ASSEMBLE

ASSOCIATION OF EUROPEAN MARINE BIOLOGICAL LABORATORIES EXPANDED

Acronym: ASSEMBLE Plus

Title: Association of European Marine Biological Laboratories Expanded

Grant Agreement: 730984

Deliverable 2.9

Final project report including access report

September 2022

Lead parties for Deliverable: SU
Due date of deliverable: M60
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GENERAL DATA

Acronym: **ASSEMBLE Plus**

Contract N°: **730984**

Start Date: **1st October 2017**

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Dissemination Type

Report	☒
Websites, patent filling, etc.	☐
Ethics	☐
Open Research Data Pilot (ORDP)	☐
Demonstrator	☐
Other	☐

Dissemination Level

Public	☒
Confidential, only for members of the consortium (including the Commission Services)	☐

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Document properties

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Abstract

This deliverable is the final report of the work carried out in the ASSEMBLE Plus project in its Networking Activities (WP3-WP6), Joint Research Activities (WP7-WP11), and in the Transnational / Virtual Access programme (WP12-WP33).

For each work package, this report provides the preparation and implementation of the activities carried out, how these reflected the overarching objectives of the project.

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1. Introduction

ASSEMBLE Plus aims to create a network of key marine biological research stations around the European coastline. The goal is to enable European biologists to study a range of unique coastal ecosystems and a wide variety of marine organisms using the most advanced approaches in modern biology, providing paid access to the participating institutions (Transnational Access or TNA) for researchers. The project addressed the need for researchers to access both marine stations for experimental purposes and to gain access to marine organism.

The Networking Activities (NAs) strengthen the culture of cooperation within and beyond the consortium, providing benchmarks for refined practices of service provision, disseminating interoperable protocols, engaging with novel user communities and sharing insights into business strategies.

The five Joint Research Activities (JRAs) were included in ASSEMBLE Plus with the objective of increasing the quality and quantity of TA of improving interoperability across the partnership and of fostering scientific integration across the consortium.

Transnational Access in ASSEMBLE Plus is provided to a total of 36 marine stations in 15 countries. The stations provide access to a high diversity of marine environments; from the high Arctic (IOPAN) and Antarctic (NERC-BAS) to the tropics (IUI and NIOZ-CNSI) and the mid-Atlantic ridge (CCMAR and IMAR). Within mainland Europe, access is provided to the Mediterranean, the Atlantic and the Baltic seas. Habitats comprise estuaries (e.g. SZN, ISMAR, CCMAR, AWI, IOPAN, UG), mega-tidal seas (SBR), cold-water coral reefs (KMRS, NUIG, SAMS), brackish seas and sea ice communities (IOPAN, TSZ, ARI, HBS), near-shore deep sea (HCMR, IMEV, NUIG, UGOT, SAMS) and volcanic seeps (high CO_2 – low pH; HCMR, SZN, IMAR). The TNA-providing stations (access providers) have modern research laboratories and a wide array of specialized research facilities to support internal and external users. Several of these also have technological backup of nearby university institutions.

Facilities include sampling and field access, biochemical and biological analysis, maintenance and culture of organisms, microscopy, molecular biology and bioinformatics. Biological resources encompass culture collections (OOB, SBR, MBA, SAMS, TZS) and bio-specimen banks (PiE-UPV/EHU). All stations host resident faculty and support personnel, engaging in cutting-edge science, e.g., on sea mammals (SOI, UG), sea turtles (SZN) and various finfish (HCMR, CCMAR, MSS).

Due to the diversity of access provided and the number of partners, a key issue of this project is to provide excellent coordination, harmonisation and quality management of access to ASSEMBLE Plus services and resources. Attention is paid to optimise interoperability with cognate initiatives offering complementary access programmes. Best practices for service provision are disseminated throughout the consortium, notably via thematic workshops but also efficient internal communication.

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2. Objectives

This deliverable is intended to report the activities performed during the ASSEMBLE Plus aimed at reaching the specific objectives of the project:

1. Enhance transnational access to a coordinated set of state-of-the-art European infrastructures for marine biology and ecology
2. Improve service provision by these infrastructures in line with their areas of excellence in marine biology and ecology, with emphasis on developing novel key enabling technologies and data solutions
3. Strengthen complementarity and interoperability within the consortium and with related infrastructures
4. Lay the logistical and strategic foundations to expand the coverage of the European Marine Biological Resource Centre (EMBRC) in both its scope and its geographical distribution and to consolidate its long-term sustainability.

3. Management and communication

3.1. Management

The management of the project was done by the Project Manager (PM) with the support of Sorbonne Université legal and financial departments. Besides the regular administrative follow-up of the project and providing advices and guidance when requested, a significant work was carried out to prepare the third and fourth amendments of the Grand Agreement.

The project manager changed in April 2020 and in October 2020 the current project manager took over the leadership of the administrative tasks. The transition was smooth as the Liaison Officer along with the Scientific Coordinator have profound understanding of the project and follow all the tasks quite closely.
The project manager assisted by the other members of the management team undertook the following tasks:

- Monitor progress of WPs, including review of scientific deliverables. Supervision of overall performance of the project.
- Monitor progress relative to milestones. Manage executive issues and warn the coordinator in time of any emergent problems.
- Logistical support of project meetings (agenda, bookings, minutes, etc.)
- Support the discussion of recommendations from the EC, external reviewers and Advisory Board.
- Organise 2nd, 3rd, 4th and Closing Assembly and meetings.
- Oversee redaction of periodic technical reports to the EC.

The project management team has also carried out continuous and fluent discussions with the EC representatives, to keep them informed about the progress of the project, and to ask them for guidance in relevant issues. Administrative issues and updates were timely discussed inside the consortium and, summing up, SU tries at all times to provide guidance and help anytime these are needed inside the consortium.

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3.2. Communication

Task 2.4. Internal Communication. Leader. Task leader: SU (assisted by AquaTT)

The objectives of this task were to manage the internal communication of the project objectives, partnership, expected impacts, outputs and results of ASSEMBLE Plus, facilitating communication flow of project partners and the development and updating of a plan for internal communication (DEP).

- The ASSEMBLE Plus project logo suite and its associated brand guidelines were completed by AquaTT in Reporting Period 1 (RP1) by M3 – December 2017. The presentation templates for both oral and poster presentations were developed to promote the project during partners' communication and dissemination activities. Basecamp was set up as the project intranet along with its user guide by AquaTT in RP1: M4 – January 2018. Basecamp has been used throughout the project for internal communication and archiving, allowing all partners to get involved at the work package level, sharing documents as well as discussing and allocating tasks. The full project portfolio of promotional material is available on the ASSEMBLE Plus website under Work Package Reporting and from the project intranet Basecamp.
- The ASSEMBLE Plus Communication, Dissemination and Exploitation Plan (D2.4 DEP) was submitted on time in RP1 at M3 – December 2017. The DEP summarises strategic and concrete actions related to internal communication and dissemination activities, describing the activities performed and dissemination and exploitation means being used to promote ASSEMBLE Plus as well as exploit project results, addressing all WP2 objectives. The DEP is a practical handbook for everything to do with the project communications, protocols on different communication and dissemination activities, with easy to find information for partners to know what their obligations are as a partner. D2.4 has been reviewed for effectiveness and updated at reporting stages in M36 - September 2020, and most recently in M60 – September 2022. V3 was distributed by AquaTT to all partners for review and suggested updates. In particular, updates included an update of the Advance Notice Protocol, an update of Intellectual Property Rights (IPR) and Patents, a progress update of the Knowledge Management and Transfer process, inclusion of the Internal Code of Social Media conduct, adjustments according to feedback from the previous phases of the project to ensure effectiveness of efforts going forward post-project. All partners were also reminded of their obligations post-project. D2.4 DEP is also available on the ASSEMBLE Plus website under Public Deliverables.

Task 2.5. External Dissemination and Exploitation Activities. Task leader: AquaTT.

The objectives of this task were to manage external communication, outreach and dissemination of the objectives, partnership, expected impacts, outputs and results of the project, implementation of public relations and outreach activities, develop and update a detailed plan for external communication, dissemination and outreach, aiming to build a large and responsive community of stakeholders for the uptake of the project's outputs and participating in the networking activities.

A portfolio of communication and dissemination resources and tools was developed in the first year of the project to facilitate promotion and widespread awareness of the project. As already detailed in Task 2.4 above, the ASSEMBLE Plus project logo suite and its associated brand guidelines were developed along with a project factsheet, promotional poster, presentation templates for both oral and poster presentations, graphics and branded merchandise to help promote the project during partners' external communication and dissemination activities. All official project portfolio material carries the reference to EU funding, and partners are regularly reminded to include it in their

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dissemination activities also, including in publications and presentations at events. Dissemination activities and external strategic communication is carried out on an ongoing basis by all partners across the full project duration. These activities are designed to raise awareness of the project, its objectives, partnership, activities and intended impacts. Task 2.5 is led by AquaTT as professional science communicators and knowledge managers and involves all consortium partners.

As already detailed in Task 2.4 above, D2.4 DEP also summarises strategic and concrete actions related to external communication and dissemination activities, describing the activities performed and dissemination and exploitation means being used to promote ASSEMBLE Plus as well as exploit project results, addressing all WP2 objectives. A practical handbook for everything to do with external communications of ASSEMBLE Plus. The most recent update in M60 – September 2022 included an updated H2020 EU emblem disclaimer text to include the correct funding agency, update of the dissemination resources and tools, updated dissemination statistics, adjustments according to feedback from the previous phases of the project to ensure effectiveness of efforts going forward post-project. All partners were also reminded of their obligations post-project. D2.4 DEP will be made available on the ASSEMBLE Plus website under Public Deliverables.

Associated with the DEP is the collection and collation of all ASSEMBLE Plus publications, dissemination and communication activities from M1 to M60 (October 2017 – September 2022), through means of the ASSEMBLE Plus Continuous Reporting Dissemination Activities template. SU manages the Continuous Reporting, compiling all information that each individual partner provides on their activities for each RP. All publications have been uploaded to the EC Funding and Tender Opportunities Portal, project website and to the open access repository the ASSEMBLE Plus Publications Collection and their associated datasets in the ASSEMBLE Plus Data Collection, for more detailed information on ASSEMBLE Plus publications see WP4 – Task NA2.2.

In addition, several partners have attended high profile conferences and events representing the ASSEMBLE Plus project and promoting its results; from October 2017 to September 2022 a total of 1,389 dissemination and communication activities were recorded by ASSEMBLE Plus partners, with an estimated reach of almost one million stakeholders. Up to the end of September 2022, the following dissemination and communication activities carried out by ASSEMBLE Plus partners were captured:

Organisation of a Conference	3
Organisation of a Workshop	10
Press release	53
Non-scientific and non-peer-reviewed publication (popularised publication)	35
Exhibition	5
Flyers	37
Training	6
Social Media	930
Website	113
Communication Campaign (e.g. Radio, TV)	52
Participation to a Conference	34

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Participation to a Workshop	12
Participation to an Event other than a Conference or a Workshop	26
Video/Film	11
Brokerage Event	6
Pitch Event	5
Trade Fair	1
Participation to activities organised jointly with other EU project(s)	10
Other	40
TOTAL	**1,389**

The reach per stakeholder type over the same period, is estimated[1] as:

Scientific Community (Higher Education, Research)	103,113
Industry	13,478
Civil society	4,040
General Public	778,399
Policy Makers	10,835
Media	29,333
Investors	25
Customers	50
Other	28,310
TOTAL	**967,583**

- The ASSEMBLE Plus Stakeholder Database was set up in RP1 and has been continuously maintained by AquaTT to engage with its community of stakeholders. The database is hosted on MailChimp and is compliant with the GDPR. Partners and stakeholders were encouraged to join the database by clicking on the 'Click here to subscribe' button on the website under News. During RP3, there have been 17 mailings, bringing the total number of mailings throughout the project to 56! As of September 2022, there are 452 contacts; 419 of which are subscribers, up by 113 subscribers since RP2!
- The ASSEMBLE Plus website (www.assembleplus.eu) was developed and delivered on time by VLIZ in RP1 and submitted as part of D2.5 in M12 – September 2018. In RP2, the website was further re-designed to improve functionality by VLIZ. In RP3, the website has been actively maintained and updated on a regular basis by AquaTT with support from EMBRC-ERIC and VLIZ carrying out general dissemination of ASSEMBLE Plus results, news, events and progress to engage with its community of stakeholders. All partners have been continuously encouraged to regularly disseminate through the project website and to notify AquaTT of any content that they would like shared. In RP3, the ASSEMBLE Plus website has had 35,215 visits, with 61,929 unique page views (see Figure 2 below) and 2,126 downloads of project outputs from the website (see Figure 3 below). The top 10 countries visiting the ASSEMBLE Plus website are shown in Figure 4 below and website visitors directed by social media channels are in Figure 5. The top five most viewed web pages were: 1)

[1] Estimation was based on input from all partners who estimated the reach per stakeholder group for each activity they undertook. Often the reach was challenging to know and so could have been underestimated.

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Transnational Access (33,800 views); 2) Research (13,115 views); 3) Partners (5,318 views); 4) Activities (3,365 views) and 5) News (2,796 views), see Figure 6 below.

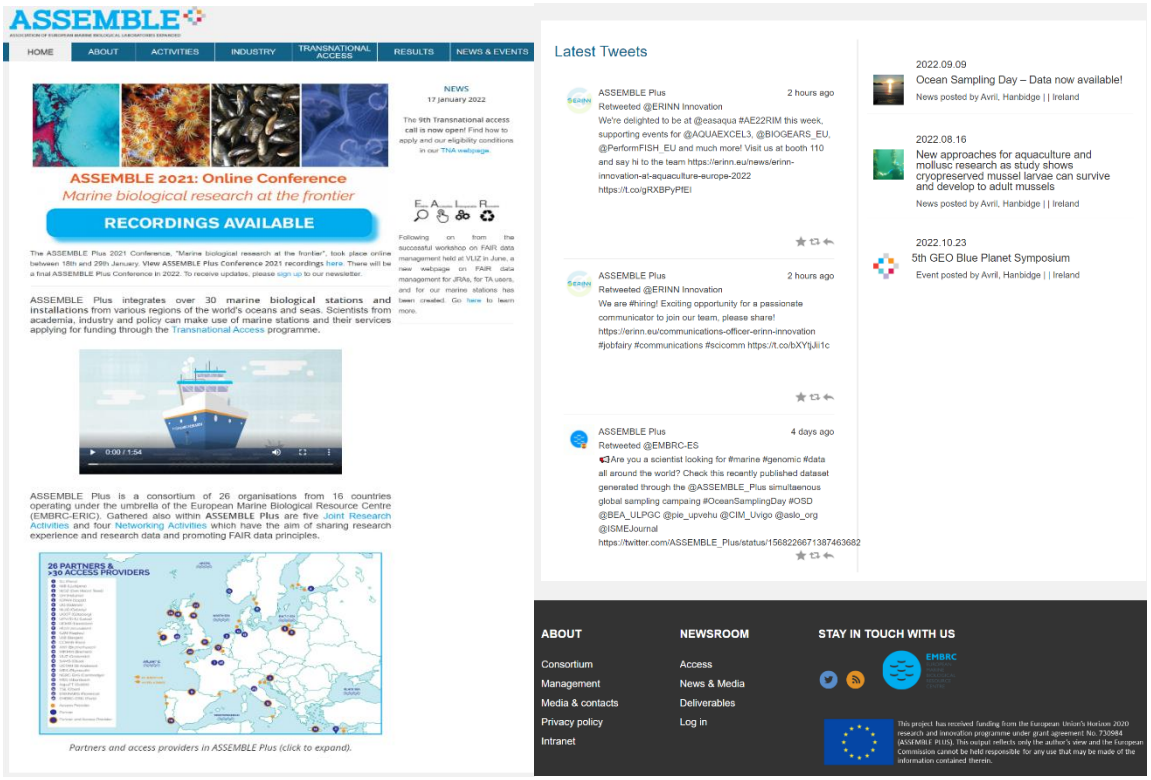

Figure 1. ASSEMBLE Plus website homepage.

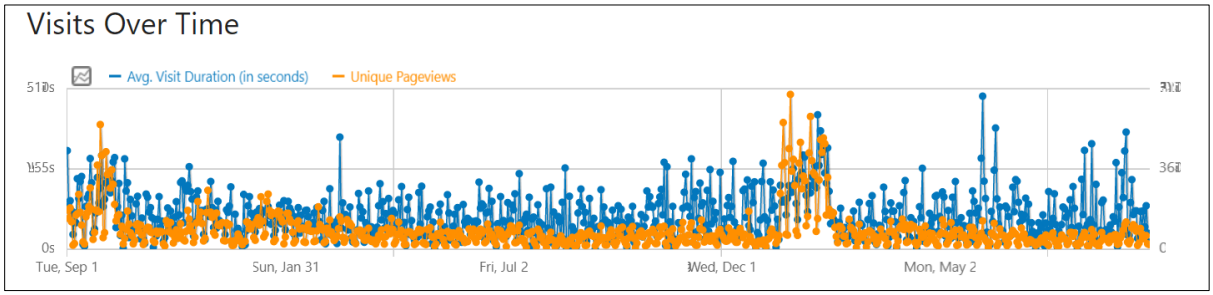

Figure 2. ASSEMBLE Plus website – Visitor overview: with 35, 15 visits and 61, 29 unique page views in RP3.

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DOWNLOADED OUTPUT	NUMBER OF DOWNLOADS
Transnational Access - Application step by step	394
Transnational Access - 4th call Flyer	373
ARMS - Handbook	233
ARMS - MSOPs	109
Public Deliverables - D8.2 Cryomar Protocol Toolbox	103
ASSEMBLE Plus Conference 2021	84
ARMS - ABS How To	55
ARMS - DMP	48
ARMS - MTA	33
OSD - Handbook	31
Public Deliverables - D2.3 Risk Management Plan	26

Figure 3. Most downloaded project outputs from the ASSEMBLE Plus website.

Figure 4. ASSEMBLE Plus website - Visitor location map and top 10 countries visiting the ASSEMBLE Plus website in RP3.

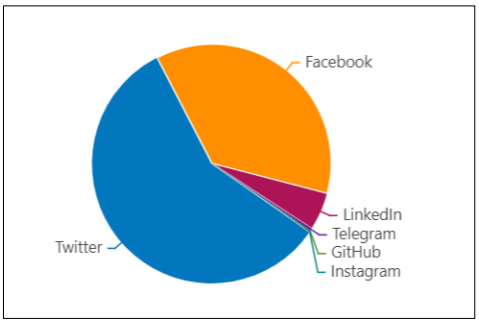

Figure 5. ASSEMBLE Plus website visitors directed by social media channels in RP3.

PAGE	PAGE VIEWS
Transnational Access	33,800 (55%)
Research	13,115 (21%)
Partners	5,318 (9%)
Activities	3,365 (5%)
News	2,796 (5%)
Results	2,955 (5%)
About	2,655 (4%)

Figure 6. ASSEMBLE Plus website most viewed webpages in RP3.

- Within the footer, the ASSEMBLE Plus website contains the EU funding acknowledgement, a link to the EMBRC website and a link to the password protected intranet, Basecamp which is the main internal communication tool of the consortium and is actively used (see Figure 7 below).

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Figure 7. ASSEMBLE Plus website footer.

- Updated webpages by AquaTT in RP3 include: under Activities → Research → Ocean Sampling Day; under Transnational Access → Success Stories *(Figure 8 below)*; under Results → Knowledge Transfer Platform - State of the Science Stories *(Figure 9 below)*; Public Deliverables and Work Package Reporting; under News & Events → News, Events, Newsletters and Press releases.

Figure 8. The Success Stories of the ASSEMBLE Plus Transnational Access Programme webpage.

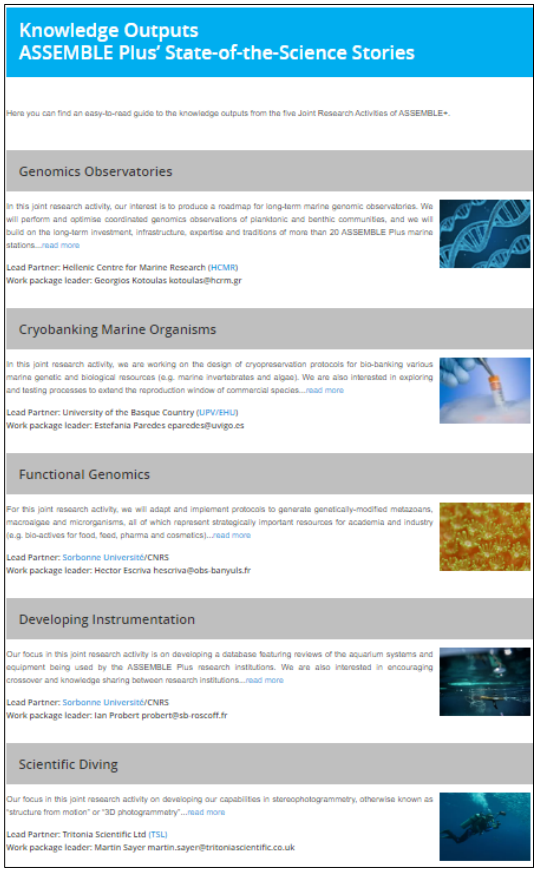

Figure 9. The Knowledge Transfer Platform - State of the Science Stories webpage.

- Press releases and promotional news articles have been developed throughout the project based on results highlighted by WP leaders, including articles for event promotion. In RP3, AquaTT and other partners have also produced a number of press releases and promotional articles at regular intervals and distributed via a range of dissemination channels such as the project website, social media channels and newsletters. AquaTT have continued to support partners with their ASSEMBLE

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Plus communication activities where requested. During RP3, nine press releases were published, bringing the total number of press releases published throughout the project to 23! All press releases are available on the ASSEMBLE Plus website under News and under Press Releases. Some examples of press releases by partners in RP3 include:

- Network of artificial reefs provides valuable data for monitoring ocean ecosystems, including early detection of non-indigenous species – 8 December 2020.
- Studies find that higher temperatures have an adverse effect on mussels – 23 February 2021.
- Sea urchins recorded attacking and consuming predators far larger in size – 12 May 2021.
- Discovery of new marine worm species as part of Horizon 2020 project, ASSEMBLE Plus – 5 October 2021.
- ASSEMBLE Plus Transnational Access, 9th and Final Call for Access – 18 January 2022
- ASSEMBLE Plus Industry Consultation – 7 April 2022.
- New approaches for aquaculture and mollusc research as study shows cryopreserved mussel larvae can survive and develop to adult mussels – 16 August 2022.
- Ocean Sampling Day – Data now available! - 9 September 2022.
- EMBRC to continue the work of ASSEMBLE Plus: Stimulating European excellence in marine biology and ecology research - 13 October 2022.

Some examples of promotional news articles by partners in RP3 include:

- EMBRC launches its new website (November 2020 – EMBRC-ERIC).
- Network of artificial reefs provides valuable data for monitoring ocean ecosystems, including early detection of non-indigenous species (December 2020 – UGOT).
- Ocean Sampling Day 2021 (May 2021 – HCMR).
- ASSEMBLE Plus researchers deliver findings and protocols to support future genomics research (November 2021 – OOB).
- ASSEMBLE Plus Conference 2022 - Marine biological research at the frontier - Registration now open! (May 2022 – CCMAR).

- AquaTT has maintained ASSEMBLE Plus social media, regularly updating the dedicated ASSEMBLE Plus Twitter account (set up in RP1), disseminating through LinkedIn, promoting ASSEMBLE Plus activities and results as well as connecting and interacting with related projects and relevant academic, industry, policy and regulatory bodies. All ASSEMBLE Plus partners have been encouraged to regularly disseminate through the project communication channels and to notify AquaTT of any content that they would like shared. For the purpose of EU visibility, and considering the space restrictions of Twitter, the project Twitter page (@ASSEMBLE_Plus) contains a pinned tweet which acknowledges EU H2020 funding: "This project receives funding from the @EU_H2020 Research & Innovation Programme under GA no. 730984 (ASSEMBLE PLUS). Any tweets reflect only the views of the project owner". Different hashtags (#) are created for various activities and communicated to the partnership. As of September 2022, the account has 984 followers (up by 159 followers in the last year!) and 1,254 tweets (up by 835 tweets, tripled in the last year!), showing its commitment to frequent and quality communication to stakeholders.

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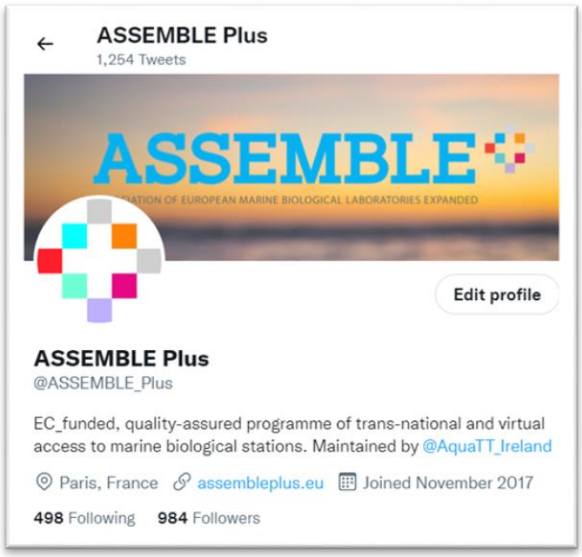

Figure 10. ASSEMBLE Plus Twitter account in M60 – September 2022.

- The ASSEMBLE Plus project video was developed and submitted on time in RP1 on 4 September 2018 by AquaTT as part of D2.5 Project Website and Video in M12 – September 2018. The aim of the video is to introduce and promote the project. The video was uploaded to the ASSEMBLE Plus website's homepage and to AquaTT's accounts of YouTube and Vimeo. In RP3, AquaTT and other partners continued to promote the video to raise awareness, attract interest in and promote the marine stations and their access opportunities. In RP3, the video was broadcast at the ASSEMBLE Plus Conference 2021 and 2022 which had a combined audience of over 400 attendees from over 50 countries! As of September 2022, the video has 512 views on Vimeo (up by 164 views since RP2) and 62 views (up by 62 views since RP2) on YouTube.
- The ASSEMBLE Plus Newsletters designed and developed by AquaTT, based on contributions from partners, compile the news, reports, events and outcomes of the project. The project newsletter is a tool for promoting the project, its objectives, partners, progress and results as well as other relevant marine biology-related news aiming to reach a wide audience including all partners, stakeholders and possible end users. Five issues have been developed, published and distributed throughout the project: Issue 1: M8 – May 2018; Issue 2: M12 – September 2018; Issue 3: M27 – December 2019. In RP3, Issue 4 was published in M43 – April 2021 and Issue 5 at the end of the project in M60 – September 2022. The newsletters were shared and promoted through the ASSEMBLE Plus consortium and their networks, the ASSEMBLE Plus Stakeholder Database, Twitter, LinkedIn, AquaTT's network and other related projects. As of September 2022, the ASSEMBLE Plus Newsletter Issue 4 was opened at least 99 times, and Issue 5 opened at least 107 times. All issues are available on the ASSEMBLE Plus website under Newsletters and Work Package Reporting.

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Figure 11. ASSEMBLE Plus Newsletter Issue 4 published in M43 - April 2021.

Figure 12. ASSEMBLE Plus Newsletter Issue 5 published in M60 - September 2022.

- Throughout the project AquaTT also developed a selection of visual aids including banners, maps of Access Providers, icons and flyers to populate the website and support the advertisement of eight Transnational Access Programme calls. In RP3, it was decided to have one more call, the ninth and final call was launched in M52 - January 2022 and closed for applications in M53 - February 2022. AquaTT developed a flyer, map of Access Providers, a timeline graphic and a press release to promote the call, all promotional materials were shared with all partners to disseminate. To further attract applications to the Transnational Access Programmes, promotional profiles were developed to outline the types of services that are available at the various marine research infrastructures and testimonials from users were published on the ASSEMBLE Plus website as Success Stories and shared through social media.

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Figure 13. ASSEMBLE Plus Transnational Access Programme ninth call promotional flyer.

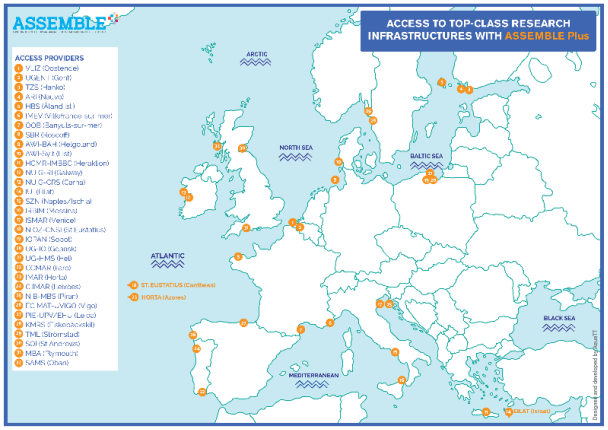

Figure 14. Map of Access Providers in the ninth call of the ASSEMBLE Plus Transnational Access Programme.

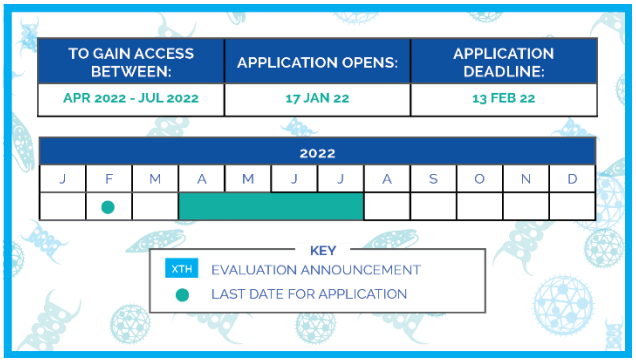

Figure 15. ASSEMBLE Plus Transnational Access Programme calendar for the ninth call.

3.3. Transnational Access

Activities and outcomes of the Transnational Access programme are described in the paragraph 6 further below in this document.

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Networking Activities (NAs)

3.4. Improving TNA provision – NA1

WP-activities to improve the Transnational Access (TNA) provision included two tasks on enabling Access to the research facilities, resources and services offered in the ASSEMBLE Plus Consortium. NA1.1 enabled the granting, regulation and support of TNA projects; NA1.2, the setting up of a single-access point to the offer. Three additional tasks focused on improving TNA. These tasks comprised the testing of service-pipelines through ASSEMBLE Plus and cognates in joint calls (NA1.3), sharing of best practices in the service provision across ASSEMBLE Plus partners (NA1.4), and improving the efficiency of the service provision (NA1.5).

