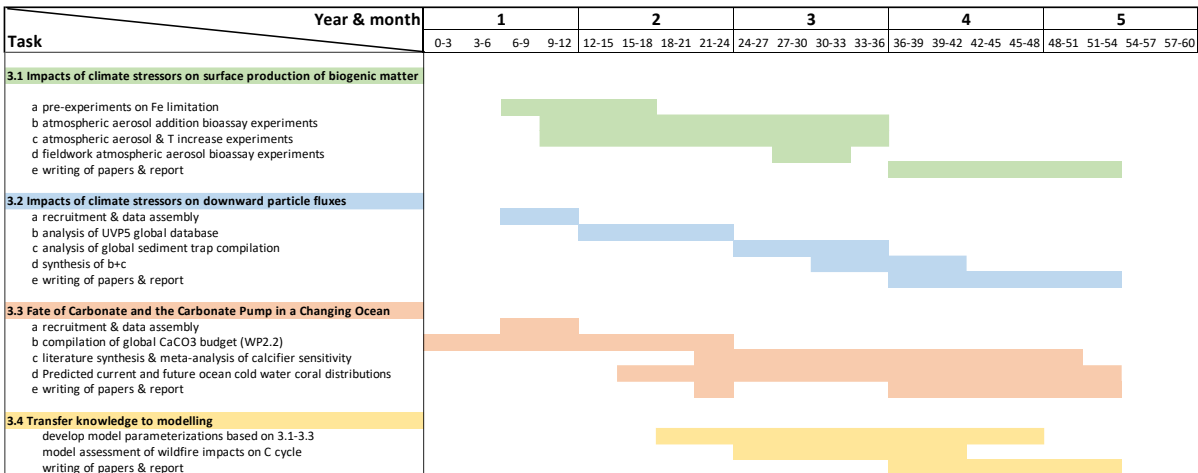
3.6. Expected results

#Identifier	Result	Partner responsible	Expected time
1	Assessment of atmospheric deposition of aerosols under a warming ocean on surface productivity and plankton community structure, based on bioassay experiments	ULPGC	M36
2	Global analysis of environmental control on C flux attenuation based on the UVP5 database	GEOMAR	M24
3	Global analysis of environmental control on flux elemental stoichiometry based on the sediment trap data compilation	GEOMAR	M36
4	Meta-analysis of the sensitivity of different pelagic calcifiers to changing ocean temperature, pH and deoxygenation	HW	M44
5	Risk assessment of the future of the carbonate pump based on global assessment of contributing organisms (see WP2) and synthesis of impact of climate stressors on different organisms	HW	M50
6	Predicted current and future ocean cold water coral distribution and	NUI	M42



#Identifier	Result	Partner responsible	Expected time
	implications for coral sequestered carbon		
7	Suite of preliminary model parameterizations for WP6, based on results from T3.1 to T3.3 (until M48)	all	M34
8	Model-based assessment of the contribution of wildfire deposition of iron to the carbon cycle	ULIV	M42

3.7. Gantt Chart





4. WP3 management

4.1. WP3 management structure and routines

WP3 partners will have regular monthly meetings to share scientific updates, discuss administrative or logistical issues and to host short science talks by WP partners. The WP co-leads will also participate in quarterly WP lead meetings organised by the project office and PI, as well as the annual general meetings organised by the project office.

WP co-lead	GEOMAR, Jan Taucher
WP co-lead	HW, Alex Poulton
Task 3.1 lead	ULPGC, J. Arístegui
Task 3.1 contributors	GEOMAR, Jan Taucher HW, Alex Poulton ULIV, Alessandro Tagliabue External collaboration with University of Tasmania
Task 3.2 lead	GEOMAR, Jan Taucher
Task 3.2 contributors	GEOMAR, Jan Taucher HW, Alex Poulton
Task 3.3 lead	HW, Alex Poulton
Task 3.3 contributors	NUI, Anthony Grehan Collaborations with Uni Exeter, LSCE
Task 3.4 lead	ULIV, Alessandro Tagliabue
Task 3.4 contributors	GEOMAR, Jan Taucher ULPGC, J. Arístegui HW, Alex Poulton NUI, Anthony Grehan

4.2. Key performance indicators (KPIs)

WP3 contributes directly to KPIs 1, 2, 3, 6, 8 and 11, and may additionally contribute to KPIs 12-21 depending on involvement of partners with international efforts such as IPCC, WOA etc.

5. Interactions with other WPs

WP3 will interact most closely with WPs 2, 4 and 6, but also have exchange with all other WPs. In particular, WP3 will supply parameterisations and datasets to WP6 for implementation and testing in the modelling work. WP3 will ensure that the new knowledge and results are able to support model



development and validation (e.g. do new parameterizations improve model-data fit?). WP3 members attended a modeling workshop (organized by WP6) and are in regular exchange with WP6 leaders for advice on how to transfer results from WP3 into model parameterizations.

Furthermore, we will collaborate with WP4 to understand the interplay between the influence of climatic factors and ecosystem factors on the biological cycling of carbon. Further collaborations is ongoing with WP2: Specifically Task 3.3 (Carbonate and Carbonate Pump) is closely aligned with activities in Task 2.2 (Biological vs Physical Controls on the Ocean C sink in key regions) and the subtask around 'Reassessing the carbonate pump and its biological controls'. Task 2.2 will determine the magnitude, dynamics and contributing organisms (plankton to fish) to the carbonate pump, while Task 3.3 will determine the sensitivity of these contributing organisms to abiotic changes. Additionally, Work in WP3 Task 3.4. will deliver an assessment of the carbon cycle contribution of wildfire ash deposition that will contribute to the budget work in WP2 and undertake testing of new parameterisations to ensure efficient integration into WP6 activity.