Task NA1.1. Grant, Regulate and Support TA: Lead partner SZN, with input from UGOT and SU

SZN and SU delivered the documents and forms to regulate and support TNA, including the TNA policy document, the User Access Contract (UAC) template and forms and annexes needed for TNA projects (D3.1). The UAC stipulates what is provided by each Party, and what their rights and responsibilities are, including IPR. To support the Applicants-Users, staff involved at TNA at Access Providers as well as User Selection Panel members, NA1 published a TNA Policy Guide. It explains principles and specifies procedures for service provision, informs applicants how to apply, explains fair and transparent procedures to determine eligibility and feasibility of submitted proposals as well as the criteria used by the User Selection Panel members to rank the proposed projects. It specifically explained Access Providers and Applicants-Users how the template-UAC can be modified to their needs, how costs of TNA need to be charged, and how Users are reimbursed for their expenses. A “Frequently Asked Questions” page was available, and the Access Officer (assembleplus_ta@embrc.eu) could be contacted for questions not covered therein. Liaison Officers at each of the Access Providers could be contacted for queries about the technical feasibility of proposals prior to submission. All the documents were made available on the ASSEMBLE Plus TNA webpages. To obtain feedback from the Users following the execution of their TNA projects, Users were asked to fill out a TNA questionnaire. The documentation was updated where needed prior to each call, taking into account this feedback as well as constructive input from legal representatives of Access Providers and Users’ home institutions.

An issue was the perceived legal complexity of the UAC. Early career users often wondered why such a complex document was needed whereas at times legal staff wanted matters in it specified in even greater detail. Agreeing on the UAC needed time, often to the annoyance of users. It should be stressed that the template UAC had to be adapted for each project and the parties were free to simplify and modify it in mutual agreement according to the requirements of the projects, but the template was composed to accommodate a wide range of Users and types of TNA.

Another issue was a User preference for well-known Access Providers. The budget for TNA was distributed based on diversity of research services, ecosystem attractiveness, and institute size. In practice, Users preferred widely known marine stations with previous TNA experience (e.g., in ASSEMBLE-Marine). So, discrepancy emerged between “funding the best TNA projects at Users’ chosen Access Providers” and “enabling all Access Providers to use their allotted TNA budgets.” This was mitigated by asking Users if their project could be accommodated at alternative Access Providers,

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often even better equipped to fulfil their needs. Users were happy with the offered alternative or provided solid reasons why the first choice was required. A frequently stated comment was that they sought collaboration or wished to collaborate with or learn from the resident research community at the chosen Access Provider. In any case, promotion on the ASSEMBLE Plus website highlighted opportunities at all TNA Providers.

Another issue was reimbursement of Users for expenses of travel, sustenance and lodging as stipulated in the UAC. A few User's complaints arose because of tardiness from the side of the Access Provider's administrations. Many of the new Access Providers did have little, if any, experience with TNA programs and lacked procedures to reimburse external visitors for incurred costs. This issue was addressed in WSs in NA1.4. At times, Users failed to deliver correct or complete receipts and other documents needed for their reimbursement or were slow to deliver. Administrators were enticed to speedily reimburse Users, and Users were explained reimbursement requirements upfront upon their arrival.

Task NA1.2. Set up a single-access point to the offered infrastructure: Lead partner VLIZ, with input from SU

The original idea of the ASSEMBLE Plus Project Implementation Committee (PIC) was to use the service access system developed in the INFRADEV-2 project pp2EMBRC, implemented for EMBRC-ERIC by VLIZ as single-access point for TNA proposals for ASSEMBLE Plus. The system was launched at M3, prior to the first Call for TNA project proposals. However, apart from the fact that this system was still fine-tuned at the time, it was too focused on individual tools and instruments rather than on integrated services. This system turned out to be User-unfriendly, and made searches cumbersome, and prone to getting lost in superfluous details. Users do not want access to a Scanning Electron Microscope (SEM), but to a service facility equipped with a SEM, and staffed with experts assisting them.

Therefore, the PIC decided to use the INSTRUCT-ERIC based ARIA access system from the 4th to the 9th and final Call. SZN paid from its NA1-budget the ARIA annual subscription fee, and VLIZ, EMBRC-ERIC and SZN populated the ARIA's ASSEMBLE Plus Access website with the services offered at the Access Providers. Tools for submission of proposals, and their screening for feasibility, eligibility and scientific quality were on-line in the ARIA web-based system as well. The system allowed for flexibility and adaptation to the exigencies of individual TNA programs. ARIA is widely adopted for TNA in RIs and related Consortia, thus allowing Users to get used to the system.

According to the User feedback, minor "children's diseases" were encountered also in early versions of the ARIA system, especially issues related to functionalities used during project submission. These issues were duly reported to the ARIA web designers and fixed ASAP.

Task NA1.3. Test TA-pipelines through ASSEMBLE Plus and cognates in joint calls: Lead partner SZN, with input from UGOT and SU

At the start of ASSEMBLE Plus we assumed that many Users needed to perform complex TNA workflows through research infrastructure pipelines linking those in ASSEMBLE Plus with those in other Consortia (ERICs, their INFRAIA's), and that Users were interested in submitting single TNA projects in combined Calls for projects by multiple Consortia. So, Task NA1.3 called for testing such research

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infrastructure-pipelines by means of a joint TNA call." A survey was conducted to all our TNA Users up to the 5th Call to uncover such incompatibilities. Results showed that ca. 14% of the ASSEMBLE Plus Users utilised results, data, or material to carry out subsequent research in other Consortia. The list included CORBEL, SYNTHESIS+, LifeWatch ERIC, ELIXIR, FNR Project ALBINA and ASSEMBLE Plus itself. None of the Users had encountered any incompatibility issues.

When asked about the possibilities of applying to joint calls by ASSEMBLE Plus and other Consortia, interviewees expressed concerns about complicating the proposal submission process. "why not simply apply independently to both, mentioning linked proposals submitted elsewhere?" In addition, joint TNA-calls were hard to organise across sister RIs because of issues with timing of calls and independent selection procedures. Also, bilateral agreements between ASSEMBLE Plus and a few sister Consortia do not cover the plethora of potential workflows between ASSEMBLE Plus and the sheer galaxy of sister Consortia.

The Joint Calls were planned originally towards the latter part of the ASSEMBLE Plus project. However, given the aforementioned findings and given that COVID-19 hindered the TNA program from mid-2020 well into 2021, the Joint Calls were dropped and the TNA funds used to accommodate regular TNA proposals, which were already challenging to accommodate given the numerous delays due to COVID.

Funds and HR in NA1.3 were used to allow the WP-leader to present seminars about ASSEMBLE Plus and sister Consortia, and their TNA programs at marine biological conferences (e.g., EPC7, Zagreb). These seminars were organised within symposia focused on PhD students and other Early Career Scientists. Several attendants enthusiastically expressed their intention to apply for TNA right away. Users and attendants alike appreciated being made aware of possibilities to perform follow-up research projects in sister Consortia, enabling them to address possible incompatibility issues upfront. Many were unaware that they were allowed to apply for TNA in multiple INFRAIA Consortia.

Task NA1.4. Share Best Practices: Lead partner UGOT, with inputs from SZN and CCMAR

Delivery of top-quality scientific services is fostered by interoperation and sharing best practices across the partnership. Therefore, UGOT and SZN oversaw the organisation of workshops for service staff in the thematic fields of the JRAs and access management. Within the field of JRA1 (Molecular & traditional tools for ecological monitoring) the 1st WS (13-14/03/2018) was organised at CCMAR. Within JRA2 (Cryopreservation) the 1st WS (02/10/2018) was organised by UVIGO and the 2nd (26-27/06/2019) at SAMS. Within JRA3 the 1st WS (16-17/04/2018) was organised by SZN. Within JRA4 the 1st WS (09-10/01/2018) was organised at UGOT. Within JRA5 the 1st WS (21-24/05/2018) was organised at UGOT and the 2nd (4-5/12/2019) at HCMR. The 1st meetings within the JRAs were usually of an organisational nature and open mainly to involved partners whereas the 2nd ones were open to relevant, interested service staff from all partners. Subsequent face-to-face meetings were thwarted because of COVID-19, forcing JRA meetings and meetings between JRAs and staff of research services within the JRA-theme to be organised by e-means.

Regarding the TNA management, SZN organised the 1st TNA workshop for liaison officers (LO; SZN-Naples, 07-08/02/2018) to familiarise them with procedures and to harmonise these procedures across the Consortium; and the 2nd TNA workshop (07-09/05/2019) to review the procedures, share

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experiences and train post-access procedures. VLIZ organised an extra TNA workshop (12-13/07/2018) to resolve issues of the EMBRC access portal. There, the decision was shared to adopt the ARIA portal.

To foster networking among service staff: a competitive grant-scheme co-funded short sabbaticals and exchanges of service staff across the ASSEMBLE Plus Consortium. UGOT and SZN established rules and procedures for regulating the exchanges, which were published on the ASSEMBLE Plus website and disseminated to the partners, together with the launching of the calls through the newsletter and via email. UGOT organised three calls; In the 1st call six applications were received; five of which were approved. The 2nd call received 11 applications, all of which were approved, some with minor adjustments based on comments from the evaluators. The 3rd call was continuous for the remainder of the project and gathered three successful applications. Two members of the Scientific Advisory Board evaluated the proposals for their expected impact on the service provision at the Access Provider. Several Sabbaticals were planned for 2020 but delayed to 2021-22 or (unfortunately) cancelled because of travel- and hosting restrictions due to COVID-19. Many staff members informed us that they would have applied if there had been no pandemic. In addition, several exchange visits took place between partners in ASSEMBLE Plus using their own institutional funding.

SZN, with input from UGOT, SU, EMBRC-ERIC, VLIZ and from the JRA-leaders, wrote a report (D-NA1.2, M56) including chapters on the thematic fields of the JRAs. The chapters contain quality benchmarks, recommended policies, procedures, best practices, user feedback as well as technological advances in the thematic fields. Also included were results of a Gaps- and Redundancies- analysis in the service provision across the consortium, and a set of recommendations on which services must be provided internally in the Consortium.

Task NA1.5. Improving the efficiency of service provision: Lead partner UPV/EHU (UVIGO), with input from SU, MSS, UGOT, and SZN

In order to improve the quality of the service provision to the User community within the ASSEMBLE Plus areas of excellence in marine biology and ecology, UPV/EHU (UVIGO), with input from SU, MSS, UGOT and SZN performed an internal mapping of existing quality management systems, accreditations and certifications across ASSEMBLE Plus. Information was collected regarding history of external user access, challenges experienced and how these challenges were resolved to improve efficiency of service provision. The results from the 26 responding stations showed that 9 provided services to external users for the first time ever, 6 for the first time in TNA, and the remaining 11 had previous experience with TNA. A total of 16 of the 26 partners had the information about the provided services available online, and 8 of these had an online system to manage service requests. Regarding quality assurance, 7 stations lacked SOPs for service provision, 8 did not have any of the individual services accredited under a recognized norm, 9 did not have SOPs to handle service requests and 6 did not have a general service provision management system. And among those stations that had one, only in 2 the system was certified under a recognized norm (ISO 9001). Finally, the stations had various methodologies for setting the prices of their services, distinguishing most of them between types of users for pricing the services and only 10 stations had a staff member as Quality Manager. With respect to the staff performance, this is mainly evaluated by supervision evaluations (16 stations), followed by customer feedback (9), number of provided services (13) and publications (12). Finally, most of the

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training in quality management activities was channelled through short visits to other marine stations (14 stations) and Quality Management (QM) workshops (13), and with less relevance, webinars (7) and QM training onsite (4). Considering these results, there is a need to generate a Quality Management System (QMS) Manual to help Access Providers to improve their service provision.

The internal QMS manual has been produced by UPV/EHU (UVIGO) recommending shared good practices for implementation across the research services made available in the ASSEMBLE Plus Consortium, identifying issues that need novel quality management approaches. The report includes a set of criteria for a European draft certification standard for service provision at marine stations, as well as a program for implementing these standards. The original plan was to beta-test the standards in a restricted number of Access Providers, but this was abandoned because of travel- and visiting restrictions due to COVID-19 and because only a few Consortium partners would benefit from such beta-testing. Instead, the QMS manual can be used by the managerial staff of Research Services all across the Consortium.

Lessons learnt, exploitation of results, impacts

All the tools developed by Task NA1.1 were tested in the TNA calls and refined and updated where needed, based on input from Users and Access Providers alike. These revised and updated tools will serve to manage the User Access in the frame of EMBRC-ERIC as well as at individual ASSEMBLE Plus partners not in EMBRC. The feedback of the TNA questionnaire showed that TNA projects are well-adapted especially to early career scientists. They gain experience with proposal writing and submission, are pulled out of their comfort zone; they go abroad, learn to work with foreign scientists in different work environments. The access providers and the consortium management learned what services and procedures to improve and what services require increased capacity. Regarding Task NA1.2, the ARIA access system functioned to the satisfaction of the Users and Access Providers alike, though minor improvements are still being adopted. It will likely be adopted in the access provision webpages of EMBRC-ERIC, though requiring some further modification to accommodate a wider spectrum of User communities and types of access. The main lesson learned from the User questionnaire in Task NA1.3 is not to provide services and add complexity to access programs on which nobody is really waiting.

Regarding Task 1.4. Face-to-face workshops are challenging to organise among service staff given their busy work schedules and commitments. Yet, e-meetings form a low-Carbon, efficient-time investment for time-constrained staff, suited to establish contacts among peers, break the ice, and exchange experiences. Regarding the short sabbaticals, it forms a logical follow-up of the e-meetings. Fewer applications were received than expected, but reactions of those who used the program show they appreciated the concept. Also, the directions of marine stations value the opportunity for their staff to visit peers to share best practices on how to organise service facilities.

The report (D-NA1.2) serves as input for EMBRC-ERIC to set its strategy for service provision. However, technical recommendations from Task NA1.4 are not the only guides for institutional policy regarding strategic planning of their services; funding from national and other agencies is another, and so are local and regional stakeholder needs. Nonetheless, there are overarching common-sense recommendations with on one extreme side of the spectrum a minimum level of services necessary at

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each marine station and on the other extreme end services that can be provided faster, better and cheaper externally (e.g., those that are the core business of sister RIs and dedicated companies). Investing heavily in the latter would lead to unnecessary duplication of effort and inefficient investment in vanity projects. These are matters to be addressed at, for instance, the EMBRC-ERIC governance.

The internal QMS manual produced by UPV/EHU (UVIGO) in Task NA1.5 forms a legacy for all ASSEMBLE Plus partners. The stations in the national nodes of EMBRC-ERIC will be encouraged to implement its recommendations; these recommendations are voluntary. However, Users -especially commercial ones- may wish quality guarantees; auto-declaration of excellence will not do, and free market competition will weed out Access Providers failing to deliver at high standards. The proposed recommendations set ambitious goals, requiring full support of the operators' hierarchies and their stakeholder communities. If realised, these achievements will ensure the ability of researchers to push the frontiers of science, the RIs ability to support companies in innovation, and Europe's leadership in marine biological research.

3.5. Improving virtual access to marine biological stations data, information and knowledge – NA 2

WP4 is about improving virtual access to marine biological stations data, information and knowledge. This was accomplished by:

- Shaping an ASSEMBLE Plus community data management plan, and individual Joint Research Activity DMPs where appropriate
- Providing training materials and training sessions in FAIR data management for the ASSEMBLE Plus partners and Transnational Access (TA) users
- Improving virtual access to data resources from ASSEMBLE Plus stations, with a specific focus on genomic data from JRA1 and existing long-term biodiversity data series
- Working with JRA1 and external partners on the development of a virtual analysis platform as a service for genomic and biodiversity data analysis.
- Creating a database of services provided by the ASSEMBLE Plus marine biological stations to use for the Transnational Access WP, and an on-line system to provide access to that information and to apply for access

Task NA2.1. Data Management Plan (DMP)

An ASSEMBLE Plus community DMP was developed in the first year of the project and delivered as D4.1. This DMP contains recommendations on how to make scientific outputs (with a focus on data, but also including publications) Findable, Accessible, Interoperable, and Re-usable by publishing in community-recommended data archives, catalogues, and portals, by using standard data file formats, by using standard vocabularies, and by choosing appropriate data licences. The updated DMP D4.2 adds information about FAIR data training material for TA users and offered via the TA pages on the ASSEMBLE Plus website, and training material for JRA users that was developed from the WP4 training workshops (online and face2face) and that is offered via the JRA pages on the ASSEMBLE Plus website. The final DMP, D4.3, contains links to the DMPs that were developed for the two programmes of JRA1 – Ocean Sampling Day (OSD) and the Autonomous Reef Monitoring Structures (ARMS-MBON) – and a summary of the actually-performed data management activities of the TA users and the JRAs.

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Task NA2.2. Creating the Knowledge Transfer Platform (KTP)

It was initially unclear what the KTP would be. Most of the partners in ASSEMBLE Plus already had scientific outputs published in VLIZ's Integrated Marine Information System (IMIS) datasets and publications catalogues, and at first the focus was on classifying this material into the categories Aquaculture and Fisheries, Marine Technology and Energy, Technology and Instrumentation, Marine Sciences, and Climate Change and Environmental Management, with additional keywords added to more deeply classify the material within these categories. The thus-classified material was then to be organised in individual webpages on the ASSEMBLE Plus website. However, together with the fact that the vast majority of the available datasets and publications fell into the latter two categories, it was realised that focussing the KTP on simply classifying material this way was not a particularly useful approach, and would not help with the *transfer* part of the "KPT".

It was decided to split the focus of the KPT into two audiences: the scientific audience and everyone else. For the scientific audience, a search interface to the IMIS datasets and publications catalogues was provided on the ASSEMBLE Plus website, allowing a filtered search of the ASSEMBLE Plus collections: this including the records from the ASSEMBLE Plus partners already in IMIS (i.e., pre-existing the start of ASSEMBLE Plus), and also the JRA and TA outputs produced during the ASSEMBLE Plus timeframe. JRA and TA dataset records were linked to their related publication records wherever possible. The work of populating these catalogues with TA and JRA data and publications falls under task NA2.3, and the work on improving the FAIRness of these catalogues falls under task NA2.4 (see below for more detail on these tasks).

For the "other" audience – anyone from the general public to the commercial – a "State of the Science Stories" section was developed for Knowledge Outputs (KOs) from the project. This online platform provides a central tool for potential users to access ASSEMBLE Plus resources, promoting and exchanging information from the researchers, their expertise, services and their outputs with the relevant user stakeholder groups. The platform allows users with access to an unrestricted, user friendly and searchable database of outputs. Commencing in RP1 and continuing throughout the project AquaTT collected KOs from the project partners. The KOs produced by the project are presented on the ASSEMBLE Plus website under “Results” as the “State of the Science Stories”. In RP3, AquaTT regularly contacted the JRAs for progress updates on their KOs, the potential applications of these KOs and their pathways to impact, with AquaTT supporting these activities. The KTP was updated accordingly throughout the project. The ASSEMBLE Plus TNA Programme users were requested to provide their user reports covering why they applied to the Programme, where they carried out their access, what they achieved and the impact the Programme has had on their research. The user reports have continuously been uploaded throughout the duration of the project to the ASSEMBLE Plus website as the Transnational Access Programme Success Stories. In RP3, some Success Stories also featured in the ASSEMBLE Plus newsletters Issue 4 and Issue 5 (please see WP2 Communications for more details).

Note that the creation of this KTP was the work of WP4, while gathering the material and the management thereof was the work of WP2. The WP4 work on the KTP is also described in the deliverables D32.3 and D32.4, which are from WP32 "Virtual Access".

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Task NA2.3. Set up virtual open access (OA) entry point to data resources

The scientific outputs from ASSEMBLE Plus – these being from the JRA and TA programmes, but also including non-ASSEMBLE Plus related outputs from the partners where so-wanted – were catalogued in the IMIS datasets and publications metadata catalogues. These catalogues store metadata about the records, this including the links to the datasets or publications themselves from where they can be downloaded (depending on the licence assigned). All the metadata in IMIS are OA and can be viewed and downloaded freely via the HTML pages (human-friendly) and via the web services (machine-accessible). To provide a point-of-entry to only the ASSEMBLE Plus datasets and publications collections in IMIS (which contains records from numerous other sources and projects), filter-search pages were provided on the ASSEMBLE Plus website: datasets and publications. Reporting on the hits to these collections are given in the deliverables D4.4, 4.5, and 4.6.

ASSEMBLE Plus requires that the outputs funded by ASSEMBLE Plus should be made Open Access. This applies to any refereed publication produced by the TA and JRA programmes, and to datasets produced by JRA. It was less clear if datasets created by the TA users were also to be included in this requirement, however we chose to make it so.

In order to accommodate the fact that this OA requirement was not always honoured for publications, we created the ASSEMBLE Plus Open Repository, in which preprints of publications otherwise submitted to non-open access journals could be viewed. Regular alerts from Google Scholar and Web of Science compensated for the lack of action in informing ASSEMBLE Plus when papers acknowledging the project were published. Many TA papers could be made more accessible this way. Statistics of the FAIRness of ASSEMBLE Plus publications can be found in in D32.4 and D4.6.

To help with the population of the datasets catalogue, material was developed for the TA users and this is provided on the ASSEMBLE Plus website (FAIR-TA-data). As IMIS is a VLIZ core service, the IMIS team at VLIZ regularly assist those creating their metadata records in IMIS, helping with the technical process and with the quality (in particular with respect to the FAIRness) of the metadata, and even with the datasets themselves. To help the JRAs with their dataset publication, material describing the steps and explaining what FAIR and Open data mean is provided on the ASSEMBLE Plus website (FAIR data management). Regular contact with the JRA was taken to help with the FAIRification of the datasets and to encourage the creation of the IMIS metadata records. This was particularly successful with JRAs 1 and 2, but less so with the other JRAs.

Another VLIZ core service used by ASSEMBLE Plus for WP4 is the Marine Data Archive. This is a general-purpose file-server based system for archiving marine-related datasets, which can then be linked to an IMIS datasets record. Datasets can then be referenced via their MDA URL, via the IMIS URL, or via the IMIS-assigned DOI (where a DOI is requested by the dataset owner).

IMIS and the MDA are two of the services suggested to be used by ASSEMBLE Plus in the DMP of Task NA2.1.

A large part of the ASSEMBLE Plus datasets collection are datasets that had been added to IMIS over the years preceding ASSEMBLE Plus by the ASSEMBLE Plus partners. An effort was undertaken to

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review these records with an eye on improving the FAIRness of the metadata, and to encourage providing more open access to the described datasets. A workshop was organised at VLIZ in June 2019 on the subject of "FAIR data: good data management for long-term biological and omics datasets from marine stations", with general topics on FAIR data, open data, and also on the use of IMIS and the MDA. Spreadsheets containing the metadata for each record created in IMIS by the ASSEMBLE Plus partners were prepared, with advice about which fields could benefit from an improvement. A few partners did respond to these, and their records were updated accordingly.

Statistics on the degree of FAIRness and the level of OA for ASSEMBLE Plus outputs can be found in the deliverables D4.3 and D4.6.

One outcome of the work done in Task NA2.3 and Task NA2.4 with respect to helping the ASSEMBLE Plus scientists make their data FAIR is a FAIR data for marine biologists course that was developed by the VLIZ ASSEMBLE Plus team and placed on the University of Gent's training platform. This course is free to use (although registration is required to use the platform), and is focussed on teaching FAIR data to students of master grade and upwards.

Task NA2.4. Improve data access and standardisation of genomic and long-term marine biodiversity observation

The work in this task was focussed on the outputs of JRA1 – OSD and ARMS-MBON. These projects collect eDNA (environmental DNA) and accompanying environmental data (measurements and images) as well as event, sampling, processing, and provenance metadata. OSD was a programme during which water samples were collected word-wide by participants on the summer solstice each year from 2018 to 2021, and ARMS-MBON saw hard-bottom sampling (via settlement plates) each year from 2018 and continuing. This task took up most of the WP4 resources in the latter 3 years of ASSEMBLE Plus.

The activities in this task consisted of the following:

- Creating and updating the respective webpages (OSD, ARMS-MBON)
- Helping to write the ARMS Handbook and Data Management Plan, and writing the OSD Data Management Plan
- Defining interoperable metadata to be used for the datasets published in IMIS and the sequences published in ENA (European Nucleotide Archive)
- Performing data management activities: archiving data for long-term storage in the MDA, downloading data and metadata to the respective ARMS and OSD Github sites and adding semantic annotations, machine-accessible data formats, and Ro-Crate data packaging
- Publishing the data in IMIS and ensuring that the metadata there defined, as well as the datasets themselves, are FAIR (e.g. ARMS 2018 record, OSD 2018 record)
- Working with the OSD and ARMS teams, and with EurOBIS, OBIS, and GBIF, to format the data into the Darwin Core Archive Occurrence-format for publishing DNA-based occurrences (this being a work still in progress by all partners, as the standard is quite new)
- Contributing to the data papers (for both projects, these will be submitted after ASSEMBLE Plus has ended)

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The original plan to extend this task to long-term biodiversity observations was dropped due to a lack of take-up among the ASSEMBLE Plus partners, from whom the long-term datasets were to be taken.

Task NA2.5 Set up virtual platform for data analysis

The original vision for this task was to take the standardised data from Task NA2.4 and connect them to a virtual analysis platform. Developing a platform from scratch was not in scope, but adopting existing platforms and ensuring that the JRA1 OSD and ARMS data would work therein, was in scope. This is reported on in deliverable N4.9. In brief, the following virtual services were promoted

1. The Marine VRE, being a web portal gathering marine-related resources: providing information about the services and links to where they can be accessed. This is a portal that had already been developed at VLIZ in cooperation with LifeWatch Belgium, and ASSEMBLE Plus is using it to list services from its members that can be used on long-term biodiversity and omics data, in particular data produced by the JRA1 projects.
2. The LifeWatch Internal Joint Initiative Tesseract workflow on Non-native and Invasive Species (NIS). This Tesseract workflow environment is an initiative of LifeWatch ERIC that began in 2019. It incorporates a number of individual workflows that each deal with different use-cases with different data, but with the overarching theme of science related to NIS. One of those workflows uses the ARMS-MBON data, and we worked (and are still working) extensively with LifeWatch in the development of this workflow.
3. The ESOC-Life Open Call project PID 14324: development of an omics workflow for marine genomics observatories, using JRA1 data. This project is funded by the Horizon project ESOC –Life, and is linked to ASSEMBLE Plus by the people and data involved. The emphasis of these EOSC-Life funded projects is making workflows more FAIR, and that is where WP4 comes in: providing the JRA1 data with full provenance metadata (the "R" part of FAIR) and ingesting back scientific results from the workflow also with provenance metadata.

Lessons learnt, exploitation of results, impacts

When developing a project DMP, it is important to include the scientists producing the data from the very beginning. Do not assume that they understand what "data management". "FAIR data", or "Open Data" actually mean; and more importantly, do not assume they understand what these terms do not mean. Within ASSEMBLE Plus there were some JRA, and almost *no* TA, scientists who understood these concepts: to most, the idea of publishing data separately from the science was a foreign concept. Treating data outputs as independent, publishable, research objects was a new idea. For many, it was considered to be sufficient to include tables and figures in a scientific paper to consider them to be FAIR and Open, and unless the journal specifically required (and checked and enforced) the separate publication of datasets (be they sequences, images, spreadsheets, etc), this was not considered necessary. For omics science, there is a very often requirement by the journals to publish the sequence in public archives (e.g. ENA), but for other sciences there is no similar requirement. *If journals could work together with data management centres and data archives/catalogues, to require certified FAIR publication of data before publication of the science, this would go a long way towards the realisation of FAIR (and Open) data in Europe*.

Among the TA users, who were mostly at MSc and PhD level, there was little understanding of FAIR data and even how to publish data, but we did encounter a satisfying level of eagerness to try and to learn. This was one of the reasons we developed the FAIR data for marine biologists course. *It would help embed FAIR data practices in the future generation of scientists if these topics were taught and*

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practised at master's level. *It would also help greatly if FAIR data management practices were more common and thorough within marine stations and university labs*. The situation in Europe is improving rapidly, but not enough attention is given to what is necessary for the "ground level" of scientists to be able to adopt FAIR data practises as a norm.

Data can be Open, but if they are not FAIR they will quite possibly be useless data. *Any project that requires Open data outputs, as well as FAIR data outputs, should include sufficient PMs assigned to the scientists producing the data to additionally make their data FAIR*, as only those scientists are able to make the datasets themselves sufficiently interoperable (via use of standard data formatting, data file formats, vocabularies) and reusable (by providing sufficient provenance (meta)data). *Rigorous, face2face, training at the start of the project, continuous checking throughout the project, and even better the provision of tailored templates for each type of data, should be adequately budgeted for*. Additionally, the data management should be a continuous process by the data creators: *checkpoints, at which the outputs that have been produced are then also archived and catalogued, should be set up every 6 months to yearly.*

If a marine station or lab has to implement a different set of data management practices for each external project they are part of, or adopt practices for only a small subset of the data they produce and just for a few years, this could have the counter-effect of *discouraging* the take-up of data management and FAIR data in the places where the science is done. This is because there are numerous systems, methods, technologies, standards, softwares, and portals that are all FAIR, but are not all immediately compatible with each other and require translating/mapping to be done. Projects could centralise the FAIR data-management efforts (including where and how data are archived, what standards are used, machine-accessible formats and software adopted, etc), however once the project ends, so will those FAIR data management practices. *Better is to allow the individual, science-producing, research centres to adopt their own FAIR data management practices*, and for projects to focus on being able to harvest those FAIR data into whatever system, technology, standards, portals etc, that that project uses.

As part of this WP, an attempt was made to improve the FAIRness of the existing dataset records from the ASSEMBLE Plus partners in IMIS. With the exception of a very few partners who were already "signed up" to FAIRness and who understood how to do this, this was not a very successful task. In most cases, the partners reported that they could not find the requested missing information (metadata or the datasets) because the person who had created the record no longer worked with them, or because the ownership of the data (and hence the permission to alter the record) was uncertain. FAIRification of existing datasets and dataset records is very much more difficult that making new datasets/record FAIR. *We recommended that all data creators collect all the possible information about their dataset as soon as those data are created, and if that information cannot immediately be ingested by the archive, portal, or catalogue that is hosting the data/record, then they keep that information somewhere internal. Ownership of data should by default be with the host institute, and that should be clear from the beginning. A data curator should be employed to take care of these steps.*

Finally, it was an extremely laborious process to pursue getting TA datasets to be published and made open access (with or without a moratorium period). Success in achieving this was limited. It is perhaps

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the case that the TA data was not the main focus of the Open Data Pilot, but for any future project wishing to do the same, much stronger regulations to en(courage/force) this, as well as *very* specifically focussed assistance, are recommended.

Publications

- Journal article: A Marine Biodiversity Observation Network for genetic monitoring of hard-bottom communities (ARMS-MBON); Obst, M. et al.; 2020; Front. Mar. Sci. 7: 572680. DOI: 10.3389/fmars.2020.572680
- Conference presentation: Genomics Observatory Use-Case: The challenge to standardise image and sequence data to Darwin Core format; Katrina Exter, Cedric Decruw, Marc Portier, Vasilis Gerovasileiou, Christina Pavloudi, Matthias Obst; 2020; Biodiversity Information Science and Standards. DOI: 10.3897/biss.4.58938.

3.6. Engaging with user communities – NA3

The overall objective of the work package was to facilitate translation of knowledge outputs to different user communities from industry, policy, society, and science. To achieve the overall aim four tasks were implemented:

- Task 3.1 - to build staff capacity in value creation and impact from the research generated as well as the importance of the marine stations and stakeholder engagement.
- Task 3.2 - to engage with stakeholder communities, bringing together the service providers, the users who have benefited from access, and other relevant stakeholders to help shape the development of Research Infrastructures.
- Task 3.3 - To carry out dedicated Knowledge Transfer to relevant industry and policy stakeholders, in particular the deposition of knowledge outputs in the Knowledge Transfer Platform (KTP) created by NA2.3.
- Task 3.4 - To facilitate Knowledge Exchange amongst the marine biological scientific community with the aim to build capacity in individual scientists.

Task NA3.1. Building RI Capacity in Value Creation, Impact and Stakeholder Engagement

The objectives of this task were community capacity building (CCB) amongst the ASSEMBLE Plus community, to build strong research infrastructure (RI) capacity in value creation, impact and stakeholder engagement from the research they are generating as well as the importance of the marine stations. In RP1 and RP2 guidelines, tools and resources were developed to support targeted members of RIs. The concepts included: Science in Society (SiS); Responsible Research and Innovation (RRI); Knowledge Transfer (KT); and Outreach and Stakeholder Engagement. The ASSEMBLE Plus community underwent training courses both physically and virtually to ensure they are capable of applying these new principles.

AquaTT carried out a survey of ASSEMBLE partners' soft skills requirements in RP1, M13 – September 2018. There were 46 partner responses and based on the findings a training course series was developed covering topics such as Intellectual Property (IP); KT; Media skills; Networking; Outreach and Stakeholder Engagement; and Policy Development.

In RP3, the online KT training course provided by AquaTT for the ASSEMBLE Plus community was held in M60 – 22 September 2022. With 12 registrants, the course focused on AquaTT's best practices for KT and impact creation, providing participants with the skills needed to facilitate their research

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output's pathway to impact, maximising the legacy of ASSEMBLE Plus and the continued efficacy of the RIs. Session one trained participants how to identify KOs within their research and session two focused on how to analyse KOs and map their pathway to impact.

Task NA3.2. Engaging with stakeholder communities to strengthen the position of European marine biological stations as excellent marine science hot spots

ASSEMBLE Plus must be able to attract a diverse user base from academia, industry and policy, so as to build strong capacity in value creation and maximise societal impact. ASSEMBLE Plus planned to address the challenge through consultation with stakeholders. For this, two ASSEMBLE conferences were planned together with meetings with stakeholders to discuss how to reach users from the different sectors. This was achieved through:

1) Two ASSEMBLE Plus conferences carried out in January 2021 and June 2022 with participation mainly of academic users and dedicated to showcase transnational access (users and providers);
2) A Knowledge and Technology Gap Forum that debated the role of RIs for policy and industry and how to improve industry participation.
3) A questionnaire directed to industry to explore their motivation.

The pandemic caused a temporary suspension of ASSEMBLE Plus activities and finally moved some of the activities online. The ASSEMBLE Plus Conferences 2021 and 2022 had as theme "Marine biological research at the frontier" and as objective to showcase recent developments in marine biology and ecology; state-of-the-art technologies available at marine stations and institutes; how to access biological resources and marine research infrastructure; how to improve services provided by marine stations; and the impact of the services provided on industry and society. There were 574 registered participants in the first conference and 246 in the second with a daily attendance rate of 100-150 participants. The conference's programme and abstracts are available at https://assemble2021.b2match.io and https://assemble-plus-2022.b2match.io.

A first knowledge and technology gap forum took place at the 2019 ASSEMBLE Plus general assembly at the National University of Ireland Galway with the participation of representatives from the local community of potential users, from Academia and Industry in the health, food and environment sectors and emphasised the importance of new knowledge and technology platforms (including research infrastructures) in the conduction of their activity, the need of staff training, and the potential for collaborative endeavours.

The second and third knowledge and technology gap forum took place online during the 2021 ASSEMBLE Plus Conference, with the participation of, respectively, policy and industrial stakeholders.

The main conclusion was that both policy makers and businesses valued research infrastructures and will resort to EMBRC / ASSEMBLE Plus provided information about services and prices are clear. Thus, a well-defined portfolio of services and communication strategy delivered to their desktop are essential to attract sectors other than academia to EMBRC. Bureaucracy and costs can, however, be

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important obstacles. Since personal contacts are important for businesses, communication targeting innovation clusters may be an effective way to reach potential business users.

A questionnaire was sent out by the Assemble partnership to companies related to the marine sector in different European countries. The main purpose of the questionnaire was to assess how knowledgeable the industrial sector is of the existence of RIs, in particular EMBRC and ASSEMBLE Plus and how best can the RIs serve industry.

The main conclusion was that there is preference for contract research allocated to the RIs, although a significant proportion of businesses also value hands-on engagement, and joint co-innovation projects seem to be an attractive proposition.

Task NA3.3. Dedicated Knowledge Transfer to Industry and Policy Stakeholders. Task Leader: AquaTT with contribution of CCMAR and other partners (JRAs, and all RI partners).
The objectives of this task were to engage with the business and public policy sectors through multiple channels, utilising the results of the project. In particular, activities have included:

Deposition of knowledge outputs (KOs) such as publications, education and training material, etc. from the marine stations as well as user reports and publications in the Knowledge Transfer Platform (KTP) created by NA2.3. Commencing in RP1 and continuing throughout the project AquaTT have collected KOs from the five Joint Research Activities (JRAs) and Network Activities (NAs). The KOs produced by the project are presented on the ASSEMBLE Plus website under the KTP as the State of the Science Stories. In RP3, AquaTT regularly contacted the JRAs for progress updates on their KOs, the potential applications of these knowledge outputs, their pathways-to-impact and Knowledge Transfer Plans and AquaTT supported these activities. The KTP was updated accordingly and included in the final ASSEMBLE Plus Newsletter Issue 5 – September 2022. Many the partners transferred their outputs through technology demonstration and workshop activities that formed part of the ASSEMBLE Plus Conference 2021 and 2022.

As part of the ASSEMBLE Plus Conference 2021 and 2022, partners showcased their research areas, facilities, while also demonstrating their equipment/technology platforms and the services they offer. Short videos gave insight into a number of European marine stations and RIs available to industry that would enable them to increase their efficiency and facilitate innovation. B2B matchmaking events were also available with industry stakeholders.

Task NA 3.4. Knowledge Exchange among Scientific Community for enhanced training of actual and prospective RI users
The idea behind this task was to familiarise prospective users, especially early career researchers, with technologically advanced platforms offered by the ASSEMBLE Plus. Two internal bids were solicited from partners for training courses using the platforms and the most innovative and relevant were selected. A total of six courses were selected covering 1) “Liquid chromatography and Mass Spectrometry methods in Marine Sciences”, 2) “Zebrafish tools for the screening of osteogenic compounds” and 3) “Practical course on meta-omics data processing analysis and organisation: bioinformatics tools to mine and share the data”, 4) “Cryopreservation of dinoflagellates”, 5) “The

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Evolution of Enzymes and Metabolic Pathways: analysis, understanding and implications for biotechnology", and 6) "Identification of larval fishes as a tool for systematics, ecology, and population dynamics". The pandemic delayed the last three courses. Participation in each course varied between 15 and 25 and ratings generally varied between 4.0 and 5.0 (out of 5).

Lessons learnt, exploitation of results, impacts

ASSEMBLE Plus is highly successful in attracting researchers from academia to carry out research projects in marine stations. This is clearly visible from the number of applications received and approved, and the outcomes of those visits are substantial in terms of publications and collaborations. This was also confirmed by the popularity of the online ASSEMBLE Plus conference with more than 500 registrations and an average of 30-50 participants per lecture or event.

It was very clear that both policy makers and businesses value research infrastructures and will resort to EMBRC / ASSEMBLE Plus provided information about services and prices are clear. Thus, a well-defined portfolio of services and communication strategy delivered to their desktop are essential to attract sectors other than academia to EMBRC. Bureaucracy and costs can however be important obstacles. Since personal contacts are important for businesses, communication targeting innovation clusters may be an effective way to reach potential business users. There is preference for contract research allocated to the RIs, although a significant proportion of businesses also value hands-on engagement, and joint co-innovation projects seem to be an attractive proposition.

3.7. Long-term sustainability – NA4

This last period of the project has been dedicated to the finalisation of task 1 and task 2 and channel and conduct activities around task 3 in the WP with the lessons learned from task 2. Task 1 concentrated in the analysis and dissemination of the history of endurance and scientific/socioeconomic contribution of marine biological stations (MBS) over their 150 years of work in Europe and in bringing forward the biographies of important marine biologists and scientists over the years. This has taken the shape of an outreach book on the history of the European stations published by the Basque University Press. Project deliverable (D4.1) on this task was delivered on due time. Task 2 was dedicated to analyse the present situation of marine biological stations in Europe through a two-tier analytical approach. Task 2.1 analysed the strengths, weaknesses, opportunities and threats of the partner stations priming for a more in-depth analyses of the business models of marine stations (Task 2.2). The result was deliverable D4.2. From there task 3 explored the funding possibilities for the work, research and service provision catered in marine biological stations into the future project programming and funding landscape.

Task NA4.1. Historical background and socioeconomic impact of MBSs and projections for their sustainable future

The historical background and impact of MBSs has been analysed by different authors and the results have taken the shape of a coffee-table outreach book. The deliverable [D4.1] "History of Marine Biological Stations: contributions to Science and Social Challenges" was delivered on the 29th of

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November 2019 as a synopsis of the book and explains its context. This context was published on a special book in the context of the "UN decade on ocean science for sustainable development", journal EKAIA of the University of the Basque Country (https://ojs.ehu.eus/index.php/ekaia/article/view/21074).

The book is divided into different chapters contributed by various authors. Chapters cover all organisational aspects of marine stations since their conception in the 20th century. Finally, seven subchapters showcase different marine stations, five in Europe (P1, P9, P12, P18, P20), one in Israel (P11) and in conjunction the total of the history of European Arctic/Antarctic stations (P5 and P21).

The contents and the spirit have been presented in different academic and outreach events during this third reporting period with two talks (besides the 4 talks delivered on the history of European marine stations in the previous years) delivered on the contents of the book:

1. Invited conference "Marine Biological stations. EMBRC standing on the shoulders of giants" during the opening of the "**EMBRC Community days**" in the University of Algarve, Faro (Portugal), 24 May 2022.
2. Invited conference "Marine Biological Stations: 150 years seeking knowledge from the sea", during the celebration of the **150th anniversary of the Station Biologique de Roscoff** (France), 6 October 2022.

29 outreach biographies of marine biologists with different links to marine biological stations have been published in the webpage of EMBRC and in Linkedin during 2021. All biographies were written by Ibon Cancio (University of the Basque Country) and edited by the communication officer of EMBRC-ERIC, Sabrina Gaber.

1. Aristotle, the first marine biologist. https://embrc.eu/newsroom/news/aristotle-first-marine-biologist
2. Charles Darwin: Marine inspiration for the conception of the Rosetta Stone of biology! https://embrc.eu/newsroom/news/charles-darwin-marine-inspiration-conception-rosetta-stone-biology
3. Sofia Pereiaslavtseva: A pioneer in marine zoology & research institution management https://embrc.eu/newsroom/news/sofia-pereiaslavtseva-pioneer-marine-zoology-research-institution-management
4. Ernest Everett Just: 'Black Apollo of Science' https://embrc.eu/newsroom/news/ernest-everett-just-black-apollo-science
5. Charles R. Richet, sharp observer stunned by the sting of marine creatures https://embrc.eu/newsroom/news/charles-r-richet-sharp-observer-stunned-sting-marine-creatures
6. John Murray, the Sir of the ocean deep and Dr Jekyll of oceanography https://embrc.eu/newsroom/news/john-murray-sir-ocean-deep-and-dr-jekyll-oceanography
7. Sir Charles Wyville Thomson, a short narrative can be fathomless! https://embrc.eu/newsroom/news/sir-charles-wyville-thomson-short-narrative-can-be-fathomless
8. Ida H. Hyde: Bringing women to the 'scientific table' https://embrc.eu/newsroom/news/ida-h-hyde-bringing-women-scientific-table

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9. Mary Parke, the phycologist with 'green fingers' for tiny marine algae https://embrc.eu/newsroom/news/mary-parke-phycologist-green-fingers-tiny-marine-algae
10. Sigmund Freud, from the eel testis to neurons and psychoanalysis. https://embrc.eu/newsroom/news/sigmund-freud-eel-testis-neurons-and-psychoanalysis
11. Irene Manton, the algal cell biologist and her electron microscope. https://embrc.eu/newsroom/news/irene-manton-algal-cell-biologist-and-her-electron-microscope
12. Osamu Shimomura, from the glow of the 'Fat Man' over Nagasaki to luciferin and the jellyfish green fluorescent protein. The continuous quest for light! https://embrc.eu/newsroom/news/osamu-shimomura-glow-fat-man-over-nagasaki-luciferin-and-jellyfish-green-fluorescent
13. Selig Hecht and George Wald: travel, meet good people and you will see the light!! https://embrc.eu/newsroom/news/selig-hecht-and-george-wald-travel-meet-good-people-and-you-will-see-light
14. Mary Rice, a 'special' ambassador of the Smithsonian Institution by the ocean. https://embrc.eu/newsroom/news/mary-rice-special-ambassador-smithsonian-institution-ocean
15. Oscar Hertwig, Hermann Fol and echinoderms, because children do not travel in the beaks of storks. https://embrc.eu/newsroom/news/oscar-hertwig-hermann-fol-and-echinoderms-because-children-do-not-travel-beaks-storks
16. Johan Hjort superhero 'avenger' of fisheries research and the man who showed Forrest Gump how to go shrimpin'. https://embrc.eu/newsroom/news/johan-hjort-superhero-avenger-fisheries-research-and-man-who-showed-forrest-gump-how
17. Sir Alister Clavering Hardy, the Prince of plankton thieves! https://embrc.eu/newsroom/news/sir-alister-clavering-hardy-prince-plankton-thieves
18. Ethel Browne Harvey, the discoverer of the 'organiser' phenomenon who saw Nobel Prizes 'raining' around her. https://embrc.eu/newsroom/news/ethel-browne-harvey-discoverer-organiser-phenomenon-who-saw-nobel-prizes-raining
19. Emperor Hirohito, wishing the Chrysanthemum throne would be at sea. https://embrc.eu/newsroom/news/emperor-hirohito-wishing-chrysanthemum-throne-would-be-sea
20. Edward D. Goldberg and 'Baywatch', when the marine mussels became the lifeguards of the Bay. https://embrc.eu/newsroom/news/edward-d-goldberg-and-baywatch-when-marine-mussels-became-lifeguards-bay
21. Henri de Lacaze-Duthiers, the French advocate of zoological research by the sea, free of charge for all. https://embrc.eu/newsroom/news/henri-de-lacaze-duthiers-french-advocate-zoological-research-sea-free-charge-all
22. Henri Milne-Edwards, 27th child of his father and godfather of zoological research by the sea. https://embrc.eu/newsroom/news/henri-milne-edwards-27th-child-his-father-and-godfather-zoological-research-sea
23. Ernst Johannes Schmidt, the detective that solved the 'Eel question' with a little bit of help from good Carlsberg beer. https://embrc.eu/newsroom/news/ernst-johannes-schmidt-detective-solved-eel-question-little-bit-help-good-carlsberg
24. Salvatore Lo Bianco, the thin line separating a laboratory technician and a renowned marine scientist. https://embrc.eu/newsroom/news/salvatore-lo-bianco-thin-line-separating-laboratory-technician-and-renowned-marine
25. The value of friendship in marine science: Kovalevsky, Metchnikoff and kinship among embryos in evolution. https://embrc.eu/newsroom/news/value-friendship-marine-science-kovalevsky-metchnikoff-and-kinship-among-embryos

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26. Jeanne Villepreux-Power: Aquarium inventor and Cinderella among marine creatures. https://embrc.eu/newsroom/news/jeanne-villepreux-power-aquarium-inventor-and-cinderella-among-marine-creatures
27. Ricardo Miledi, the squid giant synapse and a pinch of calcium for your dreams. https://embrc.eu/newsroom/news/ricardo-miledi-squid-giant-synapse-and-pinch-calcium-your-dreams
28. Letters from Naples. Anton Dohrn, science facilitator in the name of Darwin. https://embrc.eu/newsroom/news/letters-naples-anton-dohrn-science-facilitator-name-darwin
29. Jacques Loeb, the engineer of life manipulating marine living 'machines'. https://embrc.eu/newsroom/news/jacques-loeb-engineer-life-manipulating-marine-living-machines

Use of resources

Resources have been fully devoted to the dedication (PM) of the editor of the book and author of the biographies in P9. The production of an infographic of a marine station included in the book has had a cost of 600 euros. In regard to book editing, printing and generation of 500 copies for the stations, prices were negotiated with the Basque University Press. Additional funds, external to ASSEMBLE Plus have been secured locally in UPV/EHU (P9) to allow a high-quality outreach book publication. The authors, some of them from institutions participating in ASSEMBLE Plus (P1, P6, P9, P11, P12, P14, P18, P20, P21), have agreed to contribute their time in kind, due to pure interest and commitment. Book should be printed by the end of 2022.

The WP leader (P9, including third link party) has dedicated 4 PM in finalising and coordinating the writing of the chapters, and in disseminating its contents.

Deviation from Annex 1 and Annex 2

There have not been major deviations in creating the contents coffee table book on the history of marine biological stations apart from some delays in recreation by some chapters by some of the contributors. Deliverable DNA4.1 was delivered on time as a summary of the book. However, the period necessary to print and editing the book have suffered a long delay. On the other hand, there has been a lot of outreach on the history of marine biological resources.

Task NA4.2. Mid- and long-term sustainability of MBSs

All MBSs in ASSEMBLE Plus provided an unsupervised SWOT analyses (a total of 25) on their activities and mission in relation to future strategic planning (Task 4.2.1). These SWOTS were evaluated and compared centrally by P1 and P9, and main results presented in a workshop organised with the help of P2 in Piran (Slovenia) on the 23rd of May 2018. This workshop gathered 33 participants from 19 MBSs, plus invited speakers and participants from EMBRC sister RIs in Slovenia, and provided an opportunity to meet with a high-level representation of the Slovenian Government regarding research infrastructures. The workshop launched a deeper analysis of the business models of the marine stations (Task 2.2).

In order to increase the MBS manager sensitivity towards greater sustainability and towards "the provision of services", the "modus operandi" of the various MBSs was analysed, gaining insight into

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the essential perspectives for an effective and efficient business model that could suit the different goals of this community. The approach was based on a questionnaire, launched online via a survey monkey, and an analytical instrument to visualise the value creation process of the organisations and to envisage potential diversifications of the management practices. This modelling approach was adapted from a business modelling tool for technological core facilities, describing the "input-process-output" transformation within the studied MBSs, also considering the relations of reciprocity among the various elements, i.e.: the resources, the infrastructure and the products. More than 80% of the participants responded (n=27), allowing for a robust basis for the interpretation of results. Raw results of the survey were presented in an on-line workshop in November 2020 and the final outcome of the analysis was presented in a workshop during the 2nd ASSEMBLE Plus Conference in June 2022.

MBSs are research infrastructures providing access to marine ecosystems and their biological resources for educational and research purposes, often placed in peripheral maritime regions outside the major industrial and decision-making hubs. In order to improve the sustainability of the MBSs and create new prospects for their strategic development, the study has focused on effective integration and efficient complementarities, as pillars of the ecosystem ability to provide research services and attract new users. The MBSs analysed were observed to operate following a “research and education team” approach rather than a “service provider” model; even the longest-standing MBSs, operating since the late 19th century, still adopt this model. While non-financially evaluated products remain, the main target output these modern MBSs appear multidisciplinary and also deliver "financially-evaluated outputs". The longest-standing cases, however, especially distinguish themselves for a stronger governance, a strategic approach to the activity program, a marketing capacity - with the availability of a catalogue of services, a pricing policy, and a service provision regulated through a booking system, supported by an awareness of the market value of the services offered; an elevated production of financially evaluated output, with training activities for external parties, in particular toward industries, the protection and exploitation of the intellectual property generated, the generation of spin-offs and service provision for a fee.

Based in this analysis the deliverable of this task (D4.2) recommends a sustainable business model for the ecosystem of EU MBS, anchored on effective integration and efficient complementarity, as pillars of the ecosystem's ability to provide attractive services also for new users, as medium to long-term sustainability measures.

- We recommend that the MBSs strengthen the networking and consider the integration process into a structured and wide ecosystem, which would lead to an increased visibility, increased number of users, stronger collaborations, increase the opportunity to be involved into relevant EU projects, and provide a more secure market for a diverse set of activities and output types;
- a balance of activities between multidisciplinary research activities and service provision, with a related varied portfolio of resources for technical and scientific staff, has the potential to increase societal challenges and funding streams and therefore sustainability, as demonstrated by the longest standing MBSs; however, different models can also be valid in terms of sustainability, providing that their main activity and the organisational processes are aligned with the market needs and the policy environment;

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- we highlight the relevance of the governance and in particular the governance for innovation. Intellectual assets are increasingly important for innovation, and in particular non-technological innovation and other new forms of innovation. Intellectual assets play a pivotal role in the increasing fragmentation of global value chains and in the globalisation of business services (OECD, 2008). A strong governance and management team, together with a mission re-alignment towards the European needs for innovation, would enable the pathways towards increased technology and knowledge exchange (IP and knowledge creation) and an intensification of the research output uptake.
- we recommend a strengthening of the marketing strategy and service/pricing policies, also resourcing the marketing activity with dedicated personnel.

These recommendations pinpointed in DNA4.2. "A business model for an ecosystem of mature European Marine Biological Stations" (March 2022) may contribute to lay the basis for a further integrated ecosystem of mature MBSs in Europe. The outcomes have been sent for publication in the peer review journal (open access) "Environment, Development and Sustainability", an international, multidisciplinary journal covering all aspects of the environmental impacts of socio-economic development.

Use of resources

All participants participated in the first workshop on the primary analysis of business model questionnaire that took place online in November 2021. Most of participants participated as well in the final presentation of results in the second ASSEMBLE Plus Conference 2022 (online). Partner 9 and 27 have dedicated 3 and 5 PM each in analysing the questionnaire and drafting the deliverable and the paper on the deliverable.

Deviation from Annex 1 and Annex 2

The major problem of this task was the change in project leader that left this task without task leader. This was solved this year through the incorporation of partner nº 27 to the project (ERAMARIS). A delay in the presentation of delivery of this task was proposed an accepted together with the acceptance of the incorporation of ERAMARIS. This implied also a delay in the milestone associated to the delivery that was supposed to take place in month 30 but that took place in 2022. An additional workshop was organised with the framework of the ASSEMBLE Plus conference 2022 (June, 2022) to a broader audience to explain the main outcomes of the study.

Task NA4.3. Negotiation with scientific and financial stakeholders toward sustainability of MBSs post H2020

ASSEMBLE plus through its different partners and very importantly through EMBRC headquarters has participated in different fora, meetings, workshops and brokerage events discussing sustainability issues into the future. Main aspects developed during these last years have been, strengthening regional placement, networking and growth of EMBRC, **contributing to European Strategic Priorities**.

Regional placement. Within the first EMBRC science strategy 2018-2022, and as observed the SWOT analysis of MBSs in Task 4.2 regional implementation of the service provision scheme locally was envisaged as crucial. Different marine stations have stablishing regional links and the creation of trust towards achieving Regional Innovation ecosystems on Marine Biological Resources. Moreover, during

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2019 a paper was published as a contribution of EMBRC-ERIC, UPV/EHU and SBU (partners in the project) to Open Access Government (Gras et al., Developing research in maritime regions through innovation ecosystems. OPEN ACCESS GOVERNMENT, 204: 342-343 (2019) ISSN 2516-3817), on the need to create Regional Innovation Ecosystems for the Blue Bioeconomy and around regionally placed research infrastructures (marine biological stations). In that respect the UPV/EHU together with the regions of the Basque Country and Brittany participated in the Blue Bioeconomy Forum Final Stakeholder event in Brussels in June 2019

(https://webgate.ec.europa.eu/maritimeforum/en/node/4358), that resulted in the publication of the "Blue Bioeconomy Roadmap", requested by the European Commission (DG-MARE) and the executive Assembly of SMEs (EASME). The Roadmap was published in December 2019 (https://webgate.ec.europa.eu/maritimeforum/en/node/4448), incorporating the ideas defended by EMBRC-ERIC around peripheral maritime regions and regional marine biological stations during these years. The contribution of EMBRC-ERIC, UPV/EHU, Basque Government and Brittany Regional European office is acknowledged in the text.

The project ASSEMBLE Plus through partners P1 and P9 has become involved in the presentations of the Smart Specialisation for Sustainable Blue Economy process by DG-Mare (European Commission), participating in the **Brokerage Event- Focus on Blue Biotechnology** that took place in Barcelona Spain on the 9th May 2022. In May 2021 the Communication on Sustainable Blue Economy (SBE) was adopted as integral part of the European Green Deal. DG MARE identified Smart specialisation strategies (S3) as a key tool to implement the Communication. S3 represent a key opportunity to prioritize regional research and innovation investments in blue economy sectors but should also lead to promote interregional partnerships and blue economy value chains across borders. In this context, DG MARE in cooperation with DG REGIO, is setting up the S3 thematic platform for sustainable blue economy to support these partnerships and value chains, facilitating the cooperation among blue economy 4 helix stakeholders. This includes of course academia and science, among them science service providers and research infrastructures. The transition towards a sustainable blue economy by creating the necessary innovation ecosystems in Member States and Regions needs implementation of the S3 boosting the competitiveness of blue economy sectors. We were informed about the opportunities offered by the I3 instrument and the importance to develop blue economy interregional value chains. Matchmaking activities have been supported in order to allow networking and exchange, promote synergies between stakeholders, exchange potential partnership ideas and share best practices and lesson learned.

As there are plenty of opportunities for regionally based MBSs and RIs clustered at the pan-European such as EMBRC level in this S3 platform context, Elena Hatziyanni (DG MARE-Unit A3 | Sea-basin Strategies, Maritime Regional Cooperation & Maritime Security, European Commission) was invited to present its objectives inside the workshop "Business models and Smart Sustainability of Marine Stations" of the ASSEMBLE Plus Conference, 23th of June 2022.

Networking and growth of EMBRC. An important aspect observed in the Business model analysis is the need for MBSs to strengthen networking and consider the integration into a structured and wide

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ecosystem. Taking advantage of the WS organized in Piran first contacts were stablished with Slovenian government to explore possibilities of Slovenia to be incorporated into EMBRC-ERIC. Finland trough the Tvarminne Zoological Station of the University of Helsinki is also pending approval of incorporation of EMBRC into their roadmap of research infrastructures. Finally, and through the partner marine stations of the University of Gothenburg (partners in Assemble 2022) Sweden finally joined EMBRC in 2022 becoming the 10th country to join. Ukraine, before the war started, also showed interest in knowing about EMBRC and eventually consider the possibility of joining.

Contributing to European Strategic Priorities. Purely supporting fundamental research is no longer considered sufficient for the European research infrastructures. Under Horizon Europe, one of the strategic drivers is that of the Green Deal, for economic growth and sustainable development and resource exploitation. There is also a commitment to address Europe's biodiversity decline with the Biodiversity Strategy for 2030. In accordance with these strategies, MBBs need to be able to convincingly demonstrate how they contribute to regional, national and Europe's societal challenges, in particular those related to Environment, Food, and Health. The Horizon Europe Missions are also of high importance. In particular, Mission Starfish (Restore our Ocean and Waters) needs to be taken into consideration.

Being able to demonstrate the contribution of MBS to national and European policies and priorities will also allow them strengthening the European Research Area as demonstrators and implementors of best practices in Open and FAIR Data, promoting international cooperation, improving access to excellence, and supporting research and innovation ecosystems to improve excellence and competitiveness. The culmination of these activities will ensure that MBRs will be a strategic partner for the delivery of marine related policies delivering solutions to the challenges society faces today.

MBSs will contribute to European strategic priorities very importantly by implementing research services that can be widely used by the scientific community. MBSs need to rethink the way services are organized and presented. Services need to evolve from a simple catalogue of equipment and facilities to more advanced and sophisticated services. In the first instance, an analysis of the services offered, and their utilization needs to be performed to remove those that are barely used, or not at all. MBSs need to update and renew their service catalogues to be more intuitive and user friendly and better suited to be presented to the new Horizon Europe oriented projects. MBSs need to explore further its data and bioinformatics capabilities. Here networking or belonging to a European RI could be vital as through pooling resources a centralised organisation can act as a central hub linking datasets, tools, capabilities, analytical platforms, and their ultimate deployment into societal challenges. Creating centralised services, could also create services that are greater than the sum of the parts. connecting services into a "pipeline". Setting up such services will require an increased level of cooperation amongst MBSs partners as well as agreeing on standard operating procedures, to ensure robust, reliable, and reproducible results.

Internationalisation. MBS alone or in association have the potential to link up with a number of organisations outside of Europe, representing European research capabilities, demonstration abilities, and ensuring European participation in global research. International engagement is important to

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increase the number of non-European researchers using our research facilities integrating European research capabilities beyond the continent.

With the UN Decade of the Ocean, MBSs must capitalise on the spotlight on the sea to and use the Decade to forge collaborations internationally. EMBRC has become involved in three UN Decade Programmes: OBON (Ocean-Biomolecular-Observing-Network), Marine Life 2030, and Marine Practices. In the context of OBON, EMBRC was invited to submit EMO BON for official endorsement as a UN Decade Project. These three programmes will constitute important opportunities to project the abilities of MBSs, and open opportunities to be involved with research globally, whilst also gaining visibility in the policy sphere.

In terms of bilateral relations outside of Europe, South Africa and Australia have RI roadmaps similar to the ones produced in Europe. EMBRC has had discussions with the South African Environmental Observation Network (SAEON) and the University of Western Cape to collaborate towards shared protocols for genomic observation and integrated service pipelines for bioprospecting. The Australian Integrated Marine Observation System (IMOS) have also shown interest in the sharing of protocols and standards in genomic observation. In Japan, there has been interest in collaborating on marine model organisms from Shimoda Marine Station. In Latin America, there has been much enthusiasm about working together, and the member of the general assembly of EMBRC Inmaculada Figueroa leads the project RESINFRA-EU-LAC.

EMBRC has had contact with the Marine Biodiversity Observation Network (MBON, part of GEO BON). This group of marine biologists with a focus on biodiversity is dominated by American researchers so it provides opportunities to launch collaborative ties with the USA. EMBRC has also been contacted and the Partnership for Observation of the Global Ocean (POGO) which both work in the observation space, globally. The interest within these organisations is to collaborate on shared protocols, best practices, data and metadata standards and working to ensure that EMBRC research and observation can work as contributions to global One-health monitoring.

European RIs, have also a capacity to contribute to sharing benefits with countries at a more global “corporate” scale, for example in the context of the use of biological resources. International cooperation and multilateralism are currently being discussed within the Convention on Biological Diversity in the debate on benefit-sharing for the utilisation of Digital Sequence Information and in the High Seas future treaty. The scientific community is asked to give evidence on how capacity-building and international cooperation in research contribute effectively to the global benefit-sharing mechanism. RIs and EMBRC should be part in building a new paradigm that de-individualise the benefit-sharing for the utilization of biological resources in research whilst guaranteeing a fair and equitable contribution in the new international open science system. As a supplier of marine biological resources from dozens of countries, MBSs are well positioned to be part of these mechanisms, positioning EMBRC as a central and trusted partner in accessing biodiversity for research purposes from across the globe.

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MoUs with other scientific players. As an RI, EMBRC works to connect initiatives, projects, and communities across marine biological science, strengthening the community as a whole and creating new opportunities for excellent science. Given the rich diversity of marine life, marine biology has potential to advance many aspects of biology. In this respect MBSs need to stablish relationships with other domains and disciplines of science. An excellent example of this commitment is the MoU EMBRC signed with EMBL in 2021. Beyond facilitating joint activities between EMBL and EMBRC's partner scientists, the collaboration agreement will facilitate EMBL's access to marine biodiversity, sampling facilities and techniques, and experimental facilities for its field campaigns.

The EMBRC and Euro-BioImaging also signed a collaboration agreement on 14 May 2020 to enhance communication about their respective services, to promote the development of joint services, and to encourage best-practice sharing and staff exchanges. The collaboration agreement will focus on facilitating access to marine model organisms and encouraging the use of advanced microscopy techniques in their study. In 2022 there has been already a project awarded coming from this collaboration (EC call HORIZON-INFRA-2022-TECH-01-01: "R&D for the next generation of scientific instrumentation, tools and methods") entitled IMAGINE/IMAGINEXT: Next generation imaging technologies to probe structure and function of biological specimen across scales in their natural context, where different MBSs of ASSEMBLE Plus are partners.

EMBRC also became more involved with the EuroMarine network in 2021. EuroMarine is a member-based, interdisciplinary, collaborative network of European marine organisations and research institutes.

Partner 9 has dedicated 2 PM to this task.

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4. Joint Research Activities (JRAs)

4.1. Genomic observatories – JRA1

JRA1 (WP7) has been building a community of practice and implementing Genomics Observatories of microbial Marine Biodiversity by the introduction of Next Generation Sequencing methods coupled with environmental data across broad geographic scales. Key element of such a community is to secure high data and metadata standards and develop good practices around standard procedures at all steps from sampling, biobanking, complex sample processing, data annotation and publication. In close collaboration with NA2, the data thus produced should conform to FAIR data principles for Open Science, allowing data comparability and reuse.

This was accomplished by:

- Addressing all ASSEMBLE Plus partners to shape the core of a GOs network spreading the word of strict standardization of procedures to avoid station specific biases
- Re-addressing the network of stations of Ocean Sampling Day (OSD) 2014 materialized within the FP7 Micro B3 project to sensitise the international community on Ocean Observation
- Implementing protocols and standards to perform DNA metabarcoding for prokaryotes and eukaryotes for samples from the water column and from Autonomous Reef Monitoring Structures (ARMS), using the marker genes 16S rRNA (OSD) and 18S rRNA ((OSD and ARMS), and by production of large amounts of shotgun metagenomics sequencing data (OSD).
- Supporting the expansion of DNA barcoding reference databases
- Operating OSD and ARMS Samplings across stations
- Contributing in the release of FAIR Data

Task JRA1.1. GO standards-literate community building

Biodiversity monitoring across huge geographic and ecosystem distances is a challenging task, especially when, as in the case of JRA1, involves the introduction of new methods, such as Genomics and production of big datasets. Genomics Observatories are networks of (broadly) distributed stations; it requires operation by personnel that understands the possible biases at each step of a long chain of operations and procedures and the necessity for highly coordinated processes, the conscientious, strict application of standardised protocols.

The implementation of a GOs literate community has had two lines of operations; (a) Plankton monitoring community by adopting the Ocean Sampling Day (OSD) practices already been developed within the FP7 Micro B3 project and (b) The hard sediment biodiversity monitoring by use of Autonomous Reef Monitoring Structures (ARMS).

An in-person workshop in the beginning of the project (NA1) has introduced all the challenges and brought the expertise of Micro B3 to all the JRA1 partners. The community included more than 200 OSD registered stations (GDPR conformed links). In the case of OSD, we have adopted with small modifications the protocols and practices that had already been developed and tested in Micro B3, introducing a new strategy for shotgun metagenomics. The protocols and description of practices had been communicated in a large community of registered stations across all continents, with a dense network in the Mediterranean and North Atlantic. The communication has been by emails and involved intensive activity of answering questions and clarifying all details, while over the successive years of

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OSD sampling events, progress have been made by broadly sharing lessons learnt by understanding the origin of faults occurred at individual stations.

In the case of ARMS, community building has been a longer and more intensive process, due on one hand to non-existing previous knowledge among the ASSEMBLE Plus partners, and on the other to the big challenges of the placement and retrieval of ARMS requiring expertise in scientific scuba diving. Nevertheless we took advantage of developments in US (http://www.naturalhistory.si.edu/research/global-arms-program) who generously offered support and training, and have established a highly motivated ARMS community in Europe (http://www.assembleplus.eu/research/ARMS-MBON), implementing an ASSEMBPLE Plus network of 20 ARMS (ARMS BON) stations in the Mediterranean and the Atlantic; this took many training workshops with in person presence, as well as by video conference and has also took advantage of the operations of JRA5 (diving). ARMS-MBON is now part of EMO BON established by EMBRC which has become part of GEO BONs Marine Biodiversity Observation Network (MBON).

Most JRA1 stations operated both OSD and ARMS, the two activities forming key elements of ASSEMBLE Plus Genomics Observatories.

Task JRA1.2. GO-Sampling Day

The implementation of a network of GOs included the materialization of a one-year application of the Ocean Sampling Day, and an equivalent deployment of ARMS, including all the downstream work of sample centralization and biobanking, nucleic acid extraction, preparation of DNA metabarcoding and shotgun metagenomics libraries, sequencing, data and metadata curation, and making data available.

Then the data that initially would simply planned to become public, on the way, higher objectives have been adopted; the release of data followed the emerging FAIR data principle (NA2), which since then became priority area in European research. The outcome went beyond any initial ambition.

There have been two OSD events taking place in the summer solstice, OSD2018 and OSD2019 in the pre-COVID period, followed by much less successful OSD2020 and OSD2021, which have been affected by the epidemics. For OSD2018, 62 stations have delivered 16S rRNA, and 48 stations for OSD2019. Much more have been sampled but samples have either been bio-banked locally because of the cost of sending it by dry ice to Crete, or have been sent in Crete but never been delivered for different reasons, or did not deliver good or sufficient DNA quantities.

In parallel, there have been a one-year monthly OSD sampling (OSD 12x), aiming to assess the seasonal variation of coastal biodiversity. FAIR OSD data have been produced for only OSD2018 and OSD2019 with more than fifty stations each year. For most of those stations there are also data from OSD2014 produced by Micro B3, so that there is an already emerging time series, which is a key element of long-term observatories. The OSD 2020, OSD 2021 and OSD 12x samples have been processed up to DNA extraction and biobanking. When we include all samples sent there are around 1000 filters stored on station's Deep freezers, the big majority are centralized at HCMR. On the other hand, the initial ambition to also apply meta transcriptomics has not been realized as this has been a very demanding task, in an already very ambitious project. Experience gained through JRA1, showed that each new

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data type added, requires a major effort to implement, and meta-transcriptomics is not an exception to the rule.

The European ARMS programme (ARMS-MBON) is a network of Autonomous Reef Monitoring Structures (ARMS) to assess the status and changes of hard-bottom communities of near-coast environments, using genetic methods supplemented with image analysis and visual inspection methods. ARMS are three-dimensional units consisting of stacked settlement plates attached to the sea floor which are mimicking the complexity of hard bottom marine substrates, attracting both sessile and motile benthic organisms. The ARMS network, which has been developed within JRA1 has also received support from the Swedish Agency for Marine and Water Management and the Interreg project GEANS, comprises of 25 observatories distributed across European coastal waters and the polar regions, creating the so named, ARMS-MBON network (http://www.assembleplus.eu/research/ARMS-MBON). One of our scientific goals is to identify newly arrived Non-Indigenous Species (NIS), facilitating an early warning system, and to track the migration of already known NIS in European continental waters.

Starting with a test phase in 2018, ARMS-MBON has been working with annual cycles of deployment-retrieval, with each cycle having a design, deployment, and analysis phase. ARMS units are deployed for periods of a few to many months, depending on the local conditions. The network has deployed a total number of 134 ARMS units. The first sampling campaign (2018) deployed 20 ARMS across 11 sites, the second campaign (2019) deployed 53 ARMS across 18 sites, and the third campaign (2020) deployed 61 ARMS across 20 sites. The number of deployments and deployment locations is gradually increasing year after year (25 by now). For this reason, there have been developed a specific partner registration sheet to allow new partners to register new observatories and receive consultation as well as training. ARMS-MBON is now part of the European Marine Omics Biodiversity Observation Network EMO BON (https://embrc.eu/emo-bon). Both OSD and ARMS have received considerable in-kind contributions by the participating institutes.

Task JRA1.3. DNA barcoding & meta genomics

The main Genomics methods used for the assessment of microbial prokaryotic and eukaryotic biodiversity at the community level are: (a) DNA metabarcoding mainly targeting the marker genes 16rRNA for prokaryotes, and 18S rRNA for eukaryotes; the data delivered are used for taxonomic assignment and abundance estimations allowing to address several questions, and (b) shotgun metagenomics which also offers the above, together with ample information on the functional potential of microbial communities based on annotation of (meta)genomes and Metagenome Assembled Genomes (MAGs). The latter, brings information of on metabolic and regulatory networks on top of the geographic, oceanographic and ecosystem data, allowing the investigation of genomes to ecosystems associations and constituting effective hypothesis generation tools. The same data can also be used for bioprospecting purposes. The above methods have been applied by use of standardised protocols and procedures.

The application of the above methods allowed to produce data for two successive OSD events, OSD 2018 and OSD 2019, which took place during the respective summer solstices. These data have been

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made publicly available (NA2) following the FAIR data principles. These two events and the whole process has allowed to identify challenging steps in the process, one being the shipping of samples under deep freezing conditions, a process which is very expensive and not available in some stations. It has also taught us that even simple tasks, when they broadly distributed and in absence of real meetings, may not be trivial.

In the case of ARMS-BON there has been priority for standardization of procedures across stations by using the same processes and protocols for sample retrieval, DNA extraction, PCR amplification and sequencing. Detailed protocols for DNA extraction, PCR amplification, and sequencing are available on the website (http://www.arms- mbon.eu/) under Molecular Standard Operating Procedures (MSOP). In the case of ARMS we have investigated the diversity of eukaryotes, by means of markers chosen. The comprised the mitochondrial cytochrome c oxidase subunit I (COI), the nuclear 18S small ribosomal subunit (18S rRNA), and the nuclear Internal Transcribed Spacer (ITS1). Unlike OSD, where data have not been analysed yet, other than preliminary analysis meant for a data paper, in ARMS there has been some pilot data analysis for (a) purposes of benchmarking for the effectiveness of fixatives for sample preservation DMSO vs ethanol, and (b) for the estimation of effectiveness in discovering Non-Indigenous Species (NIS) by analysing ARMS from Sweden and from Greece. In the case of NIS, combined analysis of genetic and image data resulted in 72 identified species from the Swedish ARMS, with 8% overlap between genetic and image-based species observations while in Greek ARMS, the analysis resulted in 69 identified species with only 4% overlap between genetic and image-based communities, highlighting the high degree of complementarity of image and genetic data collected by the ARMS. Interestingly, while the sessile fractions are dominated by sequences from chordates (tunicates), the motile fractions are co-dominated by arthropods, nematodes, molluscs, and single cellular eukaryotes.

One obvious drawback for DNA metabarcoding is the still incomplete DNA barcoding reference databases, which limit positive taxa identifications and can also lead to misidentifications. DNA barcoding reference databases offer great added value to monitoring biodiversity by DNA metabarcoding, as it increases taxonomic resolution. UPMC at Roscoff has developed over the years several DNA barcoding reference databases. Here it has been supported by ASSEMBPLE PLUS and produced RoskoBaz, a unified database for the collection and curation of marker genes for annotation of metabarcodes of the marine microbial planktonic communities. A GitHub exporter has been developed, which generates various outputs directly usable by commonly used bioinformatic tools and available via the GitHub webpages for the different databanks (https://github.com/roskobaz/).

DNA barcodes have been produced in several microalgae (18S, 28S, ITS) and in invertebrates (Ascidia, bivalves, Gastropoda, etc.).

Task JRA1.4. GO virtual-access portal

Producing data to monitor biodiversity across scales, is only meaningful if the data can be trusted for what they measure with precision and accuracy in ways that allow to be comparable across spatial and time scales. To be comparable, the date needs to be Open in special ways, that is to be easy to Find (to be Findable), when they are found, to be in forms making them easily Accessible, to be Interoperable

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so that data in diverse formats and locations can be brought and used together, and to reusable as new data will be added following the same standards, processes and protocols. These traits constitute the much-desired FAIR data principle for Open Data. For these reasons, JRA1 has been the appropriate test bed for the improvement of processes towards the production of Open FAIR Data. This task in the case of OSD data, has been led by VLIZ with the participation of HCMR, GFBio and in the case of ARMS it has been led by VLIZ, in interaction with the University of Goteborg and HCMR, and with the in-kind contribution of all JRA1 partners, as well as in collaboration with LifeWatch ERIC.

Therefore, JRA1 served as a use case for -omics, image and environmental data in close interaction with NA2 (WP4) by giving detailed description of all data and metadata, so that effective access to FAIR data could be designed, implemented and offered by NA2 and its Task NA2.3 "Set up virtual open access entry point to data resources": Task Leader VLIZ; participants HCMR, MBA, MPI (and all other partners).

Lessons learnt, exploitation of results, impacts

JRA1 was about introduction of -omics methods for assessment and monitoring marine biodiversity in a across a network of stations operated across countries or continents. The process involved production of several different data types, and for each type of data, a multi-step chain of actions was required; each step in the process, can affect the outcome in ways that bias the results and the estimations. In three years of activities, we have encountered several of the problems that can be met, from sampling, sample storage, sample shipping, primer choice, PCR, library preparation for sequencing, multiplexing samples, and so on. A major lesson learnt for broadly distributed stations, is that even simple processes may be misunderstood, and applied inappropriately affecting data quality. A sample that is shipped without dry ice or any preservative, will fail to deliver any data. Still many samples have been sent by simple post, or ignored instructions sent by written.

Networks of observatories operating in coordinated ways, is first a social structure that needs to have an identity and social cohesiveness driven by vision. To have a corporate spirit, there is need for a stable structure and office/management that will run all the communication, will tightly coordinate and be always available to answer questions, visit, develop training material, and motivate.

JRA1 produced -omics big data and the data have been released close to the end of the project. Therefore, their exploitation has started only recently and as first steps, we have addressed the data only one or two questions in order to demonstrate their usefulness presented within data papers. In the case of ARMS with just the first analyses it has been shown that this is a very effective tool for assessing non-indigenous species or cryptic species, and that the sessile community on an ARMS, is very distinctive from the motile benthic organisms. The exploitation of data has just begun and is already very dynamic with ongoing studies leading to manuscripts e.g. on invasive species, phylogeography, biogeography of benthic invertebrates in European coastal waters.

The OSD data are even less exploited. In a preliminary analysis of three year's data (OSD 2014, 2018, 2019) across Mediterranean and either side of North Atlantic, it appears to exist relative stability of the same stations across time, with the intra station variability to be smaller than the inter-station

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variability. Also, in all stations, OSD2014 estimates of biodiversity levels is higher that OSD2018 and OSD2019. We need to be cautious with the results, as there has been a small modification in one of the primers of 16S RNA in OSD2018, 2019, which might be the cause of the differences. This requires further investigation, and constitutes an example for the need to stick to the same protocols across years; in the case that a change becomes necessary because of great improvement in may bring, benchmarking of the method is required comparing the changed methods with the previous one is required.

62 stations have delivered 16S rRNA for OSD2018, and 48 stations for OSD2019. Much more have sampled but samples have either bio-banked locally because of the cost of sending it by dry ice to Crete or have been sent in Crete but never delivered for different reasons, or did not deliver good or sufficient DNA quantities. Another lesson learnt is that delivering FAIR data is a far from trivial task, discouraging individual scientists form making available the time for this. On the other hand, it is of primordial importance, a sine quoi no for GOs requiring a dedicated coordinating office, to pass the message and give the means for appropriate training and multifaceted support and the development of consciousness about the importance of delivering FAIR data.

The above lessons and work with other infrastructures and communities has had important impacts. It has inspired and contributed in the preparation and establishment of EMO BON (https://embrc.eu/emo-bon), a network of long-term observatories applying Genomics methods and lessons learnt from JRA1, is the implementation of the EMO BON long term observation of coastal biodiversity from Red Sea and the Mediterranean to North-eastern Atlantic up to the Arctic cycle, producing bimonthly GOs data for the water column, and benthic soft and hard sediments. EMBRC systematically works to address the needs of the European Green Deal and UN's Decade of the Ocean and is an observation infrastructure to be expanded to cover more stations and ecosystems and to address new data types (images, other -omics etc) and offer multiple services such as testing sampling devices, testing new methods for data production in the spirit of expanded observatories by comparing with its trusted data to be used as reference data.

Publications

- Obst M, et al. (2020) doi: 10.3389/fmars.2020.

4.2. Cryobanking of Marine Organisms – JRA2

WP8-JRA2 has the objective to design, standardize and coordinate criteria for the development of cryopreservation protocols for the long-term conservation of marine organisms. Our first objective was to elaborate a directory of methodologies available and a state-of-the-art review of the published protocols for marine organisms. In additional, JRA2 has a big component of experimental research and coordination between partners working with similar cell types. Experiments have started on all the tasks in WP8 showing already useful results in the development of clear and standardized protocols for key species. These protocols have applications for research which will increase the potential demand of service in the marine stations but also have industrial applications for the aquaculture

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sector as well as revert in social impact for the European society due to the applications in conservation of natural resources and marine water quality assessment.

- Deliverable 1. Directory of methodologies available and a state-of-the-art review of the published protocols for marine organisms. 2018
- Deliverable 2. Workshops:
    - **Workshop1** took place in Cartagena (Spain) October 2nd 2018 Cryobanking in Aquatic Species was organised as an interaction activity along the network AquaExcell to exploit synergies and maximise interaction. We gathered 17 attendees (in person and online) from 8 different institutions. Thirteen talks from several attendees took place and we finished with a round table.
    - **Workshop 2** took place in SAMS (UK) 26 and 27th June 2019 Cryopreservation of Genetic Marine Resources: from the ocean to your Marine Station was organised as an interaction activity for the scientific community. We gathered 30 attendees from 10 different institutions.
- Deliverable 3. CRYOMAR PROTOCOL TOOLBOX 2020

JRA 2-CRYOMAR has produced an extensive report on the De-fragmentation of existing cryobiological knowledge relevant to the marine sector, a JRA specific discussion forum has been stablished using Basecamp and we have produced comprehensive depository of methodology.

JRA 2-CRYOMAR is reporting advanced research in sperm and larvae of molluscs of economic importance like mussels (*Mytilus galloprovincialis*), oysters (*Crassostrea angula*) or clams (*Chamelea gallina) with applications for water quality assessment, aquaculture and conservation.*

Cryopreservation protocols have been developed for macro algae (*Saccharina latissima)* and are being developed for recalcitrant microalgae like dinoflagellates. We are also reporting advances in the cryopreservation of fish sperm (*Chelon labrosus, Solea senegalensis* and different strains of zebrafish), these protocols are very important for the maintenance of pollution sentinel fish species, aquaculture relevant fish species and zebrafish lines for research, aquaculture and monitoring of marine water quality.

Finally, JRA2-CRYOMAR is reporting a massive effort for standardisation and sharing of protocols and procedures through a ring test on mussel cryopreservation among three different marine stations (UPV/EHU, CCMAR) and the organization of a large capacity workshop open for all ASSEMBLE Plus members to disseminate methodologies and share first-hand experience.

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Task JRA 2.1. De-fragmentation of existing cryobiological knowledge relevant to the marine sector, establishment of a JRA specific discussion forum and depository of methods (Participants: UPV/EHU, SAMS, UPMC).

This task focussed on collating and making available data on the range of approaches employing conventional cryopreservation and vitrification that have been used to conserve marine biological materials. This was gathered for practicality and applicability in the different Tasks in this WP. A dedicated discussion forum was stablished to refine methodologies and facilitate methodological trouble-shooting. Objectives have been fully met in this task.

Task JRA 2.2. Exploring the potential to cryopreserve marine invertebrate larvae, embryos and/or gametes and to develop appropriate biobanks and procedures (Participants: UPV/EHU, CCMAR).

Pooling the expertise across the consortium, robust methodologies are being developed and validated, first steps have been taken towards cryopreservation of mussel sperm for Cryo-banking and posterior functional analysis of motility. Four meetings have taken place to run a ring-test exercise Faro (Algarve), Vigo (Galicia) and Plentzia (Basque Country) for environmental monitoring application. Sperm sampling and Cryo-preservation protocol has been established for mussels, although first attempts during 2018 spawning season were not satisfactory in the Basque Country or Faro. The sampling, cryopreservation, sample shipping and motility measurement has taken place in the spring 2019 and 2020 results are currently being analysed. Two manuscripts are being produced with results of cryopreservation experiments for the *M. galloprovincialis* larvae that had been designed by Universidade de Vigo for Aquaculture applications. In this task CCMAR has been working in the development of cryopreservation protocols for *Chamelea gallina* and *Crassostrea angulata* sperm and larvae, two important commercial bivalve species. For *Chamelea gallina* several cryoprotectants were tested and a preliminary protocol was developed using EG and DMSO as cryoprotectants. For *Crassostrea angulata* sperm, optimization of previous protocols was done taking into consideration the addition of sugars and antioxidants. Protocols incorporating antioxidants were made in collaboration with the University of Vigo. One member of Vigo team was at CCMAR testing the effect of antioxidants on the quality of post-thaw sperm. Objectives have been fully met in this task.

Task JRA 2.3. R&D on cryopreservation, protocol development and cell recovery in teleost germ cells (Participants: CCMAR, UPV/EHU)

UPV in Plentzia studies thicklip grey mullets Chelon labrosus as sentinels of environmental health in pollution monitoring campaigns in sites of the Basque coast with high prevalence of xenoestrogenic chemical compounds (produce fish feminization). Within the scope of this JRA attempts have been done to assess sperm mobility upon sperm cryopreservation instead of in fresh sperm. Cryopreservation should allow carrying out the analyses in the laboratory, after sample collection in the field. Protocols for mullet sperm cryopreservation have been applied, although procedures have been hampered by the difficulties of obtaining “flowing” males in estuaries (spawning occurs in the sea, where sperm hydration takes place). Sampling for further refinement of the protocol in the field will continue during autumn 2020. CCMAR has been optimizing sperm cryopreservation protocols in zebrafish strains and in Senegalese sole. In the case of zebrafish, the selection of donor fish samples based on fish age and striping frequency was stablished and new protocols for sperm cryopreservation developed taking into consideration alternative methods such as the use of biofreezers (-150ºC). In

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Senegalese sole, research was focused on the analysis of post-thaw quality to ensure the development of a secure method to transfer to industry. Objectives have been fully met in this task.

Task JRA 2.4. R&D on cryopreservation and biobanking of macroalgae (Participants: UPMC, SAMS)
At SAMS, the team have investigated a method for cryopreserving gametophytes of the brown seaweed, *Saccharina latissima* and this has resulted in a paper submitted to JAPh: Visch W, Rad Menendez C, Nylund GM, Pavia H, Ryan MJ, Day JG. (2018) Underpinning the development of seaweed biotechnology: Cryopreservation of brown algae (*Saccharina latissima*) gametophytes. Objectives have been fully met in this task.

Task JRA 2.5. Cryopreservation research on Amphioxus (Participants USTAN)
Amphioxus are seasonal spawners, and unfortunately the timing of their spawning in the late spring didn´t allow time to start the experiments in 2018. Experiments are therefore scheduled for next spawning season to test a number of cryopreservation techniques on embryos, and then to evaluate using markers and/or sequencing techniques. USTAN has suffered a serious fire incident and therefore they will not be able to produce any substantial results by month 24. Discussions of possible alternatives and out-of-the-box approaches are being discussed to try to cover the experiments during the life of the ASSEMBLE Plus as soon as the USTAN facilities are up and running again. At USTAN they participated on the analysis of prior knowledge and on both WP workshops. After exploring all avenues to continue the work plan it had been impossible to overcome the unexpected issues caused by the fire, the objectives have only been met in the preliminary phases of the work.

Task JRA 2.6. Development and application of novel cryopreservation approaches to cryopreserve a wide range of protists, microbial consortia and mutant libraries (Participants, SAMS; UPV/EHU, UPMC, MBA, CCMAR, NIOZ)
Dinoflagellates are recalcitrant to conventional cryopreservation, SAMS is developing research on the cryopreservation of 2-3 species of dinoflagellate cysts using conventional techniques and encapsulation. MBA carried out a screening of strains in the MBA culture Collection using a standard method to determine which, if any, survived. Only *Amphidinium* retained viability, morphology and motility, producing healthy cultures. *Prorocentrum* and *Scripsiella* showed 'normal' looking cells with no motility but no cell division. Universidade de Vigo has tested all methodologies currently available for microalgae cryopreservation to try to address recalcitrant species cryopreservation and only Vitrification with ultra-fast laser warming has given some preliminary hopeful ideas, more research is needed on this specific task. UPV has initiated the application of protocols of cryopreservation of microalgae as applied in the Station Biologique de Roscoff (SU) handling, keeping and transfer of its collection of 500 microalgae strains. Technical staff of UPV used mobility funds granted from an Assemble+ NA2 call and visited the infrastructure in Roscoff to receive specific training in microalgae cryo-preservation, in order to cryo-preserve a considerable proportion of the 400 strains in the Basque microalgae culture collection. NIOZ has successfully developed a cryopreservation protocol for hypersaline microbial mats that can now be preserved at – 150 ºC and can be grown again for 120 days. NIOZ is extracting/processing DNA for the determination of the bacterial community composition post cryopreservation. Objectives have been fully met in this task.

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Lessons learnt, exploitation of results, impacts

1. Cryopreservation of new species and cell types. Protocols available in: web Assemble+, Oceanbestpractices Repository and Protocols.io
2. Spreading knowledge about the uses and benefits of cryopreservation: meetings, workshops, networking with other projects (like Aquaexcel or Synthesis), Organization of a brokerage event at the Assemble conference 2020.

Brockerage event on Cryopreservation: we had 4 speakers ranging different interests and points of view/needs: from a private company, a researcher awarded by SHERPAdoMar for their entrepreneurship on aquaculture, a researcher working on conservation of marine biodiversity and a representative of JRA2 that presented the CRYOMAR Protocol Toolbox and new protocols developed. Attendance 32 people.

Communications to meetings

- International Symposium of Marine Science, Vigo, Spain, 20-22 June 2018
- 55th Annual meeting of the Society for Cryobiology 2018, Madrid 10-13 July (Spain).
- 56th Annual meeting of the society for cryobiology. San Diego, USA 2019
- Foro malacológico de la sociedad Española de malacología – Vigo (Spain) 19-21 September 2019
- Society for Low Temperature Biology Annual meeting. Seville (Spain), 2-4 October 2019
- 57th Annual meeting of the society for cryobiology. 21-23rd July 2020 online
- 'Cold in biology and medicine - 2020' 44th Annual conference Organized by the UNESCO chair in Cryobiology 19TH May 2020 online
- Society for Low Temperature Biology Annual meeting. online October 2020
- Cold in Biology and Medicine conference. 45th Annual Conference, Organized by the UNESCO chair in Cryobiology 19 - 20 May 2021 Online.
- 58th Annual meeting of the Society for Cryobiology 2021. 20 -23 July 2021.Online
- MARTECH 2021, 16-18 June 2021 Online

3. Proof of concept- application of cryopreserved cells, Coordination and standardisation of protocols, Expand / implement marine biological resources in biobanks, Shared Good practices in biobanking cryopreserved cells, equipment options, liquid nitrogen handling and safety…

4. Strengthen or created links in the cryo-users community that will last in time. There have been several TAs attracted by the knowledge on Cryopreservation/Biobanking:

- From Institute for Problems of Cryobiology and Cryomedicine Ukraine to ECIMAT
- From Universidade de Vigo to Stazione Zoologica Anton Dohrn (IT)
- From University of Exeter (UK) to ECIMAT

Publications

Important production of data and publication of manuscripts in open access (Green and gold). There are still at least 2 papers that are in several degrees of production (from data treatment to writing) and that will be published in the near future:

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- Selection criteria of zebrafish male donors for sperm cryopreservation. Article in Journal **Zebrafish 2018**
- Comparative study on cellular and molecular responses in oyster sperm revealed different susceptibilities to cryopreservation. Article in Journal **Aquaculture 2018**
- Electric ultrafreezer (− 150 °C) as an alternative for zebrafish sperm cryopreservation and storage. Article in Journal **Fish Physiol Biochem 2018.**
- Toxicity tests of cryoprotecting agents for *Mytilus galloprovincialis* (Lammark, 1819) early developmental stages. Article in Journal **Cryobiology 2019 + Dataset in IMIS**
- Long term survival of cryopreserved mussel larvae (*Mytilus galloprovinciallis*). Article in Journal **Cryobiology 2019 + Dataset in IMIS**
- Underpinning the development of seaweed biotechnology: Cryopreservation of brown algae (*Saccharina latissima*) gametophytes. Article in Journal **Biopreservation and Biobanking 2019**
- The Use of Cryopreserved Biological Material for Water Quality Assessment. Article in Journal **Frontiers in Marine Science 2019.**
- Cryopreservation of Algae. In: Cryopreservation and Freeze-drying protocols. **Springer 2020 Book Chapter**
- Cryopreservation of marine invertebrates: from sperm to complex larval stages. In: Cryopreservation and Freeze-drying protocols. **Springer 2020 Book chapter**
- Larval cryopreservation as new management tool for threatened clam fisheries. Article in Journal **Scientific Reports 2021 + Dataset in IMIS**
- Long-term study on survival and development of successive generations of *Mytilus galloprovincialis* cryopreserved larvae. **Scientific Reports 2022 + Dataset in IMIS**
- **Thesis dissertation by Pablo Heres** " Mollusks cryopreservation and variability along development and species" Universidade de Vigo (Spain) **2021** http://www.investigo.biblioteca.uvigo.es/xmlui/handle/11093/2895

4.3. Functional genomics – JRA3

The general objectives of this WP were:

· to implement/adapt specific protocols for generation of genetic resources for a panel of emerging/prospective marine model organisms;
· to generate a reference set of carefully phenotyped or genotyped genetic resources of different marine organisms ranging from bacteria to metazoans;
· to produce and provide access to the phenotypic or genotypic data necessary for the functional description of the genetic resources.

During the duration of the project the different participants in this WP developed (and they will continue developing) the various activities and experimental approaches that were detailed in the project. Depending on the model, the results of these years are at more or less advanced stages of development, but overall, we can estimate that this WP has produced numerous results for the three tasks.

Task JRA3.1. Functional genomics in marine metazoans

Our objective was to develop a CRISPR-Cas9 gene editing protocol for the following marine metazoans: ascidians (*C. intestinalis, C. robusta and P. mammillata*), amphioxus (*Branchiostoma lanceolatum*), the sea urchin *P. lividus*, and *Clytia hemisphaerica*. All the participant teams, are expert for each model

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and developed completely the experimental approaches. In parallel to the development of CRISPR-Cas9 gene editing protocols, collection of phenotype description by gene expression studies have also been provided.

The partners in the OOV (Villefranche-sur-Mer, France), applied the CRISPR/Cas9 technology mainly to three marine invertebrate models; the jellyfish *Clytia hemsphaerica*, the sea urchin *Paracentrotus lividus* and the ascidian *Phallusia mammillata*. CRISPR/Cas9-mediated gene knockouts are now routinely used in *Clytia* and *Phallusia* systems in the laboratory. A transgenic protocol for *Clytia* has been successfully established. An implementation of the CRISPR/Cas9-gene knockout to the sea urchin *Paracentrotus lividus*, has turned out to be challenging and we will continue our effort even after the Assemble-plus contract. Finally, CRISPR/Cas9-mediated gene knockins remain to be established in these animal models. Finally, there is a new study that benefited from the Assemble plus JRA3 project (under review for *Science Advances*), in which conserved meiotic mechanisms in the cnidarian *Clytia hemisphaerica* was revealed by *Spo11* knockout (Mounro et al).

The partners in the OOB (Banyuls-sur-Mer, France), applied the CRISPR/Cas9 technology and TolII transgenesis mainly to the ascidians *Ciona intestinalis* and *Phallusia mammillata* and to the amphioxus *Branchiostoma lanceolatum*. Gene editing in the ascidian *Phallusia mammillata* was adapted from C. intestinalis protocols, however, low mutagenesis rates led to the use of microinjection of synthetic sgRNA/Cas9 complexes as published by McDougall et al., 2021.

We also established CRISPR/Cas9 gene editing by microinjection of synthetic sgRNA/Cas9 complexes into fertilized eggs of *B. lanceolatum*. Validation of genome editing by genomic analysis has been performed. Interesting results were obtained for *B. lanceolatum* also for TolII transgenesis approaches.

Moreover, both at OOB and St Andrews, we generated a significant number of novel expression patterns (around 60 genes/species) in ascidian and amphioxus (and a subset in deregulated context). These data have been published and will be publicly available in coming publications and through a dedicated database (Aniseed). And finally we generated an ontology for *B. lanceolatum*.

The partners at SZN focused on setting up knock-out technology by CRISPR/Cas9 in *Ciona robusta* and sea urchin. The *Ciona robusta* is a suitable model organism for the application of a wide range of molecular biology technique, in particular in the recent years the advent of new technologies, as CRISPR/cas9, gives the opportunity to explore the potential role of a target gene involved in the regulatory pathway of a specific cell population. As part of the study on development of the *Ciona robusta* nervous system we developed a strategy to knock-out several genes possibly involved in development. CRISPR/CAS9 technology was applied to generate mutations. A library of sgRNA has been prepared containing more than 50 different sgRNA belonging to 12 genes. All have been tested for their efficiency on *Ciona* genome. The results showed that the efficiency rate of the identified sgRNA was quite low (less than 10 % of the tested sgRNA) and the efficiency is lower if we consider the phenotype observed. For the delivery of CRISPR components we used electroporation of *Ciona* fertilized eggs. This method is mostly adopted for *Ciona* because it led to skip the microinjection of the eggs, which can represent for *Ciona* a problem, since the small dimensions and sticky eggs. Regarding the preparation of the CRISPR/cas9 plasmids we tested both methods described for the preparation of the sgRNA guide : the single reaction of PCR which allows to prepare U6>sgRNA cassette, also called OSO - PCR (one - step- overlap PCR),that allow the electroporation of this cassette into the fertilized eggs. And the preparation of the U6 > sgRNA F+ E scaffold plasmid. This last has been the more convenient method to prepare reliable plasmid to be used in CRISPR/Cas9 experiments in *Ciona*.

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Task JRA3.2. Functional genomics in macroalgae

The partners at SBR worked on the establishment of a CRISPR-Cas9 based system on the brown alga Ectocarpus sp. We obtained extremely interesting results using the CRISPR-Cas9 approach. CRISPR-Cas9-based gene knockouts were generated using both biolistic and microinjection approaches involving simultaneous KO of a positively-selectable endogenous marker gene (APT and any target gene of interest). We have so far applied this approach to seven different target genes and generated mutants for all of them.

Task JRA3.3: Functional genomics in microorganisms

In this WP, implementation of transgenesis and gene editing in different microorganisms have been worked out. Thus, in Sorbonne Université, we set up the experimental conditions to complement the diatom *Phaeodacytlum tricornutum* knock-out lines and to perform targeted functional characterization of a gene of interest (complementation of KO lines with functional mutations). Giovagnetti et al., Plant Physiol 2022. Moreover, a method to introduce an antibiotic resistance gene into the plastid DNA of another diatom species, *Cyclotella cryptica,* based on homologous recombination was successfully developed. In addition, this technique was used to specifically target a desired region in the plastid genome, which was confirmed after sequencing. However, homoplasmic mutants have not yet been obtained.

Finally, a CRISPR/Cas9 RNP-based method was used to mutate genes of interest encoded in the nuclear genome. Using this technique, we produced KO lines of *C. cryptica* for the genes LPA3 and ATPC, which are involved in photosynthesis. Mutant lines are unable to grow properly in phototrophic conditions.

Protocols for gene editing of the pennate, benthic diatom *Cylindrotheca closterium* were also developed in Ghent University. We thus established a successful biolistic transformation protocol (needed for the gene editing protocol), albeit with low efficiency, and we adapted the established protocol for proteolistic-mediated RNP transformation from *Phaeodactylum tricornutum* to *C. closterium*.

At the SZN, we worked to adapt the *Phaeodactylum tricornutum* biolistic transformation protocol to another diatom, *Pseudo-nitzschia multistriata,* and we successfully improved the transformation efficiency (dx.doi.org/10.17504/protocols.io.b5jgq4jw). We also adapted the *P. tricornutum* proteolistic protocol for CRISPR/Cas system application to *P. multistriata*: inclusion of the *P. multistriata* genome in the CRISPOR and CHOPCHOP databases (http://crispor.tefor.net/; http://chopchop.cbu.uib.no/) for specific gRNAs design; identification of the endogenous drug-sensitive genes UMPS and APT, used as selectable markers and test of the corresponding sgRNAs in Cas9 in vitro assay; determination of the optimal drugs concentration. And finally, we adapted the *P. tricornutum E. coli* conjugation protocol to *P. multistriata*: optimization of temperature condition and production of constructs containing expression cassettes specific for *P. multistriata.*

At the OOB, we worked on the development of a new bacterial model, *Kordia algicida,* to address the role of *luxR* genes in microalgal pathogens. We first identified target genes and constructed the necessary vectors. Thus, Lux R-like genes and a genomic safe harbor (GSH) site were identified in the *K. algicida* genome to permit the construction of a luxR gene deletion in a suicide vector and a complementation vector respectively. The latter vector was modified by site directed mutagenesis to facilitate use of the vector for the insertion of other GSH sites and/or promotor sequences in the future. Then, we realized conjugation experiments in *K. algicida* using the same methods successfully employed in another Flavobacteria, *Zobellia galactanivorans* but the vector transfer was unsuccessful even after multiple optimizations of the method. Our conclusions are that the generation of mutants

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in bacteria can be hampered by efficient restriction-modification (RM) systems. A search of the *K. algicida* genome revealed the presence of all 4 different types of RM system: type I, type II, type III and type IV (mcrBC-like). One strategy to overcome the RM systems is to protect the vector DNA by premethylation as demonstrated by Wang et al (2015) for *Synechocystis* PCC6803. We are currently collaborating with Yongtao Zhu (Minnesota University, MN) whose team has successfully produced Flavobacteria mutants using this strategy.

At SBR, we adapted transformation protocols using bacterial conjugation methods in the marine picocyanobacteria *Synechococcus* to study the function of selected genes. Several optimization steps have been performed to increase the efficiency of mutagenesis in various *Synechococcus* strains (WH7803, A15-62, WH8102, BL107) using either conjugation or electroporation. We have also worked in collaboration with Prof. D. Kehoe (Indiana University) to develop a protocol based on the CRISPR/Cas9 system.

The application of these protocols to various gene targets led to the generation of several mutants, some of which have already been physiologically and/or biochemically characterized. Inactivation mutants by single cross over of two genes (*mpeW*, *mpeQ*) of the marine cyanobacterium *Synechococcus* sp. A15-62 and complementation experiments notably demonstrated the involvement of these genes in type IV chromatic acclimation (CA4), a process that allows these cells to match their pigment content to the ambient light color (blue or green; Grébert et al., 2021). This approach was also applied to knockout and characterize the function of the four putative photolyase genes of *Synechococcus* sp. RS9916 (Haney et al., submitted). Furthermore, the CRISPR/Cas9 method was applied to the sensor of a two-component system, *nblS*, as well as to the putative AraC-like regulators *fciA*, *fciB* and both *fciA* and *B* genes. The physiological characterization of the *fciB* mutant showed that it is unable to perform CA4 and is stuck in the blue light phenotype, demonstrating the regulatory role of the encoded protein on *mpeW* gene transcription, while the characterization of the other mutants is still under progress (Dufour, Grébert et al. in prep). Results obtained on the functional characterization of the different genes involved in the biosynthesis and regulation of phycobilisomes have been summarized in Grébert et al. (2022).

At MBA CRISPR/Cas9 technology for gene knock-out in haptophytes (*Emiliania huxleyi, Isochrisis galbana*) has been worked out with generation of protocols for genetic transformation of *Emiliania huxleyi* and *Isochrisis galbana*. And at the OOB similar protocols have been developed in chlorophytes (*Bathycoccus prasinos* and *Ostreococcus lucimarinus*).

Publications

Protocols provided (through the deliverables or through publications):

-Darras S (2021). *En masse* DNA Electroporation for *in vivo* Transcriptional Assay in Ascidian Embryos. *Bio-protocol* 11(18): e4160. DOI: 10.21769/BioProtoc.4160.

-CRISPR/Cas9-knockout protocols for *Phallusia* and *Clytia* were published in McDougall et al (doi: 10.1007/978-1-0716-0974-3_13) and Momose et al (2018), respectively. A short description of the *Clytia* transgenic protocol was published in Weissbourd, Momose et al (2021), which will be followed by a more detailed protocol (in preparation).

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-Protocols for amphioxus microinjection and CRISPR-Cas9 have also been provided through deliverables.

-Transformation protocol + CRISPR-RNP protocol for *C. closterium* through deliverables

-Biolistic transformation of *Pseudo-nitzschia multistriata:* dx.doi.org/10.17504/protocols.io.b5jgq4jw

-Transformation of marine *Synechococcus* strains by conjugation :

https://www.protocols.io/private/CC4013E9DA0F11E986100242AC110005

-Transformation of marine *Synechococcus* strains by electroporation :

https://www.protocols.io/private/47F7B8EDD9EF11E986100242AC110005

-Protocols for electroporation and biolistic of haptophytes have been delivered:

https://www.protocols.io/view/biolistic-transformation-of-emiliania-huxleyi-8tzhwp6

https://www.protocols.io/view/biolistic-transformation-of-isochrysis-galbana-2pugdnw

https://www.protocols.io/view/pignat-vector-8frhtm6

https://www.protocols.io/view/microparticle-delivery-of-crispr-cas9-ribonucleopr-bvxen7je

https://www.protocols.io/view/method-for-electroporation-of-isochrysis-galbana-c-hmab42e

Research production (manuscripts, conferences, etc, including DOI for each production):

McDougall A, Hebras C, Gomes I & Dumollard R. (2021). Gene editing in the ascidian *Phallusia mammillata* and tail nerve cord formation. ***Methods Mol Biol*** doi: 10.1007/978-1-0716-0974-3_13.

Momose T, De Cian A, Shiba K, Inaba K, Giovannangeli C & Concordet J-P. (2018). High doses of CRISPR/Cas9 ribonucleoprotein efficiently induce gene knockout with low mosaicism in the hydrozoan *Clytia hemisphaerica* through microhomology-mediated deletion. ***Scientific reports*** DOI:10.1038/s41598-018-30188-0

Munro C, Cadis H, Pagnotta S, Houliston E & Huynh J-R. (2022). Conserved meiotic mechanisms in the cnidarian *Clytia hemisphaerica* revealed by Spo11 knockout. ***bioRxiv*** doi: doi.org/10.1101/2022.01.05.475076

Weissbourd B, Momose T, Nair A, Kennedy A, Hunt B, & Anderson DJ. (2021). A genetically tractable jellyfish model for systems and evolutionary neuroscience. ***Cell*** doi: 10.1016/j.cell.2021.10.021.

Chowdhury R, et al (2022). Highly distinct genetic programs for peripheral nervous system formation in chordates. **BMC Biology** 20, 152.

Meister L, et al. Functions of the FGF signalling pathway in cephalochordates provide insight into the evolution of the prechordal plate. **Development**. 2022;149(10):dev200252.

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Leon A, et al. Gene Regulatory Networks of Epidermal and Neural Fate Choice in a Chordate. **Molecular Biology and Evolution**. 2022;39(4):msac055.

Caccavale F, et al. Crosstalk between nitric oxide and retinoic acid pathways is essential for amphioxus pharynx development. **eLife**. 2021;10:e58295.

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Subirana L, et al. Asymmetron lucayanum: How many species are valid? **PLOS ONE**. 2020;15(3):e0229119.

Le Petillon Y, et al. Spawning Induction and Embryo Micromanipulation Protocols in the Amphioxus Branchiostoma lanceolatum. In: S. S, editor. **Brain Development Methods in Molecular Biology**. 2047. 2019/09/26 ed. New York, NY: Humana 2020. p. 347-59.

Aase-Remedios, et al. (2020). More than one-to-four via 2R: evidence of an independent amphioxus expansion and two-gene ancestral vertebrate state for MyoD-related Myogenic Regulatory Factors (MRFs). **Mol. Biol. Evol**. 37(10): 2966-2982.

Aase-Remedios, M.E., et al. (2022) Amphioxus muscle transcriptomes reveal vertebrate-like myoblast fusion genes and a highly conserved role of insulin signalling in the metabolism of muscle. **BMC Genomics**, 23: 93.

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Deviation from annex 1 and annex 2

Object: non-achievement of the result concerning deliverable D9.4 **Collection of mutant and transgenic/enhancer trap lines for model organisms**

The deliverable D9.4 has not been realised by the participants in the JRA3 work package for a number of organisational, scientific, and administrative reasons.

Firstly, and perhaps the most important reason is that this deliverable was first proposed in the first draft of the ASSEMBLE Plus project during its preparation, prior to submission. However, after receiving the approval of the project by the European Commission, with the budget cut that was imposed at that time, we decided that it was impossible to realize the D9.4, since it requires a significant amount of human resources that was not feasible with the final budget. Subsequently, this deliverable was supposed to have been removed from the final version accepted by the European Commission. However, due to an oversight, this change appears to never have been made and it was

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not noticed by the JRA3 team before very late in the project. At this point it was no longer possible to make a project amendment.

The second reason why D9.4 has not been carried out is that is that the initial budget was extremely underestimated, and the work was not feasible even with the full budget. Of course, the huge manpower requirement for this deliverable could not have been imagined at the beginning of the project since the work of fine-tuning the genetic modifications in the different proposed models had not yet been done, and as often happens in research, no matter how much one foresees costs and time to do a job, we often realise that both the time and the cost had been underestimated.

The third reason is that, despite the impressive results we have obtained in JRA3, which surpassed the expectations of both JRA3 and the project as a whole,, the work is not yet scientifically mature enough where the work proposed in D9.4 could be done. This still requires a lot of time and effort, as well as budget, to automate many time-consuming processes.

These three reasons are an example of how ambitious our initial project was. Clearly, today we do not regret having aimed so high at the beginning, since in research, only when ambitious projects are initiated do we achieve results that advance science and society, as, fortunately, has been the case with JRA3, in which incredible results have been obtained for practically all the biological models that have been worked on. Nonetheless, we are frustrated by the oversight of the inclusion of a deliverable that we had intended to remove, but never was. We hope that our project evaluation team will understand that these things can happen, especially in a project that has gone through multiple project managers and two different coordinators.

4.4. Development of instrumentation – JRA4

Understanding the responses of biological entities (individuals, species, species assemblages) to single and/or combined environmental forcing(s) is a focal point of biological research. In addition to field sampling and in situ experiments, controlled in vitro experiments are crucial in this regard. European marine biological stations have a long history of providing facilities for field collection and ex situ observation of marine organisms, but modern marine biological research increasingly requires access to state-of-the-art on-site experimental facilities. In light of the diversity of marine organisms in terms of size, trophic modes and reproduction processes, there is significant demand for facilities for conducting on-site experiments at different scales, from a few litres up to several cubic metres. Experiments generally require precise regulation of multiple environmental parameters, including (but not exclusive to): temperature, light quality and quantity, salinity, dissolved and/or particulate nutrient availability, oxygen concentration, pCO2 and other carbonate chemistry parameters, the alternation of emersion/immersion cycles (reproduction of tidal cycles), and physical water mass dynamics (flow speed and turbulence). Over the years, systems designed to regulate some (but rarely all) of these parameters have been developed in most of the marine stations involved in the consortium. However, these systems have most often been developed for specific research projects by in-house (and sometimes external) research teams, often by non-permanent staff. The result is that the technical knowledge and expertise required to maintain and operate (and therefore provide access to) these systems has often not been perpetuated beyond the duration of specific projects. Another

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consequence is that systems have been designed without concertation between marine stations, meaning that inter-site reproducibility of experiments is most often highly compromised.

The objective of this WP was to produce a set of technical specifications to facilitate future cross-consortium implementation of standardized experimental systems for the culture of marine organisms for biological and ecological research.

Task JRA4.1. Collaborative R&D to improve and harmonize design of selected categories of experimental systems

Collaborative R&D in this WP focussed on different categories of experimental equipment according to the interests of different partners. The R&D conducted in these different categories is summarized below (more detailed information can be found in Deliverable 10.1).

Tidal simulation systems

The tidal simulation system designed at UPV-EH controls water level in benthic tanks (0.7m3 fiberglass tanks) with a continuous water input and proportional control of the drain. The system has an ultrasonic level sensor that constantly monitors water level in the tanks, with an electrovalve system adjusting it automatically and constantly to the selected curve. Tidal curves can be programmed in advance, selecting water level as speed of increase/decrease of water level. In addition to control of tidal simulation, temperature and salinity can be monitored and controlled in thus system, thus allowing simulation of conditions found in estuaries.

SBR developed a gravity-based tide simulation system. To simulate low tide, the water in the experimental tank(s) flows into the header tank by natural gravity draining. To simulate high tide, the flow induced by pumping into the experimental tank is higher than the maximum flow of the evacuation. The level mounts in the tank until reaching the upper-level evacuation. Temperature (via Techo units), salinity and pH (via CO2 injection) can be controlled in the header tank and regulated via an Aquatronica control module. Different versions of the system were developed with tank volumes between 300 L and 25 L, with replicate tanks (up to 12) in versions with smaller volume tanks.

pH control systems

At KMRC, options were explored to create realistic natural variability in experimental systems that could be transferred to any marine station, including in developing countries. Two approaches were tested: (i) using commonly available existing technology (pH stats); (ii) a simplified protocol using no technology and based on manual manipulation of seawater chemistry. Both approaches followed the established best practices in the field of ocean acidification for the manipulation and measurements of the carbonate chemistry.

(i) In natural coastal ecosystem, biology is often one of the main drivers through the balances between photosynthesis, respiration and calcification. KMRC explored the possibility to take advantage of this natural process to create variability in the experimental system:

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- pH was manipulated using a pH stat system (AquaMedic) in a 50L header tank continuously fed with deep seawater pumped directly from the vicinity of the marine station and heavily aerated to equilibrate at atmospheric CO2 (400ppm). Four different pH levels were tested ranging between 8.1 and 7.5, covering present and future pCO2 under different IPCC scenarios.

- Water from this header tank fed experimental aquariums containing seagrass at the same density as observed in the field. Aquariums were exposed to a 12:12 photoperiod.

- The carbonate chemistry was then monitored following best practices in both the header tank and the experimental aquariums.

The presence of seagrass led to a 0.5 pH variability as observed in the field. This system was successfully tested to evaluate the impact of pH variability on sea urchin larvae. The details of the experimental set-up and the results of the experiments will be published in Cossa et al. (in prep).

(ii) Not all laboratories are equipped with pH stats. As an alternative, we explored the possibility of manual water changes to create natural variability in an experimental unit (1L). This was tested for an experiment aiming at understanding the role of pH variability on sea urchin larvae. The water used for the experiment were equilibrated manually at different target pH in 30L tanks using CO2. Water in the experimental unit was changed manually every 12 hours. Larvae were filtered on a 100mm mess ensuring that they were always under water and transferred to fresh seawater at the target pH before being returned to their aquarium. Measurements of the carbonate chemistry confirmed that this approach allowed to maintain the pH at the desired levels and create a day-night pH variability. The details of the experimental set-up and the results of the experiments will be published in Duvane et al. (in prep).

At CCMAR an enhanced unit for ocean acidification experiments was developed, with CO2 levels being controlled through pH. The overall characteristics of the Acidification Unit are: 3 independent systems (2 CO2 levels + control); controlled CO2 level between 410ppm and 2000ppm; control system with degassing column to assure 410 ppm of CO2; each system's header tank can provide up to 4m3/h of seawater to the experimental tanks; flow-through system; temperature control in 2 systems with heat pumps; continuous logging of pH and temperature of each header tank; continuous logging of pH, temperature, salinity, dissolved O2, ORP and turbidity of the water entering each header tank; different types experimental tanks (20L(48) ;110L (24); 650L(6)). Before the water enters the acidification systems, salinity, dissolved oxygen (% sat, ppm), pH, temperature, salinity, ORP and turbidity are measured every minute. Temperature control with heat pumps was also installed in two of the three acidification systems. To aid temperature control, the salt water supplied to each acidification system passes through a titanium plate heat exchanger using a water source with a constant temperature of 20ºC. In this way it is possible to significantly reduce the daily temperature fluctuations of the salt water.

MBA mesocosm facilities were updated to install new Aqua Medic pH computers, and these were being tested in two long-term experiments on the effects of temperature, pH and salinity on the invasive oyster M. gigas and the *Mytilus edulis/galloprovincialis* hybrid.

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Multi-parameter monitoring and regulation

The Red Sea Simulator (RSS) facility at the IUI in Eilat was designed to simulate climate change associated future conditions in the Red Sea. This state-of-the-art, large-scale, flow-through system comprises 80 independent experimental aquariums. pH and temperature in each aquarium can be set to a user-defined off-set from ambient reef values. The system is regulated and monitored by a two-armed robot, equipped with sensors on each arm. Work focused on improving continuous monitoring of the RSS flow through aquaria system. A new monitoring robot was assimilated with better sensor-carrying capabilities and improved mechanics. The new robot which monitors 64 tanks (40L each) 24/7 was equipped with sensors for dissolved oxygen, pH, temperature, salinity, a camera on each arm and a Monitoring Pulse Amplitude Modulated (PAM) fluorometer. The new robot was tested and successfully assimilated to run during experiments on corals in the RSS.

At the Finnish ASSEMBLE Plus partners (University of Helsinki, Tvärminne Zoological Station (UH-TZS), together with the Third Parties University of Turku, Archipelago Research Institute (UTU-ARI) and Åbo Akademi University, Husö Biological Station (AAU-HBS)), development of experimental facilities and related instrumentation focussed on a range of systems for testing the ecosystem effects of climate change, for example heatwaves. At all three stations (TZS, ARI, HBS), existing indoor as well as outdoor experimental facilities were upgraded, new mesocosms installed and functional systems for manipulation and monitoring of temperature and salinity developed. In addition, TZS developed and successfully tested a set of heated benthic chambers for subtidal experimentation done using SCUBA diving, which allow the study of in situ effects of e.g. marine heatwaves on the functioning of benthic ecosystems (including macrofaunal bioturbation, benthic nutrient cycling and the physiology of the fauna). The chambers were developed in collaboration with an underfloor heating company.

OOV established and tested a design for relatively small experimental systems (litre to several dozens of litres per tank) in order to control mono- or multi-parameters (temperature, pH, light). The configuration of experimental system can be used for different types of macro-organisms (for benthic species regular tanks can be used, but for macroplanktonic species (jellyfish, salps…), specific Kreisel tanks are needed to maintain organisms alive during the experiment).

UPV-EH designed a system for real-time monitoring, visualization and data-base creation of the environmental variables in the experimental tanks at the ECIMAT mesocosm facility. The system has a central unit to compile data and 12 portable units with wireless connection, to which sensors are connected allowing data to be sent in real-time to the central unit. Each of the portable units can connect to up to 4 sensors. Aqualabo sensors for temperature, salinity, pH and dissolved oxygen are installed, but other variables (turbidity, PAR, etc) could also be monitored.

OOB worked on the development of new microcosms able to perform ecotoxicological tests according to health and safety standards regarding the use of pollutants. A room for “toxicological and ecotoxicological experiments” was installed with dual high-efficiency particular air (HEPA) filtration in the ventilation system, which allows working with powdered toxins or for operations which could generate aerosols. The secondary HEPA (in series) ensures that toxins are not released inadvertently into the environment. The room is thermostatically controlled (15-25°C) and is supplied with fresh

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water and sea water with mechanical filtration systems from 200 to 0.2 microns. It can accommodate a 300L tank for the decontamination of effluents by treatment with activated carbon, if needed.

Pressure sensors

To investigate infauna behaviour VLIZ integrated pressure sensors (Honeywell type 26PC) into a plastic tube with a sealed bottom and open top. Each sensor contains a pressure port close to the wall of the tube and a reference port in the seawater plenum inside the tube. Sensors are positioned at a specific depth, typically < 1 cm away from the study animal depending on the auto-ecological knowledge of the fauna and the sediment type. Hydraulic activities are recorded at a rate of 200 Hz. Sensors are calibrated before deployment by stepwise filling of a tank to different heights (i.e. pressures) of sea water used in the experiments to determine the relationship between sensor output and hydraulic head. In total hydraulic activities of 32 animals can be studied independently and simultaneously for several weeks depending on the sample frequency and data storage capacity. Porewater hydraulic signatures are linked to different behavioural activities based on simultaneously recorded time-lapse footages and/or solute dynamics using microsensors. The developed facility has been used to investigate the behavioural consequence of variable pressures in the marine environment, such as the ocean warming, acidification and noise pollution.

Lighting systems

OOB developed a system for measuring the growth of microorganisms and automated recording of luminescence under controlled conditions of light wavelength (red, blue green) provided by individual LED lights for each well of multi-well plates. Developments focussed on allowing a wide range of light intensities (1 to 1000 microEinsteins/m2.s1), improving homogeneity of light from well to well, integrating 4 LEDs for each well covering the whole light spectrum (white, blue, red, green), developing programmes for simulation of realistic sunlight conditions, integrating temperature control (6 plates) and a cheap and open source robot.

SZN developed a system composed of 4 modules, each with three 500 L experimental tanks and one 800 L conditioning tank, all modules equipped with systems for controlling temperature and light quality and quantity from the surface to 30 m depth, with sinusoidal simulation of daily light cycle. SZN also developed the Pholia light system composed by 3 three panels equipped with RGB diodes (LEDs), each diode providing the blue, red and green light which can be independently modulated. The system can mimic the light present in all marine environments (surface, bottom, etc.) in any season and the light that planktonic microorganisms can encounter - in terms of intensity and colour - during their movements in the water column.

Raceway system

CCMAR developed a system with rectangular tanks in a raceway configuration in semi-closed system, equipped with pumping capacity that allows performing forced swimming experiments with marine fish. Raceway tanks with controlled water current velocities are known to promote enhanced rates of growth and better welfare, as described for several species of fish as a consequence of sustained swimming, often accompanied by better feed conversion efficiency, improved muscular- skeletal development, improved osmoregulation and improved disease resistance.

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Task JRA4.2. Establishment of technical design specifications for experimental systems and associated infrastructure

An on-line database was created in the context of this WP with the objective of cross-consortium recording of detailed technical information for experimental systems and associated infrastructure. The database was developed using the Drupal content management system by an external subcontractor. The database was designed to contain information on experimental systems (e.g. tidal simulation system, raceway, etc.) and also upstream research aquarium infrastructure (e.g. pumping and filtration systems) required to aliment the experimental systems with seawater. The central elements of the database are:

- Institution: marine station in which the system is located;
- System: overall experimental or infrastructure system (e.g. seawater provision system);
- Process: individual element of a system (e.g. seawater primary treatment);
- Component: equipment component within a process (e.g. sand filter);
- Category: type of component (e.g. filter, pump, tank, etc.).

Multiple data fields are included for each of these elements. For example, for each component, users can provide information on supplier, make, model, cost, date acquired, technical capacity, dimensions, as well as an open field for remarks. Images, technical schematics and associated documentation can be uploaded and linked to the component in question. The interface allows user-friendly navigation among all elements. The search function allows searching according to any of these elements. The on-line interface is currently for internal use only, with access protected by a user management procedure.

Lessons learnt, exploitation of results, impacts

A variety of innovative experimental systems were developed by WP partners, all of which have been (or soon will be) opened for access to infrastructure users. WP outputs have therefore already expanded the service offer in terms of in-house experimental facilities available via EMBRC for all partners, as well as increasing the technical knowledge and experience of staff who manage and operate these facilities. Researchers are used to transnational interactions with colleagues, but this is rarer for technical staff. This WP demonstrated the enthusiasm for, and utility of, networking between technical staff of the marine station partners. Some partners experienced delays in implementation of the work program due to unforeseen delays in renovation work being undertaken in aquarium facilities (and in one case an accidental fire which seriously damaged facilities). The networking aspect of this WP helped these partners to recover from these setbacks. Infrastructure developments of this kind are long-term activities and a key lesson learnt from this WP is that it would be highly pertinent for EMBRC to consolidate the networking of technical staff over the long-term in order to increase the efficiency and scope of future developments in this strategically important domain. In this context, thematic workshops for biological resource centre staff of EMBRC members are planned, and contributors to the database developed in this WP will be expanded to other EMBRC partners and the web interface integrated into the EMBRC site, ensuring a long-term legacy for the WP.

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Publications

- Cossa D, Infantes E & Dupont S (*in prep*) Short-term pH Variability by Seagrass meadows: A hidden cost in marine calcifiers in future OA conditions.
- Duvane J & Dupont S (*in prep*) Phenotypic plasticity on the sea urchin Echinus esculentus larvae under constant and fluctuating seawater pH conditions.
- Vargas CA, Cuevas LA, Broitman BR, San Martin VA, Lagos NA, Gaitán-Espitia JD & Dupont S (2022) Upper environmental *p*CO2 drives sensitivity to ocean acidification in marine invertebrates. Nature Climate Change. 12: 200-207.

4.5. Scientific diving – JRA5

Scientific diving is a widely-used, well-established, research platform within the Assemble+ partnership. This WP was based on a unique partnership of diving units within the EU that are working across a geographical gradient that presents an exceptional diversity of subtidal and littoral environments and related ecosystems.

There are a number of emerging underwater technologies that can contribute to enhancing the quality and quantity of science delivered through diving but their application is incomplete across the partnership. The main objective of the WP was to generate standard operating procedures which will enhance diving-based science delivery markedly across the network, while creating a common service with the potential to engage with a wider, and more diverse, user-group.

Within the funding limitations of this JRA, two breakthrough technologies, Structure from Motion photogrammetry and prototype sub-tidal logging stations, were evaluated over at least one year.

The WP was started in May 2018 following a delay with the status of TSL.

Task JRA5.1. Structure from Motion 3D Photogrammetry

The task examined whether common standards could be applied across a widely diverse environmental and research application matrix. In addition, assessments were made on whether different software/hardware applications markedly influence outcome quality. The photogrammetry assessments were carried out on targets where intra- and inter-annual change would be anticipated. Three-dimensional photography-based technologies were examined against a range of inter-dependent influencing factors.

The task was based on the adoption of common application standards. A draft SOP was used in the initial phases of the WP and was tested by the partners. Feedback informed several revisions and a technical draft was accepted as the initial milestone in September 2019. This draft formed the basis for constructing the models and detailed the methods for undertaking the measurements required for the comparative analyses. The final version was completed in 2021; full dissemination to the wider community will be through a special session at the 7th European Conference on Scientific Diving to be held at Roscoff in April 2023 (postponed for two years because of COVID).

Task JRA5.2. Diver-deployed seawater temperature time-series

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Aquatic physicochemical data are important for understanding how ecosystems function and the long-term consequences of anthropogenic drivers, for example the steady rise in greenhouse gas emissions, and temperature rise. There is large-scale monitoring of sea surface conditions using both remote sensing and in-situ platforms but there is a lack of depth-resolved profiles for inshore regions. This is a significant data gap as inshore water conditions are important for commercial activities (e.g. aquaculture and fisheries), as well as driving many of the biological traits that determine productivity and distribution of species.

Subtidal seawater temperature recording stations were deployed during the WP and data were delivered by four of the partners (TSL, IO-PAN, HMCR and TZS). The diver-deployed dataloggers returned data that show marked differences in results depending on the depths of deployment. Initial comparisons with accepted remote sensing-based surface seawater temperature datasets (e.g. The Operational Sea Surface Temperature and Ice Analysis (OSTIA) system) demonstrate that established methods of broad-scale seawater temperature produce erroneous results when compared with data collated from quite moderate water depths. In some cases, the errors are small and can be compensated for. However, the differences were considerably larger where the diver-placed loggers were at, or below, water column thermoclines. The main implication from this study is that submerged loggers should be employed in all cases where the target depth is relevant.

Lessons learnt, exploitation of results, impacts

3D photogrammetry has the potential to provide significant step changes in many scientific disciplines that depend on diving. However, emerging evidence suggests that care must be taken when generating models especially where they provide baseline information for time-series analyses. These issues were illustrated in this JRA where true comparative analyses were compromised by the variation in competencies with the modelling software, changes or differences in the software versions, and hardware limitations (principally computing power). It was evident from the study that, while being an exceptionally powerful research tool, 3D photogrammetry requires dedicated staff time and needs to be supported with high-performance computing. It is recognised that both of these requirements may not be available in units where the primary aim is only to support scientific diving, compared with units that employ scientists that dive. The study was valuable in providing a platform to illustrate these limitations and will contribute to the scientific literature by highlighting where care must be taken in using metrics generated from this technique when used underwater. Full dissemination of these results will be made to the wider community through a special session at the 7th European Conference on Scientific Diving to be held at Roscoff in April 2023 (postponed for two years because of CoVid).

Although previously known, this JRA has demonstrated clearly that inshore seawater temperature measurements are influenced by the location and depth of deployment of the recording device, and the type of instrument used. For climate change studies, remote sensing databases are not always representing the actual thermal changes that are happening underwater on multiple scales. Whereas these issues can be addressed through the use of scientific moorings, diving-based management of sub-tidal recording stations can be more cost-effective and less damaging to the environment. Data from this JRA are being analysed to levels that will support publication in 2023.

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Publications

- Sayer, M., Dawson, K., Mogg, A., Lévèque, L., Balazy, P., Sokolowski, A., Dailianos, T., Attard, K. and Asplund, M. (2021). Standard Operating Procedure Guidelines for Photogrammetry. Association of European Marine Biological Laboratories Expanded. D11.1; 27pp.

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5. Transnational Access (TNA)

5.1. Objectives of the Transnational Access programme

The TNA programme of ASSEMBLE Plus aimed at the achievement of two objectives of this project: objective 1 ("Enhance transnational access to a coordinated set of state-of-the-art European infrastructures for marine biology and ecology"), and objective 2 ("Improve service provision by these infrastructures in line with their areas of excellence in marine biology and ecology, with emphasis on developing novel key enabling technologies and data solutions"). This last objective had also implication in objective 4 ("Lay the logistical and strategic foundations to expand the coverage of the European Marine Biological Resource Centre in both its scope and its geographical distribution and to consolidate its long-term sustainability").

5.2. TNA preparation

Before the launch of the TNA programme, access providers discussed and established common procedures to ensure harmonised TNA provision and user satisfaction: these provisions were established in the "TNA policy document" (detailed in the D3.1) produced by WP3. This document provided a detailed policy for regulating, granting and supporting TNA. The provisions of this deliverable have been fully implemented among the community of liaison officers (LOs) and the User Selection Panel (USP) and enforced by the Access Officer (AO). The TNA policy document has been reviewed and updated by the AO at rolling basis during the implementation of the TNA programme, with the inputs of LOs. An update of this document was released on the website before the launch of each TNA call.

The TNA programme was available at 26 of the 32 partners (and their Affiliated Entities) in the consortium, collectively giving access to 37 access providers (which comprised marine research institutes, marine stations, research departments within the same partner) and an overall of 102 installations. In order to give meaningful information to the prospective users, the installations defined in Grant Agreement were further divided in specific services, using a "service taxonomy" commonly used among the access providers: this refined classification resulted in 400 services. Detailed information of these services was collected by the AO in collaboration with the LOs and made available online in the access system and in a specific webpage of the ASSEMBLE Plus website. A campaign of advertisement has anticipated each of the nine TNA calls launched. From call 5 onwards, a page dedicated to TNA applicants from private companies and small and medium enterprises was published on the website to engage potential users from this user's community.

5.3. TNA implementation

Nine calls of TNA were launched: the first call was launched on February 2018 and the last was closed on February 2022, each of them with a defined period of proposal submission (ca. seven weeks). Applications requiring only remote access could be sent instead at rolling basis (no deadline for submission). The AO, in collaboration with LO interacted and responded to the applicants' questions to ensure a smooth application process and a pre-feasibility assessment of the proposals submitted. Project proposals were submitted by applicants through an online access system: in the third call, the existing access system in place (adapted by the existing EMBRC access system) was replaced by the

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"ARIA access management system" developed by INSTRUCT-ERIC: this system granted more usability for the AO, the LOs and the User Selection Panel and a wider and more complete integration of the different phases of the TNA "workflow" (see D3.1) in a single online system. Each project proposal was assessed for eligibility by the AO, for technical feasibility by the LOs and for scientific excellence by the USP: each proposal was evaluated by one external member from the Advisory Board and one internal member from the Project Implementation Committee (PIC). Conflicts of interest during the scientific review were avoided, ensuring that PIC members of the USP would not evaluate proposals to or from their own home institute or applicants affiliated with institutes of their own home country. All the details of the USP composition and of the proposal selection procedure were defined in the TNA policy document and published in a specific page of the website. The AO assisted TNA users to re-locate their projects to alternative access providers in case they were not considered feasible anymore (because of resource unavailability, logistic issues, travel delays, etc.). The AO monitored the execution of the TNA programme in collaboration with the LOs, through the use of proper documents ("confirmation of access") to track the number of unit of access delivered and to collect other relevant info of the TNA users. The AO informed TNA users to comply with the "Open Research Data Pilot" initiative reminding them to submit their Data Management Plan after the completion of their TNA project and to participate to a survey to give feedback on the services used and the overall TNA experience.

To avoid budgetary issues at the access providers, each call had a defined "access window", a period of time of six months after the formal acceptance of the project, in which each TNA project should have been carried out. A review of the TNA budget has been performed before the onset and launch of the last two calls, by collection of financial updates from the partners. TNA projects were performed from April 2018 until July 2022 (4 years and 4 months). In collaboration with WP3, the AO convened two online workshops with LO to collect feedback of the access provision and find solutions to emergent issues.

5.4. TNA results

Applications – selection

Over nine TNA calls, 739 single applications2 to single access providers were submitted by a total of 529 applicants (the two values differ because: a. applications addressed to more than one access provider by a single project leader in the same call were counted as single applications; b. applications by the same project leader over different calls were also counted as single applications).

Only 7 applications over 739 (0.95%) did not meet the eligibility criteria (not transnational or not in the scope of marine research). Accepted proposals after the feasibility check and the scientific review were 71 (9.6%). This resulted in a total of 518 unique3 users (project leader and their team) accessing the TNA partners in the consortium. Research teams were usually composed by a single or two researchers, more rarely by more than two members.

[2] An "application" is defined as a single TNA project proposal submitted by one project leader to one access providers in a given call.
[3] "Unique" users: researchers participating to more than one call are calculated only once.

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Applicants – home institutes countries

Applications to the TNA programme originated in large majority in European institutes (568 applications, 76.8%), mostly from Italy, Spain and Germany. This value raises to 89.2% (91 applications) if we add those coming from United Kingdom. Non-European applicants (excluding then UK) represented the 10.8% of the applications received (80), below the 20% maximum quota of access reserved in H2020 projects to European-based researchers. Applicants from non-EU institutions were mostly based in institutes of the United States, Argentina and Russia. See Fig. x. for the complete list.

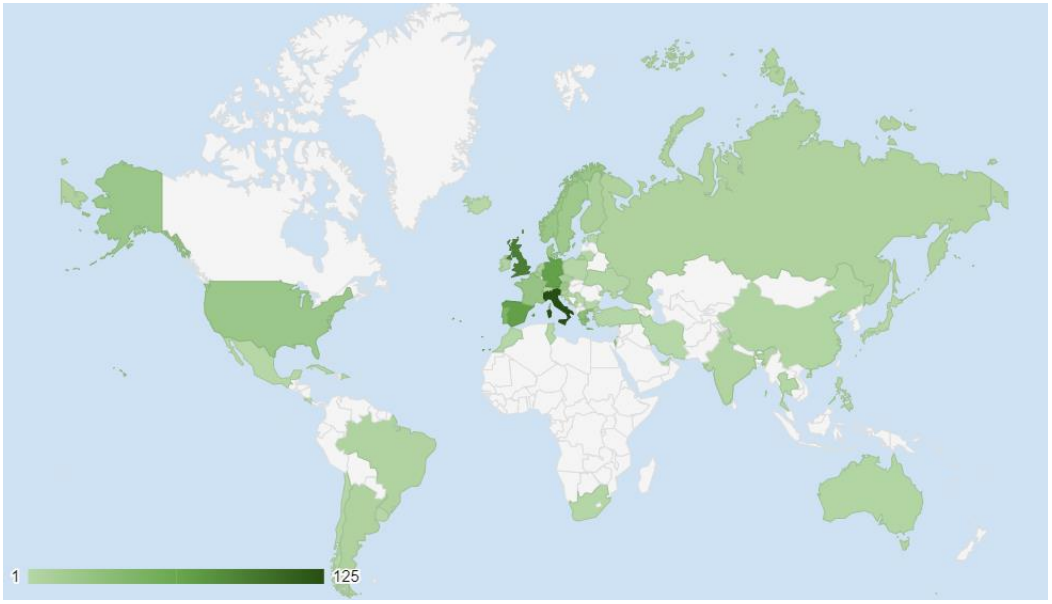

Figure 16. Home country institutes of the applicants (world view).

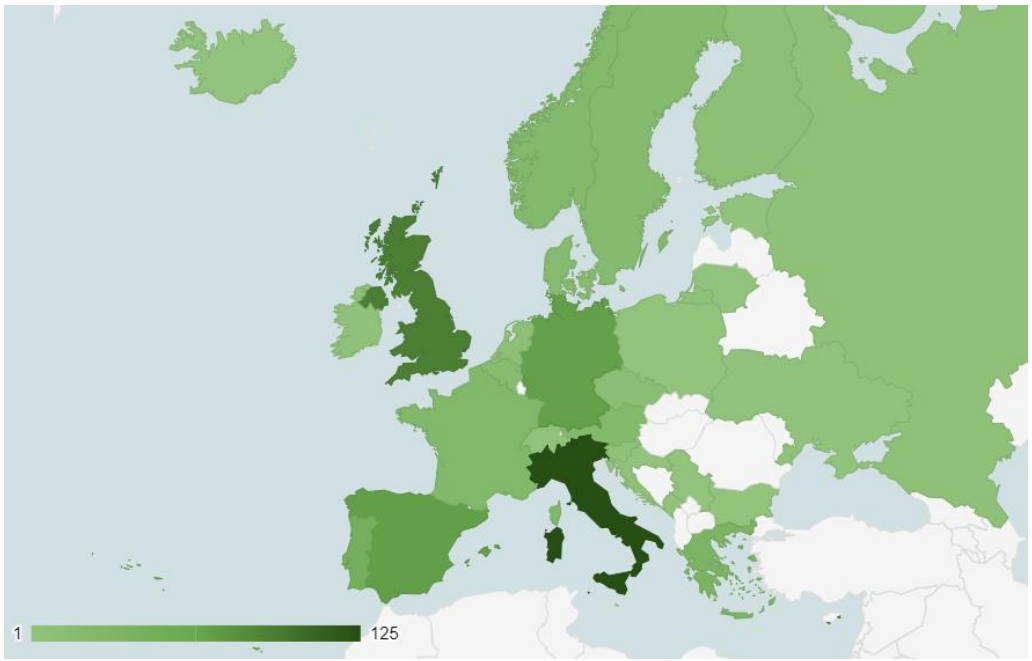

Figure 17. Home country institutes of the applicants (Europe view).

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*EU country**	*applications*	*EU country**	*applications*	*Non-EU country**	*applications*
Italy	125	**Montenegro**	2	**United Kingdom**	91
Spain	69	**Poland**	2	**USA**	22
Germany	68	**Turkey**	2	**Argentina**	7
Portugal	46	**Iceland**	1	**Russia**	7
Greece	34	**Lithuania**	1	**Brazil**	6
Israel	28	**Malta**	1	**India**	5
France	26	**Serbia**	1	**Australia**	4
Austria	24	**Tunisia**	1	**Cina**	4
Norway	24			**Philippines**	4
Sweden	20			**Cuba**	3
Denmark	19			**Dominican Republic**	3
Belgium	17			**Chile**	2
Czech Republic	11			**Japan**	2
Finland	10			**Thailand**	2
Netherlands	10			**South Africa**	2
Ireland	6			**Bermuda**	1
Slovenia	5			**Costa Rica**	1
Croatia	4			**Iran**	1
Switzerland	3			**Morocco**	1
Estonia	3			**Mexico**	1
Ukraine	3			**Uruguay**	1
Bulgaria	2			**United Arab Emirates**	1

Table 1. Home institution country of the main applicant and number of applications.
**"European countries" are considered here as those associated to the H2020 funding programme.*

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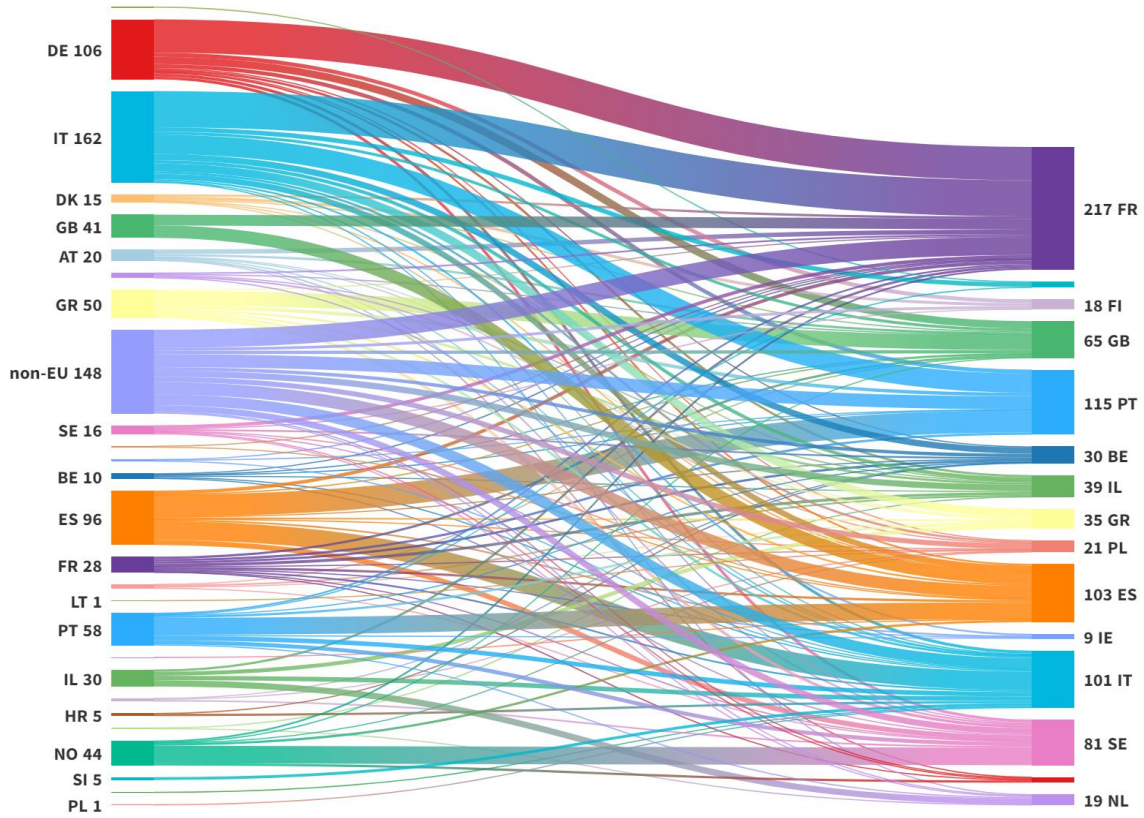

Figure 18. Flow of application from home country of the researchers (left) to access providers countries (right).

Applicants – their home institutions and career status

The vast majority of applications come from applicants whose home institutions are Universities and Research Organizations (424 and 304, respectively). Only few applications came from the private sector (Small and Medium Enterprises, 5) or from Other Legal Entities (6). Applications were submitted equally by researchers in their postdoc, senior or doctorate (PhD student); a minor part consisted of early career scientists. While the TNA programme has been popular among academic researchers and considered highly rewarding in terms of use of state-of-the-art facilities, of results obtained and as overall experience (see paragraph "User satisfaction"), it failed to attract users from private companies. This may be due to the scarce attractiveness of the TNA programme to companies because of: lack or low communication of the benefit of the TNA and of the overall ASSEMBLE Plus project, limited amount of time offered by the TNA (one month), complicacies related to the requirements of the Open Access policy, absence of previous connections with academic institutes for research and development projects. Connection between access providers and companies will require to establish relationships with the private sector via company fora or dedicated personnel.

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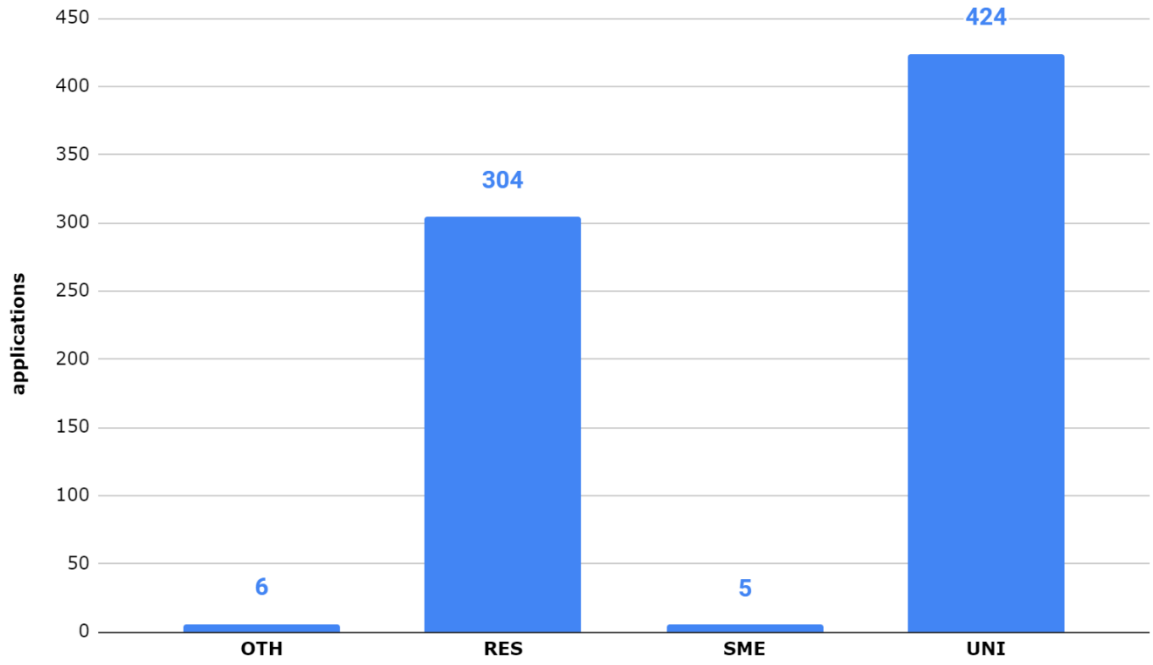

Figure 19. Home institution type of the applicants.

(UNI=University, RES=Public Research organisation, SME=Small and Medium Enterprise, OTH= Other organisation).

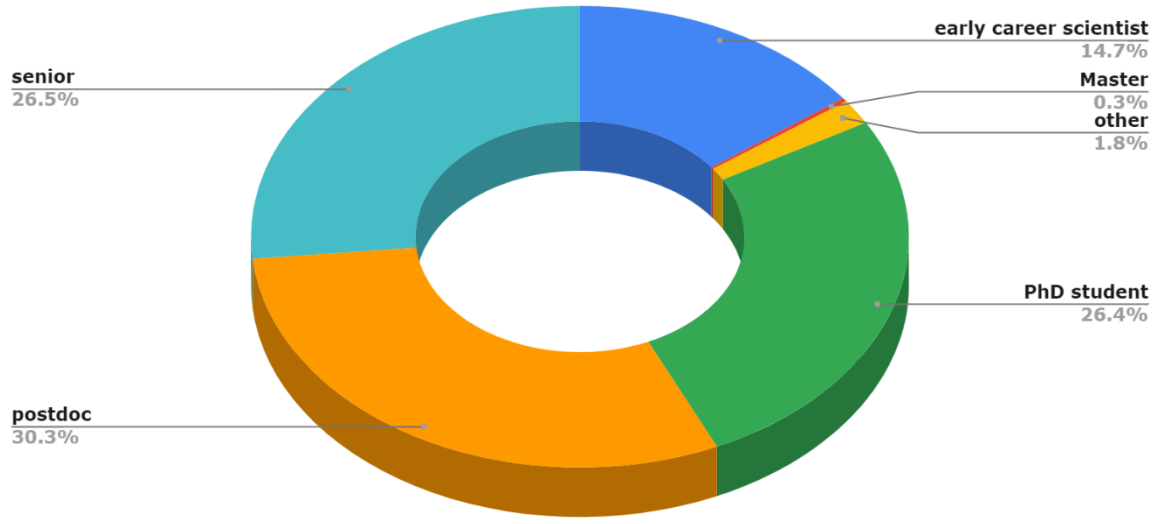

Figure 20. Career status of the project leaders applying to the TNA programme.

Applicants – scientific domains

The TNA programme has attracted scientists from the domains of Life Sciences & Biotech (67.4%) and the Earth Sciences & Environment (28.8%); fewer applicants came from other scientific domains (Chemistry, Mathematics, and Engineering: 2.1%, 0.9% and 0.8% respectively). The large majority of applicants were or defined themselves as marine biologists (71.6%). In terms of scientific domains of provenance, no appreciable difference exists between marine and non-marine biologists, the only

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exception being scientists coming from the Engineering and Mathematics fields (see fig. x). Despite the evident general interest for marine stations in the biological and environmental community, scientists from non-marine fields applied for accessing services for marine biology and ecology. The gender of the project leaders was equally represented (51.2% females and 48.8% males).

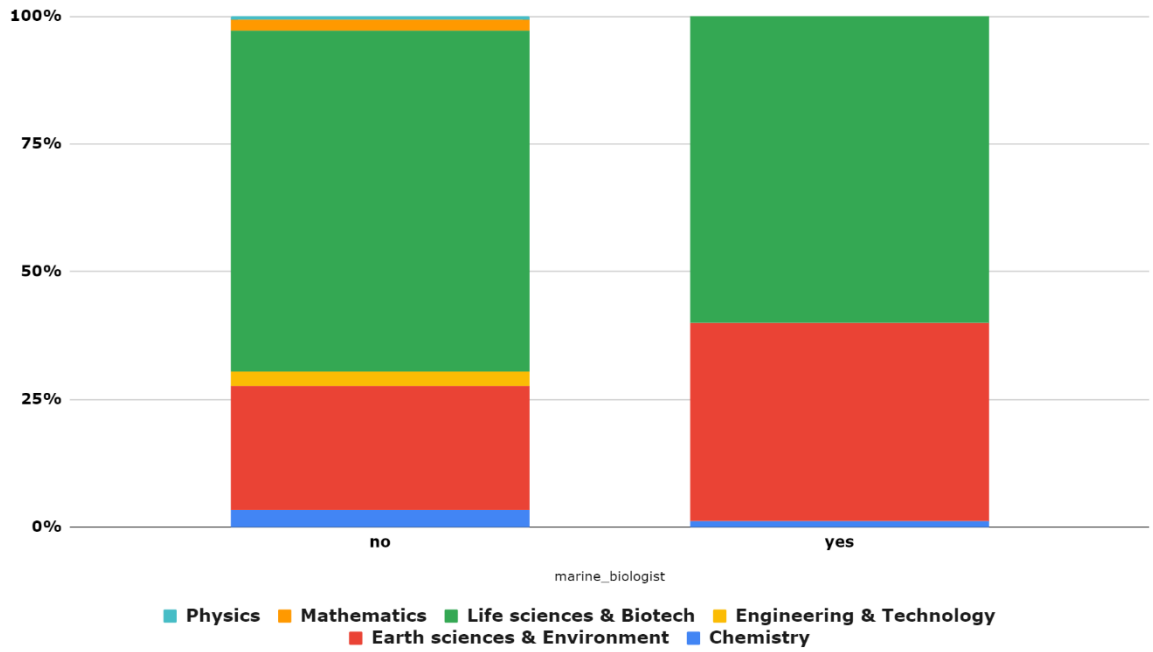

Figure 21. Main scientific domain and "affiliation" to the profession of marine biologists.

Applicants – access providers selected

The most requested access providers were SBR (Roscoff, France), followed by IUI (Eilat, Israel), KMRS (Kristineberg, Sweden) and SZN (Naples, Italy). Submission of applications was not distributed evenly over the course of the nine calls, with a subset of institutes receiving more applications than others (fig. x), irrespectively of the country of the access provider.

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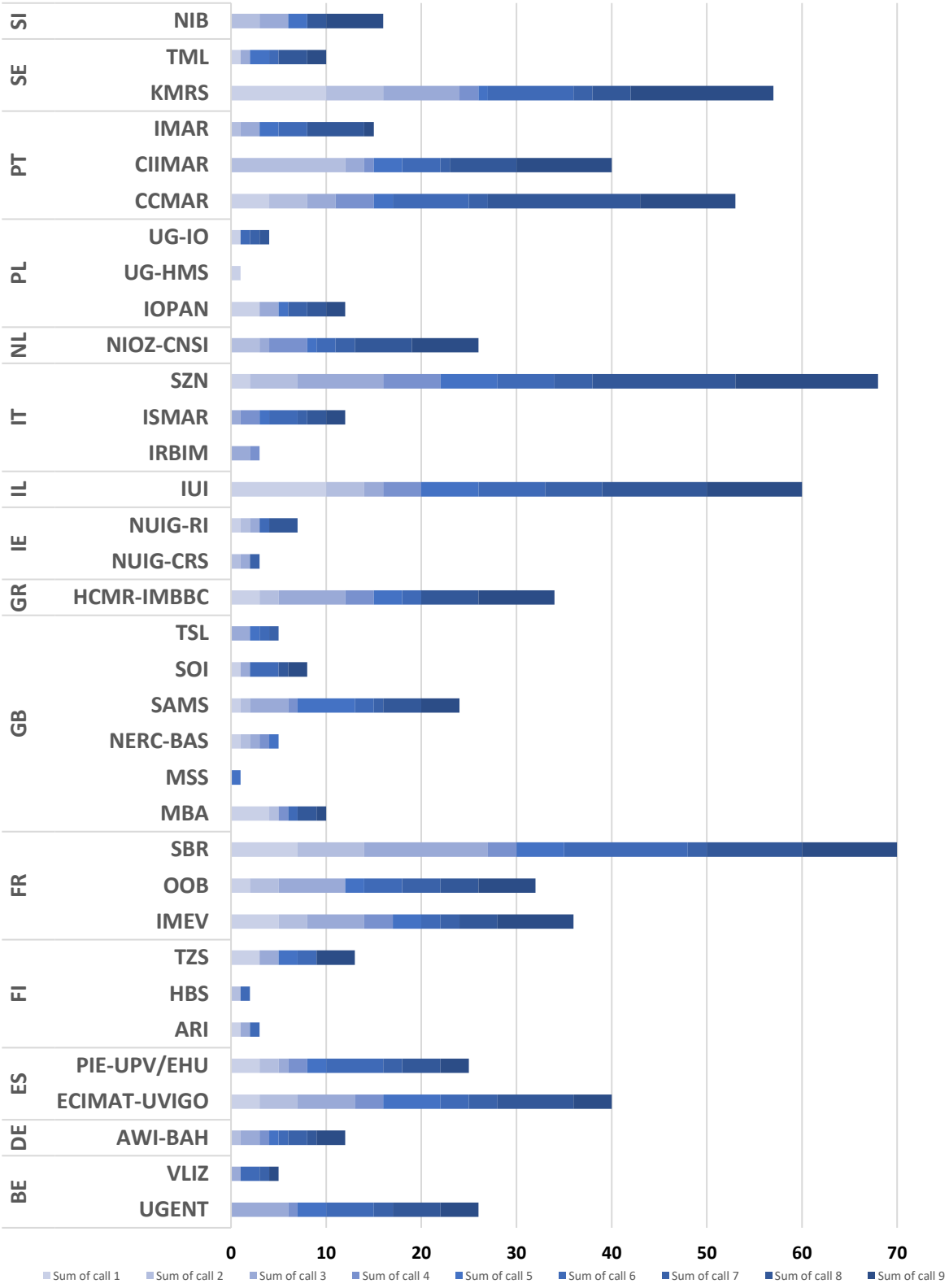

Figure 22. Applications per call for each access provider.

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Applicants – services required and type of access

The top three research services per application most in demand were experimental facilities (wet labs, aquaria, mesocosms; 31.4%), ecosystem access (research vessels and SCUBA diving; 31.7%), and technology platforms (bioassays, imaging, molecular biology and omics; 18.5%) followed by biological resources (marine model organisms, culture collections; 13.5%). Fewer requests were received for supporting facilities, e-services and expert advice (overall, 8.5%). Request of services was predominantly required for on-site services (91.4%) or combined together with remote access (2.4%); remote access requests accounted for the remaining 6.2% of the requests.

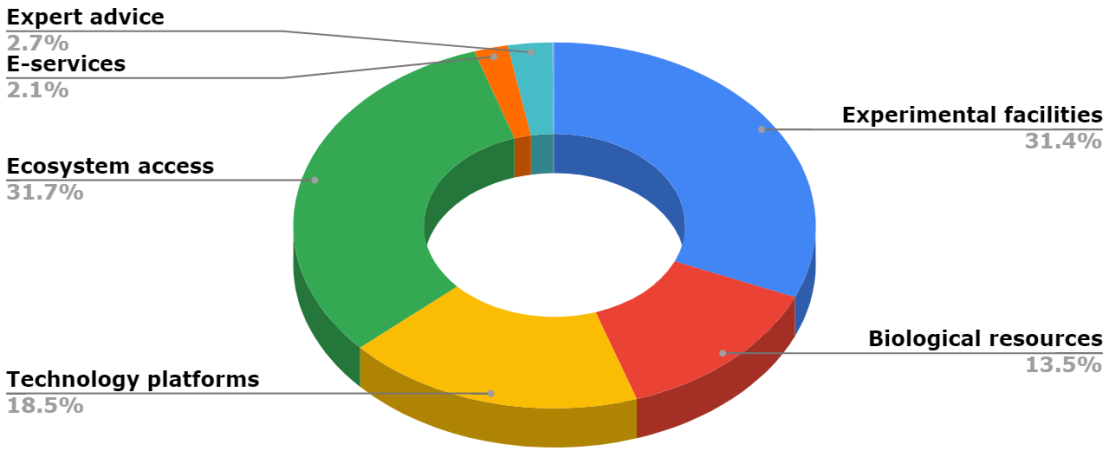

Figure 23. Type of services requested.

TNA and COVID-19: effects and countermeasures

The pandemic outbreak of COVID-19 occurred in the first months of 2020 and the later pandemic waves have negatively impacted the TNA programme in different ways: international travels (at the basis of on-site visits) were not allowed; furthermore, several access providers were temporarily not available for access to external users. The consortium has responded to the pandemic consequences with proper countermeasures, in order to continue to give access to facilities and to execute the TNA programme, such as:

a) Extension of the "access window", initially set at six months after the acceptance of the project, to an indefinite term (but still within the end of TNA programme, July 2022).
b) Conversion of on-site to remote projects, whenever possible, to all the users willing to do so.
c) Promotion of remote services, publishing on the website a list of facilities and services available for remote access http://www.assembleplus.eu/access/remote-access.

5.5. User satisfaction

At the conclusion of the TNA visit, project leaders were asked to submit an online survey to evaluate their satisfaction in terms of scientific, technical, logistic, administrative and financial support offered by ASSEMBLE Plus for their research. Results showed in the following paragraphs have been obtained from a survey answered by 334 users (63.5% of total unique users).

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Advertisement of the TNA funding

The outreach of the transnational access was mostly based on personal contacts (55.1% of the answers). Other users have been reached through different websites (EC RIA, infrastructure, Grant Agreement; 24.3%). Outreach through emails and conferences has been useful for the remaining 20.6% of the users.

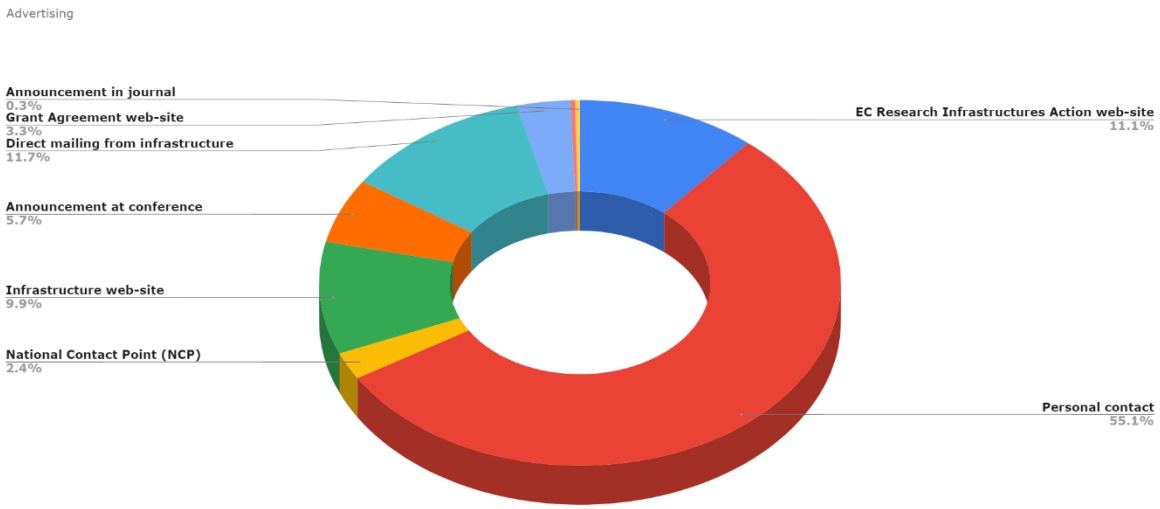
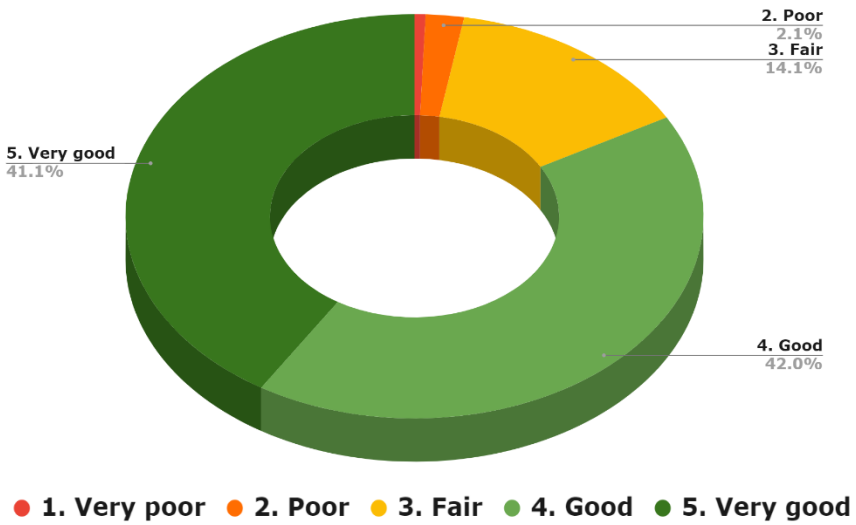


Figure 24. How the users got to know the TNA of ASSEMBLE Plus.

Advice to use the most appropriate service for TNA experiments

Users were generally happy about suggestions and indications received by liaison officers and local researchers regarding how to improve their design experiments with the most appropriate services (317 users). Only nine users (2.7%) indicated the advices received as “poor” (7) and “very poor” (2).



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Technical support provided

The vast majority of the users (316) were very satisfied with the technical support received during the access, in terms of setup of experiments and results interpretation (very good, 56.7%; good 29.8%, fair 10.4%). Only ten users reported the support received as "poor" and "very poor" (overall, 3.1%).

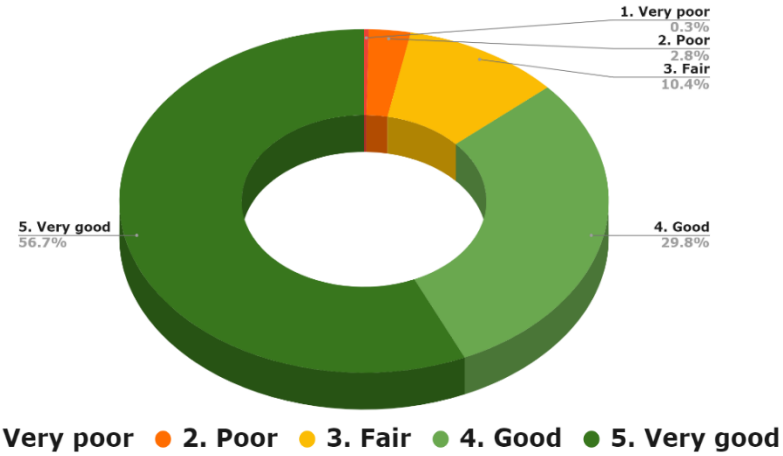

Figure 25. Satisfaction on the technical support received.

Need of ASSEMBLE Plus funding

Only the 10.4% of researchers stated that they could have run their research project without the ASSEMBLE Plus funding (not shown). The great majority of all other users applied for the TNA funding either because they were unable to pay the fee to use research services (29.1%) and for covering travel and subsistence expenses to their user group (44.4%). The remaining part indicated other reasons such as having difficulty or not being eligible to apply to access to infrastructures.

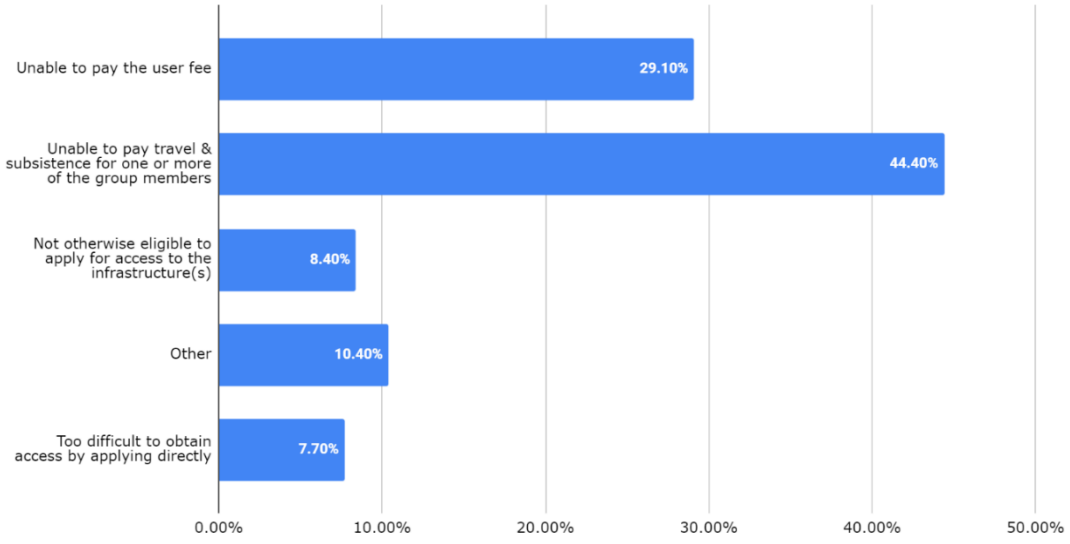

Figure 26. Reasons for the need of the ASSEMBLE Plus funding

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Overall satisfaction

Overall, there is general agreement among the users about the benefit and the positive outcomes resulting from the TNA programme of ASSEMBLE Plus: the vast majority of users indicated their overall experience of the TNA as very good (65.0%), good (27.9%), and fair (5.8%). Only four users judged the overall TNA experience as "poor".

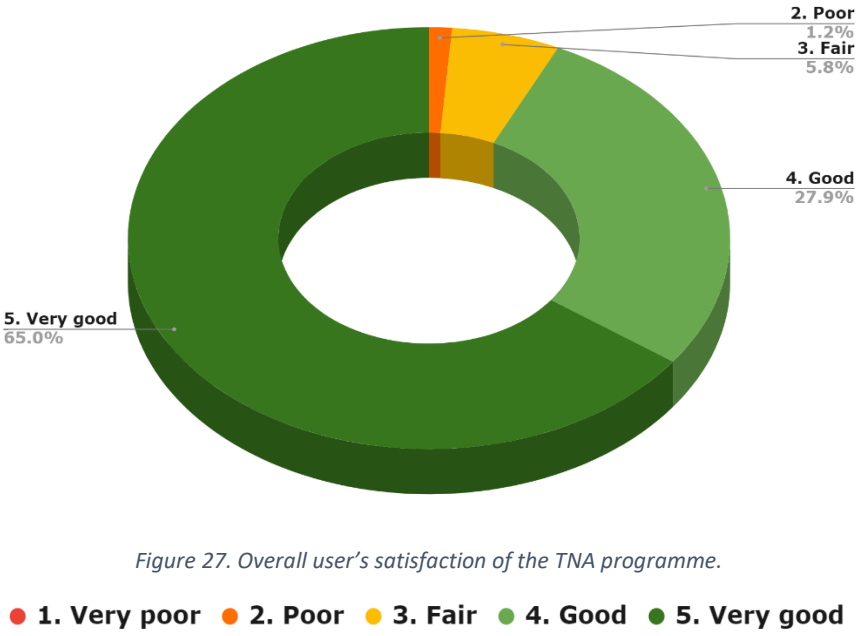

Figure 27. Overall user's satisfaction of the TNA programme.

5.6. TNA outcomes and conclusions

Implementation of the TNA programme

The TNA policy document and the experience of TNA liaison officers have ultimately reached a degree of maturation to consent a smooth implementation of the TNA programme.

Visibility of the TNA programme

In terms of outreach, the TNA programme has reached a good level of interest within the marine biological community, being capable of attracting researchers from several different countries (European 84.6%, international 15.4%) and from different scientific fields (notably, from the "Life Sciences & Biotech" and "Earth & Environment" domains). Scientists from the Engineering and Mathematics domains, not typically associated with marine biology and ecology sciences are less interested in the TNA programme. The application rate from researchers outside of the EU is 15%, closer to the maximum 20% quota defined in the Grant Agreement. Applicants have been informed of the opportunity of the TNA programme and its calls through different websites and in particular through word of mouth from their colleagues.

Participation to the TNA programme of the private sector

The TNA programme of ASSEMBLE Plus has failed to attract researchers from private companies. Previous TNA projects (ASSEMBLE Marine, EMBRIC) have shown that the private sector rarely like to travel to another country to reach the services they need. They show a preference for working with local partners, so the funding scheme of TNA is not a suitable tool for many of them. Undoubtedly, we

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lacked penetration power with our communication into the private sector. Generally, the academic sector finds it difficult to identify the appropriate channels, language, and tone to appear as an attractive opportunity for companies. The private sector also works on much shorter and immediate timelines, meaning that the long evaluation process and the predefined call dates of the TNA are not suitable for them. Finally, it is also possible the Open Access policy is off putting to the private sector due to a worry of loss of competitive advantage, sharing of data, and potential loss of IP. It appears that the TNA format is ill-suited to companies and that a change in approach is required to convince them to use the services of marine stations and related research institutes. In all likelihood, the flexible approach of European Research Infrastructures, though not free, can be a more attractive option. However, the communication approach will also need to be adjusted appropriately to factors important in the private sector, such as discretion, full retention of IP, flexibility, cost effectiveness, competitive advantage, and a made-to-measure approach.

Delivery of services

The onset of a continuous open call (from call 4th) for remote access has allowed to receive applications all-year round. Projects requiring only services offered by remote access have been reviewed upon their receival, potentially giving more relevance to the delivery of biological samples or experiments results at the user's home institutions. Despite this possibility, the number of remote access applications has still been low (total remote access requests 3.2%), even during the international travel restrictions due to the COVID-19 pandemic outbreak occurred in Spring 2020. The pandemic has had evident consequences also on the performance on-site projects, causing the delay of many TNA projects now postponed of few months or put on stand-by. In particular, TNA projects requiring seasonal samplings (in the field or in controlled conditions) have currently been delayed of one year. The community of liaison officers is in contact with these users in order to host these projects as soon as international travel will be again possible. The last TNA call (8th) closing on the next 4 October 2020 will allow access until summer 2021. A higher average number of applications is expected given the coincidence of the TNA windows in the spring and summer seasons in 2021, usually more attracting for: i) users requiring on marine biological resources obtained directly from the field and ii) studies on biological processes occurring at seasonal scale.

Differences in service delivery among access providers

Applicants have showed more interest for a limited number of access providers, instead of being equally distributed. While this may depend to: i) differences in the effort to advertise the TNA programme by each institute / country; ii) the amount and the diversity of services offered in the TNA; iii) stochastic factors; there is a general skew in terms of access requests towards some access providers, generally those who have participated in previous TNA programmes (FP7) or have a historical tradition of hosting researchers at their premises.

A successful way to mitigate imbalances of attractivity of the access provider (and hence problems in terms of hosting capacity in a given call) is to reallocate a TNA project towards an alternative access provider, which can equally respond to the needs of the hosted research team. Alternative access providers are suggested by the access officer through a search in the database of the services offered and upon agreement with liaison officers. The research team to be hosted make ultimately the choice

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on the possible reallocation. The imbalance on the attractiveness of access providers can be further mitigated highlighting clearly specialisations of an access provider in specific research topics through their dedicated facilities and available resources. This can encourage applicants to explore different access providers in future.

The preference of users for some specific access providers has led to consider a redistribution of the budget allocated for the TNA programme among the partners. This change will be necessary to: prevent budget shortages (i.e. for access provision and for travel & subsistence reimbursement of users) at the most required access providers and ii) increase the overall number of accepted users in the TNA programme. The consortium has recently approved to redistribute funds according to the emerging budget limitations. After a positive feedback of the EC project officer regarding this issue and the proposed solution, the management team is currently at work for submitting budget changes in an amendment of the Grant Agreement.

Feedback of TNA users

The overall positive feedback of the users regarding the support received, in terms of technical advices and funding offered, demonstrates the high quality of services provided by the partners in the TNA programme and the need of researchers of top-class services for fostering their research projects in the marine domain and in other proximal scientific domains.

Financial management issues

Whereas the TNA programme has been popular and successful, it has also been complex and cumbersome to manage, both from the consortia's perspective, as well as on over-sight from the European Commission. A simplification of the TNA financial mechanism would greatly facilitate its implementation, and also its effectiveness. These changes are only means for RIs and not for institutions providing services independently of an RI. At this purpose we suggest the following changes:

- Travel & subsistence costs: In order to ensure that the better part of the budget goes towards science, we recommend that users are reimbursed only for budget travel and lodging to a modest maximum. Users should cover any additional costs for travel and subsistence.
- Service Pricing: The current tables for justifying service costs are complicated and time consuming. Most RIs have price lists that are fully calculated, transparent, and audited. These should be eligible as costs for the services, doing away with the current service tables.
- Central allocation of TNA Budget: part of the complexity of the TNA mechanism has been the need to predefine budgets for each service providing partner in the project. It is impossible to predict where users will go. By placing the budget centrally with the RI legal entity, services could be used wherever requested, allowing for a more efficient reimbursement system.
- Simplification of TNA budget redistribution: More flexibility should be allowed in the transfer of TNA budget between partners, and also between travel and research budgets through dispositions in Consortium Agreement (instead of the fixed dispositions of the Grant Agreement). Again, this would simplify the spending of the funds and reduce the money needing to be returned to the Commission due to the complexity of redistribution. In particular, budget should be easily transferable within the consortium without lengthy Consortium Agreement amendments.

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7. Resources used to provide access to Research Infrastructures

The table below reports the value of Person Months (PM) used at each access provider (Beneficiary and Linked Third Party) during the full duration of the Transnational Access programme (TNA).

Beneficiary/Linked Third Party	PM	short name Installation(s)	Explanations of tasks
SU	23.99	SBR, IMEV, OOB	Scientific, logistic and administrative support to the TA users
NIB	2	NIB	Administration and organisational tasks (communication with users, coordination of visits, preparation of agreements, follow up visit and help on site, collecting reports and confirmation documents)
NIOZ	2.1	Lab/ecosystems	scientific, logistic and administrative support to the TA users
UH	6	Lab/ecosystems/aquaria and research vessel, ARI, HBS	scientific, logistic and administrative support to the TA users
IOPAN	15	All installations	Laboratory and facilities, Scientific services: Research vessel, Scientific diving, taxonomical expertise, chemical analysis
UG	14.5	r/v Oceanograf	Cruise planning. Mobilization of the vessel. Participation of in-house scientists in the cruise.
NUIG	6	NUIG-RS, NUIG-CRS	Scientific, technical and administrative support
UGOT	24	Labs	Technical and administrative support
UPV/EHU		Ecosystem access and biological resources; Tissue biobank	Scientific, technical and administrative support
ECIMAT-UVIGO	2	MLABS ECIMAT	Scientific, technical and administrative support
HUJI	4.3	BIOGEN, AQUALABS, ECOACCESS	Scientific, technical and administrative support
SZN	0	SZN	Coordination of TNA to SZN, ISMAR and IRBIM
CCMAR	4.5	Labs, Ramalhete marine station, boats/vessels, diving	Scientific, technical and administrative support
CIIMAR	18.9	Aquarium, Ecosystem, Labs / Platforms	Scientific, technical and administrative support
IMAR	0.9	RHIBS-IMAR	Technical support
AWI	2	BAH/Sylt	Coordinating user–station interactions
VLIZ	9	All installations	Technical and administrative support
UGENT	18	Molecular analysis, Structural and chemical analysis, Experimental ecology (culture collection)	Technical and administrative support
SAMS	2	Seol Mara, Lab access, CCAP	Scientific, technical and administrative support

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USTAN	5.4	Ecosystem, Advanced microscopy	Technical support
MBA	2	Ecosystems/Ship, National Marine Biological Library, Live cell Imaging, Cell and Molecular Facilities, Marine Microalgae Cultures Collection	Scientific, technical and administrative support
UKRI-BAS	6.1	Rothera. Natural Environment Research Council, British Antarctic Survey with aquarium installations on the Antarctic Peninsula (Rothera) and Cambridge, UK	Technical support
MSS	0	-	-
VLIZ	9	All installations	Technical and administrative support
UGENT	18	Molecular analysis, Structural and chemical analysis, Experimental ecology (culture collection)	Technical and administrative support
TSL	1	Scientific diving	Diving services and photogrammetry

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8. Impacts

In this section the expected impacts defined in the Description of Action have been reviewed to see how the project has been relevant in the actions defined, how it has contributed to their achievement.

1. "Researchers will have wider, simplified, and more efficient access to the best research infrastructures they require to conduct their research, irrespective of location. They benefit from an increased focus on user needs."

The access website of ASSEMBLE Plus has provided a user-friendly interface to access state-of-the-art marine facilities, model organisms and coverage of European ecosystems (along with special ecosystems in Atlantic islands, polar and Caribbean regions) to more than 500 users. During the project, a common ontology and terminology of the service offer has been established and refined with the feedback of users and liaison officers, and it is currently implemented in the EMBRC service offer. EMBRC has also integrated the same access system (ARIA, developed by INSTRUCT-ERIC) and it will take advantage of the experience gained by its operators (partner's institutes). Overall, ASSEMBLE Plus has successfully improved the access to the consortium facilities through a democratisation of access to marine research facilities without the need for collaborations or prior contact, harmonised procedures for application and review of projects, regular calls for access promoted through all the partners' communication channels, and offering greater visibility of available platforms for access through the TA calls. These procedures have now become an integrated component for all the partners that wish to efficiently provide services for marine biology to a larger community of users. A testament to the achievement of this objective is the fact that researchers working outside of the community and marine biology have been able to access ASSEMBLE Plus facilities and discover a new model organism highly relevant to their work.

2. "Operators of related infrastructures develop synergies and complementary capabilities, leading to improved and harmonised services."

The workshops, training courses, and staff exchanges carried out but the NAs have ensured that partners have benefited from each other in areas of common interest, for example in the JRAs, and build lasting relationships and collaborations. In JRA2, the experience gained from drawing on the experience of working on many different species allowed the consortium to enable cryopreservation of species and tissues previously impossible to preserve with this method. The sharing of experiences has also allowed partners to develop the areas related to their particular competencies, for example in JRA3 on functional genomic tools, where a number of techniques have jointly been developed to genetically modify a broad selection of model organisms. These are now available to the research and innovation communities even beyond the duration of ASSEMBLE Plus. On the access front there, the project has allowed the marine stations with many years of experience to share best practices and experience on service provision, and how to successfully receive users. This has been a critical component in ensuring a harmonized experience for users when using ASSEMBLE Plus services.

3. "There is less duplication of services, leading to an improved use of resources across Europe. Economies of scale and saving of resources are also realised due to common development and the optimisation of operations."

Whereas a reduction in duplication of services was envisaged, it has become clear in the project that duplication of platforms is necessary in some cases. The strength of the ASSEMBLE Plus consortium is

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not just on specialised facilities and particular instruments but rather, the strength sits in the expertise on particular marine organisms, habitat types and how they can be studied and analysed using the technical platforms. In addition, some duplication is turning out to be beneficial, particularly on platforms that are in high demand. ASSEMBLE Plus has raised the awareness amongst partners of what is available in Europe for marine biological research, reducing the chance of duplicating unique systems, and encouraged service providers to promote their expertise as part of their service offers. The project has thus enabled users to identify the unique selling points of the sites and where to go to find the expertise most relevant to their needs. In terms of optimisation, the COVID outbreak has required our access providers to extend their service offer also through remote access (so, without the necessary presence of users on-site), traditionally not widely used in marine sciences.

4. "Innovation is fostered through a reinforced partnership of research organisations with industry."
Big efforts have been made in ASSEMBLE Plus to reach out and attract users from the private sector. Consequently, the project has seen some projects from the private sector and projects with strong potential for application, including in aquaculture and biotechnology.

However, it has proven difficult to convince companies to utilise the TA mechanism and it appears to be of little attraction to the private sector. The feedback received from companies was that travel to different countries to access the facilities they need was too time-consuming and costly, preferring by far to forge local collaborations wherever possible. It appears that TA programmes requiring travel to other countries is not a model that works for the private sector. Companies prefer to pay for their access to have it on their terms. Nonetheless, the project has succeeded in raising the awareness of the available platforms and expertise that exist for their benefit substantially. Technological advances and new protocols have been showcased at two online conferences, participated by more than 800 attendees.

5. "A new generation of researchers is educated that is ready to optimally exploit essential tools for their research."
ASSEMBLE has been very successful in attracting early career scientists to its TA programme (PhD students and post-docs, ca. 200 researchers). Many projects with early career scientists have requested access to specific expertise and platforms in order to learn how to use or improve their skills on, including some of the new tools and techniques developed in the JRAs. ASSEMBLE Plus, with its high appeal and accessibility for less experienced researchers, has been able to provide new skills to hundreds of early career scientists. This has contributed to broadening the skill sets of young scientists, allowing them to deploy these new capabilities in their own research. From the feedback the TA programme received from early career scientists was that it also provided them with an opportunity to write one of their first competitive proposals and try for the first time to write an application related to their research.

The internal "staff exchange programme" has also contributed to share best practices among our partners, contributing to train technicians and local access officers to the methodologies of service provision.

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6. "Closer interactions between a larger number of researchers active in and around a number of infrastructures facilitate cross-disciplinary fertilisations and a wider sharing of information, knowledge and technologies across fields and between academia and industry."

The TA programme has attracted scientists not familiar with techniques of marine biology (ca. 30% of the overall applications), to have access to resources and facilities for marine science they have never used before. During their on-site stay or through remote access, researchers from the domains of chemistry and environmental engineering have benefitted of the expertise of technicians and researchers of our sites, allowing them to explore techniques which have never used before. This has allowed to extend the aims of their studies, contributing to interdisciplinary areas such as bio-remediation, ecotoxicology, metabolomics, imaging and machine learning approaches. Cross-disciplinary fertilisation has also occurred during the stay of TNA users at the access providers, by sharing aims and results of their experiments with dedicated seminars presented to the community of scientists of our partners.

While the TA programme did not gather the interest of users from industry (see point 4 above), the wealth of data and workflows generated in the JRA will still be kept and made available by our partners to foster this kind of partnerships with companies through a more customized and tailored approach, based more at local or regional level, rather than transnational.

7. "For communities which have received three or more grants in the past, the sustainability of the integrated research infrastructure services they provide at the European level is improved."

As many of the ASSEMBLE Plus partners are also service providers in the research infrastructure EMBRC, an important aim of the project was to build capacity and ultimately ensure that the project developments were maintained and sustained in the research infrastructure at the end of the project. In the first instance, the JRAs have contributed protocols for cryopreservation and genetic manipulation of marine organisms, it has developed a suite of new experimental platforms, monitoring protocols, and a genomic observatory that all continue to be available and operational through EMBRC. Most of these will continue to be developed within EMBRC as they now underpin further activities and services. A strong emphasis in this project was placed on training the partners in providing access to their facilities. Through the Networking activities (NA) in the project, as well as through the delivery of services, all partners have learnt how to handle external users, how to develop services on platforms to attract users to their facilities. Importantly, users have been made aware of the potential of delivering services to make platforms sustainable and leverage them for collaboration in the public and private sector.

8. The integration of major scientific equipment or sets of instruments and of knowledge-based resources (collections, archives, structured scientific information, data infrastructures, etc.) leads to a better management of the continuous flow of data collected or produced by these facilities and resources.

JRA1 on Genomics Observatories continued the initiative of Ocean Sampling Day (OSD), first developed in the Horizon 2020 project MicroB3. The data produced in the context of ASSEMBLE Plus in has been supplemented with contextual data. The data has been deposited in the European Nucleotide Archive (ENA) and the metadata in Pangea, making both datasets findable and accessible. The JRA outputs are

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also having a long-term impact through the creation of a long-term DNA-based observatory in EMBRC, the European Marine 'Omics Biodiversity Observation Network (EMO BON). This initiative aims to raise the stakes and quality of marine biological observation in Europe. Not only is EMBRC implementing strict protocols, it is also insisting on a standardised metadata according to the MixS standard for genomics data (standard developed by the Genomics Standards Consortium - GSC), and Darwin Core for environmental data. Efforts to generate automated data workflows are also underway to facilitate the handling, publication, and reusability of the data generated.

9. "When applicable, the integrated and harmonised access to resources at European level can facilitate the use beyond research and contribute to evidence-based policy making."

The JRA1 of ASSEMBLE Plus has worked to develop and build genomic observatories within the consortium. These have provided the next generation of biological observation in the sea based on molecular biology tools. While there is still work required to ensure a steady translation of the data into useful indices for policy makers (such as the Essential Ocean Variables (EOVs) and the Essential Biodiversity Variables (EBVs)), the legacy of the JRA1 work has been now taken by the flagship project of EMBRC "EMO BON" (European Marine Omics Biodiversity Observation Network). The data generated by genomics observatories have great potential for supporting science-based decision making related to marine activities. Several countries are already trialing eDNA techniques to inform decisions on biodiversity, monitoring of ecosystems, and the potential in fish stock assessment. Genomic observatories can provide important information, such as the state of marine biodiversity and detection of invasive species, data relevant to monitoring and implementing the European Commission's Green Deal and biodiversity targets. With EMO BON, EMBRC will now start interactions with stakeholders through Horizon Europe projects, such as MARCO-BOLO and DTO-Bioflow, to increase the use and uptake of these new methods and data to enable better decision-making on biodiversity and environmental matters.

10. "When applicable, the socio-economic impact of past investments in research infrastructures from the European Structural and Investment Funds (ESIFs) is enhanced."

Less than 1/3rd of the partnership has received ESIFs, although as a result of the link between RIs and S3 several expect to receive significant ESIFs in the next few years. Partners that have received ESIFs report increased capability and capacity to obtain funds from public and private sectors, increased intervention in policy advising, and increased contribution towards education and employment. NA4 evaluated the current socio-economic impacts of marine stations, map funding opportunities, and address financial sustainability linking to regions and funding agencies.

ASSEMBLE Plus offers an opportunity to align multiple streams of funding (from ERDF to H2020) in support of Europe-wide research as well as regional S3 by giving greater local visibility to European investment and allowing local investment to attain pan-European visibility and impact. This will also multiply the impact locally by giving greater visibility to the regions, leading to increased collaboration between maritime regions across Europe.

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Conclusion

The project had as an overarching goal to strengthen marine biological and ecological research and innovation capabilities by facilitating access to research facilities, services and resources, and develop new tools in support of cutting-edge research. The consortium considers the project to be an overwhelming success, with almost all aspects of the project having achieved or exceeded the expected results.

An important aspect of the project were the joint research activities (JRAs), focused on developing novel tools and platforms for research. The JDAs have contributed to a plethora of marine research domains, from environmental and ecosystem research (genomics observatory, JRA1) to genetic manipulation techniques for more than 30 marine organisms (JRA3), and subsea survey techniques (JRA5). Significant contributions have also been achieved in developing new research infrastructure capabilities with advanced in cryopreservation for many new groups of organisms and biological resources (JRA2), development of a suit of new experimental systems, such as a tidal cycle simulator and marine heatwave simulators (JRA4).

But the project also contributed to the operational level of the participating institutions and staff development. Through the Networking Activities (NAs) the consortium strengthened its awareness of FAIR data, its data workflows (significantly improved our ability to generate open data, deposited in the right places, and with the right metadata), catalogues and virtual environments (NA2) for the benefit of the consortium beneficiaries and potential users. The project also enabled capacity enhancement of partner staff (NA3) through workshops and staff exchanges, and important experience was acquired in on-line engagement of stakeholders through virtual conferences based on ASSEMBLE Plus user projects and keynote speakers (NA4). Perhaps the most significant contribution of ASSEMBLE Plus has been the Transnational Access (TA) programme. In the first instance, the NA activities strengthened the consortium's ability to provide services by training the project partners in cost calculations and providing the necessary paperwork and contracts to enable a smooth and professional access programme (NA1). This allowed for a highly successful TA programme that is one of the key achievements of the project, with more than 500 researchers from public and private organisations have benefitted from access to ASSEMBLE Plus's services. Furthermore, more than 50% of these "users" were early career scientists that received training on platforms and technologies and were able to develop their personal networks and collaborations.

However, ASSEMBLE Plus has not been without its difficulties. Firstly, a destructive fire at the University of St Andrews ended all research ambitions around amphioxus in the project with the loss of the biological resources and the necessary facilities to conduct the research. Secondly, ASSEMBLE Plus suffered significantly from the outbreak of COVID-19. The huge reliance on personal interaction in the project both internally, for staff exchanges, workshops, and conferences, and externally for the visits to the research facilities through the TA programme made the execution of the project extremely challenging. A lengthy extension was required to ensure the full delivery of the TA programme, and many staff exchanges and workshops were not able to run due to travel restrictions. Some of these activities were able to limp on with the use of video conference technology, in the case of the stakeholder conferences it was even considered a big success, however the majority of users were not

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interested in conducting their research remotely, or virtually, and preferred to postpone their projects leading to a significant backlog of projects in the last year of the project. This was further complicated by the strict rules on budgetary transfer of TA funds which made it extremely challenging to move funds to the partners that were able to provide services and received many application. Undoubtedly, the TA would have had even more projects in the absence of COVID and with much more flexible rules around TA funds. We strongly encourage the European Commission to adopt the recommendations for changes to the TA rules for future projects recommended in this project.

ASSEMBLE Plus has had a significant impact on its research community and in general to European research capabilities. It has demonstrated the worth and continued relevance of marine stations and marine biological research. The project was part of the call for Integrating Activities, calls aimed at strengthening advanced research communities and in the case of ASSEMBLE Plus the project was designed to contribute significantly to the emerging research infrastructure (RI) European Marine Biological Resource Centre (EMBRC). ASSEMBLE Plus has delivered on the establishment of services and service provision with the RI, how to run and manage services and the necessary documents and agreements supporting the service activities. EMBRC became an operational European Research Infrastructure Consortium (ERIC) in 2018, cementing support and strengthening of marine biological and ecological research for the next decades. Consequently, this has provided the mechanism for ensuring the longevity, persistence, and legacy of ASSEMBLE Plus outputs. EMBRC-ERIC continues to offer access to the services and platforms developed in the project, the standards and procedures will be implemented and improved over time through the RI, and integrates the technical expertise developed through 5 years of collaboration. One of the most significant successes of the project in terms of the involvement of the RI, has been the development of a long-term genomics observatory from JRA1 in EMBRC, the European Marine Omics Biodiversity Observation Network (EMO BON), which is coming into operation and funded by the RI.

Ultimately, the ASSEMBLE Plus consortium considers the project to be a huge success, delivering many tangible outputs, strengthening collaborations amongst institutions and providing the marine biological and ecological research and innovation community with a solid support mechanism, tools, and services to support the marine research community, push discoveries and understanding of life in the sea, and an improved ability to harness new ideas, inspiration, and products from the oceans.

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Appendix 1. Scientific output of the project

Scientific outcomes of the ASSEMBLE Plus project are available in the ASSEMBLE Plus Open Repository: http://www.assembleplus.eu/results/publications. Among 123 peer-reviewed publications, 60 papers have been published by researchers who have used the TNA programme (data source: ASSEMBLE Plus). This number is expected to increase in the coming months (results obtained in the last months of the TNA, still in preparation or in draft). Results published in Open Access are overall 76.1% (considering publications from the JRAs and TNA programme. Data source: Web of Science).

The complete list of publications updated to November 2022 is available in the EC portal. A continuous tracking activity of the research outcomes of ASSEMBLE Plus will be performed by the OpenAIRE portal, in the specific page of the project. Here below is presented the publications list, as uploaded in the EC portal for the ASSEMBLE Plus project as for November 2022.

No.	Authors	Title	Type	DOI	Open Access
1	Angela Falciatore, Marianne Jaubert, Jean-Pierre Bouly, Benjamin Bailleul, Thomas Mock	Diatom Molecular Research Comes of Age: Model Species for Studying Phytoplankton Biology and Diversity	Article in Journal	10.1105/tpc.19.00158	Green
2	Tim U. H. Baumeister, Marine Vallet, Filip Kaftan, Laure Guillou, Aleš Svatoš, Georg Pohnert	Identification to species level of live single microalgal cells from plankton samples with matrix-free laser/desorption ionization mass spectrometry	Article in Journal	10.1007/s11306-020-1646-7	Gold
3	Marjorie Couton, Thierry Comtet, Sabrina Le Cam, Erwan Corre, Frédérique Viard	Metabarcoding on planktonic larval stages: an efficient approach for detecting and investigating life cycle dynamics of benthic aliens	Publication in Conference proceedings/Workshop	10.3391/mbi.2019.10.4.06	Gold
4	Tim Wollesen, Carmel McDougall, Detlev Arendt	Remnants of ancestral larval eyes in an eyeless mollusk? Molecular characterization of photoreceptors in the scaphopod Antalis entalis	Article in Journal	10.1186/s13227-019-0140-7	Gold
5	Gonzalo Quiroga Artigas, Pascal Lapébie, Lucas Leclère, Philipp Bauknecht, Julie Uveira, Sandra Chevalier, Gáspár Jékely, Tsuyoshi Momose, Evelyn Houliston	A G protein–coupled receptor mediates neuropeptide-induced oocyte maturation in the jellyfish Clytia	Article in Journal	10.1371/journal.pbio.3000614	Gold
6	Ibon Cancio	Itsas estazio biologikoen historia eta kostaldeko bioaniztasunaren ikerketa. The history of marine Biological stations and the research of coastal biodiveristy.	Article in Journal	http://hdl.handle.net/10810/47080	Gold
7	Wollesen, Tim; Rodríguez Monje, Sonia Victoria; Oel, Adam Phillip; Arendt, Detlev	Characterization of eyes, photoreceptors and opsins in developmental stages of the chaetognath Spadella cephaloptera	Other	10.1101/871111	No
8	S. Messinetti, S. Mercurio, G. Scarì, A. Pennati, R. Pennati	Ingested microscopic plastics translocate from the gut cavity of juveniles of the ascidian Ciona intestinalis	Article in Journal	10.1080/24750263.2019.1616837	Green
9	R.J.S Orr; M. M. Sannum; S. Boessenkool; E. Di Martino; D.P. Gordon; H. Mello; M. Obst; M.H. Ramsfjell; A.M. Smith; L.H. Liow	Molecular phylogeny of historical micro-invertebrate specimens using de novo sequence assembly	Other	10.1101/2020.03.30.015669	No
10	Simona Manuguerra; Giovanni PICCOLO; Concetta Messina; Stavros Chatzifotis; Ike Olivotto	Honey Bee Pollen in Meagre (Argyrosomus regius) Juvenile Diets: Effects on Growth, Diet Digestibility, Intestinal Traits, and Biochemical Markers Related to Health and Stress	Article in Journal	10.3390/ani10020231	Green
11	Roman Wenne, Małgorzata Zbawicka, Lis Bach, Petr Strelkov, Mikhail Gantsevich, Piotr Kukliński, Tomasz Kijewski, John H. McDonald, Kristil Kindem Sundsaasen, Mariann Árnyasi, Sigbjørn Lien, Ants Kaasik, Kristjan Herkül, Jonne Kotta	Trans-Atlantic Distribution and Introgression as Inferred from Single Nucleotide Polymorphism: Mussels Mytilus and Environmental Factors	Article in Journal	10.3390/genes11050530	Green
12	Paulo Gavaia; Ana Marreiros	Cryoprotectants synergy improve zebrafish sperm cryopreservation and offspring skeletogenesis.	Article in Journal	10.1016/j.cryobiol.2019.10.001	Green
13	Letizia Zullo, Matteo Bozzo, Alon Daya, Alessio Di Clemente, Francesco Paolo Mancini, Aram Megighian, Nir Nesher, Eric	The Diversity of Muscles and Their Regenerative Potential across Animals	Article in Journal	10.3390/cells9091925	Green

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	Röttinger, Tal Shomrat, Stefano Tiozzo, Alberto Zullo, Simona Candiani				
14	MICHAIL RAGKOUSIS et al.	New Alien Mediterranean Biodiversity Records (October 2020)	Article in Journal	10.12681/mms.23673	Gold
15	D Calliari, L Rodríguez-Graña, P Tiselius	Density dependent grazing rates in a natural microzooplankton community	Article in Journal	10.3354/meps13003	Green
16	Carmen B. de los Santos, Anna-Sara Krång, Eduardo Infantes	Microplastic retention by marine vegetated canopies: Simulations with seagrass meadows in a hydraulic flume	Article in Journal	10.1016/j.envpol.2020.116050	Green
17	Jeff C. Clements, Ellen Schagerström, Sam Dupont, Fredrik Jutfelt, Kirti Ramesh	Roll, right, repeat: short-term repeatability in the self-righting behaviour of a cold-water sea cucumber	Article in Journal	10.1017/s0025315419001218	Green
18	Pablo Heres, Jesus Troncoso, Estefania Paredes	Cryopreservation Of Clams For Conservation Of Threatened Fishing Resources	Article in Journal	10.1016/j.cryobiol.2019.10.158	No
19	Alba Medrano Cuevas	Macroalgal forests ecology, long-term monitoring, and conservation in a Mediterranean Marine Protected Area	Thesis/Dissertation		No
20	Patrícia Diogo, Gil Martins, Isa Quinzico, Rita Nogueira, Paulo J. Gavaia, Elsa Cabrita	Electric ultrafreezer (− 150 °C) as an alternative for zebrafish sperm cryopreservation and storage	Article in Journal	10.1007/s10695-018-0500-6	No
21	P. Heres, R. Rodriguez-Riveiro, J. Troncoso, E. Paredes	Toxicity tests of cryoprotecting agents for Mytilus galloprovincialis (Lamark, 1819) early developmental stages	Article in Journal	10.1016/j.cryobiol.2019.01.001	No
22	Robyn E. Jones, Ross A. Griffin, Stephanie R. Januchowski-Hartley, Richard K.F. Unsworth	The influence of bait on remote underwater video observations in shallow-water coastal environments associated with the North-Eastern Atlantic	Article in Journal	10.7717/peerj.9744	Green
23	Kudryavtsev, A.; Volkova, E.; Voytinsky, F.	https://pureportal.spbu.ru/ru/publications/phylogeny-cryptic-diversity-and-benefits-of-investigating-marine-	Publication in Conference proceedings/Workshop		No
24	Nunzia Limatola, Filip Vasilev, Jong Tai Chun, Luigia Santella	Altered actin cytoskeleton in ageing eggs of starfish affects fertilization process	Article in Journal	10.1016/j.yexcr.2019.05.007	No
25	Karine Kleinhaus, Ali Al-Sawalmih, Daniel J. Barshis, Amatzia Genin, Lola N. Grace, Ove Hoegh-Guldberg, Yossi Loya, Anders Meibom, Eslam O. Osman, Jean-Daniel Ruch, Yonathan Shaked, Christian R. Voolstra, Assaf Zvuloni, Maoz Fine	Science, Diplomacy, and the Red Sea's Unique Coral Reef: It's Time for Action	Article in Journal	10.3389/fmars.2020.00090	Green
26	Nunzia Limatola, Filip Vasilev, Luigia Santella, Jong Tai Chun	Nicotine Induces Polyspermy in Sea Urchin Eggs through a Non-Cholinergic Pathway Modulating Actin Dynamics	Article in Journal	10.3390/cells9010063	Green
27	Manuel Olivares, Peter Tiselius, Albert Calbet, Enric Saiz	Non-lethal effects of the predator Meganyctiphanes norvegica and influence of seasonal photoperiod and food availability on the diel feeding behaviour of the copepod Centropages typicus	Article in Journal	10.1093/plankt/fbaa051	Gold
28	Maayan Neder, Pierre Philippe Laissue, Anat Akiva, Derya Akkaynak, Marie Albéric, Oliver Spaeker, Yael Politi, Iddo Pinkas, Tali Mass	Mineral formation in the primary polyps of pocilloporoid corals	Article in Journal	10.1016/j.actbio.2019.07.016	Gold
29	Estefania Paredes, Juan Bellas	The Use of Cryopreserved Biological Material for Water Quality Assessment	Article in Journal	10.3389/fmars.2019.00454	Gold
30	Marta F. Riesco, Francisca Félix, Domitilia Matias, Sandra Joaquim, Marc Suquet, Elsa Cabrita	Comparative study on cellular and molecular responses in oyster sperm revealed different susceptibilities to cryopreservation	Article in Journal	10.1016/j.aquaculture.2018.08.049	No
31	Pavaux Anne-Sophie, Rostan Julie, Guidi-Guilvard Laurence, Marro Sophie, Ternon Eva, Olivier P. Thomas, Lemée Rodolphe, Gasparini Stéphane	Effects of the toxic dinoflagellate Ostreopsis cf. ovata on survival, feeding and reproduction of a phytal harpacticoid copepod	Article in Journal	10.1016/j.jembe.2019.05.004	No
32	Rodriguez-Riveiro, R.; Heres, P.; Paredes, E.	Cryopreservation of Blue mussel (Mytilus galloprovincialis) trochophore larvae and larval rearing development	Publication in Conference proceedings/Workshop		No

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33	R. Rodríguez-Riveiro, P. Heres, E. Paredes	Cryopreservation of mussel trochophore larvae and long-term effects: from larval rearing to settlement.	Article in Journal	10.1016/j.cryobiol.2018.10.206	No
34	Federica Scucchia, Hagai Nativ, Maayan Neder, Gretchen Goodbody-Gringley, Tali Mass	Physiological Characteristics of Stylophora pistillata Larvae Across a Depth Gradient	Article in Journal	10.3389/fmars.2020.00013	Gold
35	Wouter Visch, Cecilia Rad-Menéndez, Göran M. Nylund, Henrik Pavia, Matthew J. Ryan, John Day	Underpinning the Development of Seaweed Biotechnology: Cryopreservation of Brown Algae (Saccharina latissima) Gametophytes	Article in Journal	10.1089/bio.2018.0147	Gold
36	R. Rodriguez-Riveiro, P. Heres, J. Troncoso, E. Paredes	Long term survival of cryopreserved mussel larvae (Mytilus galloprovinciallis)	Article in Journal	10.1016/j.aquaculture.2019.734326	No
37	Ekaterina Volkova, Alexander Kudryavtsev	Not all that looks like a Tubulinean is a Tubulinean: expectations and reality for the parasitic amoeba Janickina pigmentifera (Grassi, 1881)	Publication in Conference proceedings/Workshop		No
38	F Vasilev, N Limatola, JT Chun, L Santella	Contributions of suboolemmal acidic vesicles and microvilli to the intracellular Ca 2+ increase in the sea urchin eggs at fertilization	Article in Journal	10.7150/ijbs.28461	Gold
39	Waggitt, J.; Torres, R.; Fraser, S.	Foraging seabirds respond to an intermittent meteorological event in a coastal environment	Article in Journal		Gold
40	Matthias Obst et l.	A Marine Biodiversity Observation Network for Genetic Monitoring of Hard-Bottom Communities (ARMS-MBON)	Article in Journal	10.3389/fmars.2020.572680	Gold
41	Martin V. Sørensen, Maria Herranz	Adult moulting and dimorphism in a new species of Sphenoderes (Kinorhyncha: Kentrorhagata)—Is the exception becoming the rule?	Article in Journal	10.1111/azo.12361	Gold
42	Alex McDougall, Celine Hebras, Isa Gomes, Remi Dumollard	Gene Editing in the Ascidian Phallusia mammillata and Tail Nerve Cord Formation	Article in Journal	10.1007/978-1-0716-0974-3_13	No
43	Jessica Pazzaglia, Alex Santillán-Sarmiento, Stephanie B. Helber, Miriam Ruocco, Antonio Terlizzi, Lázaro Marín-Guirao, Gabriele Procaccini	Does Warming Enhance the Effects of Eutrophication in the Seagrass Posidonia oceanica?	Article in Journal	10.3389/fmars.2020.564805	Gold
44	Sarah Atherton, Ulf Jondelius	Phylogenetic assessment and systematic revision of the acoel family Isodiametridae	Article in Journal	10.1093/zoolinnean/zlab050	Gold
45	Giovanni Andrea Vitale; Martina Sciarretta; Fortunato Palma Esposito; Fortunato Palma Esposito; Grant Garren January; Marianna Giaccio; Boyke Bunk; Cathrin Spröer; Felizitas Bajerski; Deborah M. Power; Carmen Festa; Maria Chiara Monti; Maria Valeria D'Auria; Donatella de Pascale; Donatella de Pascale	Genomics-Metabolomics Profiling Disclosed Marine Vibrio spartinae 3.6 as a Producer of a New Branched Side Chain Prodigiosin.	Article in Journal	10.1021/acs.jnatprod.9b01159	Green
46	Alexander Kudryavtsev; Fyodor Voytinsky; Ekaterina Volkova	Coronamoeba villafranca gen. nov. sp. nov. (Amoebozoa, Dermamoebida) challenges the correlation of morphology and phylogeny in Amoebozoa	Article in Journal	10.1038/s41598-022-16721-2	Green
47	Matteo Bozzo; Simone Costa; Valentina Obino; Tiziana Bachetti; Emanuela Marcenaro; Mario Pestarino; Michael Schubert; Simona Candiani	Functional Conservation and Genetic Divergence of Chordate Glycinergic Neurotransmission: Insights from Amphioxus Glycine Transporters	Article in Journal	10.20944/preprints202110.0348.v1	Green
48	Karina Frankowski; Katsumi Miyazaki; Georg Brenneis	A microCT-based atlas of the central nervous system and midgut in sea spiders (Pycnogonida) sheds first light on evolutionary trends at the family level	Article in Journal	10.1186/s12983-022-00459-8	Green
49	Matteo Bozzo; Thurston C. Lacalli; Valentina Obino; Federico Caicci; Emanuela Marcenaro; Tiziana Bachetti; Lucia Manni; Mario Pestarino; Michael Schubert; Simona Candiani	Amphioxus neuroglia: Molecular characterization and evidence for early compartmentalization of the developing nerve cord	Article in Journal	10.1002/glia.23982	Green
50	Georg Brenneis	The visual pathway in sea spiders (Pycnogonida) displays a simple serial layout with similarities to the median eye pathway in horseshoe crabs	Article in Journal	10.1186/s12915-021-01212-z	Green

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51	R. Wenne; M. Zbawicka; A. Prądzińska; J. Kotta; K. Herkül; J. P. A. Gardner; A. P. Apostolidis; A. Poćwierz-Kotus; O. Rouane-Hacene; A. Korrida; F. Dondero; M. Baptista; S. Reizopoulou; B. Hamer; K. K. Sundsaasen; M. Árnyasi; M. P. Kent	Molecular genetic differentiation of native populations of Mediterranean blue mussels, Mytilus galloprovincialis Lamarck, 1819, and the relationship with environmental variables	Article in Journal	10.1080/24750263.2022.2086306	Green
52	Ekaterina Volkova; Alexander Kudryavtsev	A morphological and molecular reinvestigation of Janickina pigmentifera (Grassi, 1881) Chatton 1953 - an amoebozoan parasite of arrow-worms (Chaetognatha).	Article in Journal	10.1099/ijsem.0.005094	Green
53	Netanel Kramer; Raz Tamir; Or Ben-Zvi; Steven L. Jacques; Yossi Loya; Daniel Wangpraseurt; Daniel Wangpraseurt	Efficient light-harvesting of mesophotic corals is facilitated by coral optical traits	Article in Journal	10.1111/1365-2435.13948	Green
54	Marion Lechable; Alexandre Jan; Axel Duchene; Julie Uveira; Brandon Weissbourd; Loann Gissat; Sophie Collet; Laurent Gilletta; Sandra Chevalier; Lucas Leclère; Sophie Peron; Carine Barreau; Regis Lasbleiz; Evelyn Houliston; Tsuyoshi Momose	An improved whole life cycle culture protocol for the hydrozoan genetic model Clytia hemisphaerica	Article in Journal	10.1242/bio.051268	Green
55	M. Cavaliere; I. Barrenechea Angeles; Marina Montresor; Carla Bucci; L. Brocani; Eszter Balassi; Francesca Margiotta; Fabio Francescangeli; Vincent M.P. Bouchet; Jan Pawlowski; Fabrizio Frontalini	Assessing the ecological quality status of the highly polluted Bagnoli area (Tyrrhenian Sea, Italy) using foraminiferal eDNA metabarcoding	Article in Journal	10.1016/j.scitotenv.2021.147871	Green
56	Filomena Caccavale; Giovanni Annona; Lucie Subirana; Hector Escriva; Stéphanie Bertrand; Salvatore D'Aniello	Crosstalk between Nitric Oxide and Retinoic Acid pathways is essential for amphioxus pharynx development	Article in Journal	10.1101/2020.06.22.164632	Green
57	Verena Dully; Giulia Rech; Thomas A. Wilding; Anders Lanzén; Kate MacKichan; Iain Berrill; Thorsten Stoeck	Comparing sediment preservation methods for genomic biomonitoring of coastal marine ecosystems.	Article in Journal	10.1016/j.marpolbul.2021.113129	Green
58	Wiebe H. C. F. Kooistra; Wolf-Henning Kusber; David U. Hernández-Becerril; Marina Montresor; Diana Sarno	The type species of the diatom genus Chaetoceros	Article in Journal	10.1080/0269249x.2022.2066182	Green
59	Anne-Sophie Pavaux; Eva Ternon; Louison Dufour; Sophie Marro; Marin-Pierre Gémin; Olivier P. Thomas; Rodolphe Lemée	Efficient, fast and inexpensive bioassay to monitor benthic microalgae toxicity: Application to Ostreopsis species.	Article in Journal	10.1016/j.aquatox.2020.105485	Green
60	Ricardo Cardoso Neves; Reinhardt Møbjerg Kristensen; Nadja Møbjerg	New records on the rich loriciferan fauna of Trezenar Skoden (Roscoff, France): Description of two new species of Nanaloricus and the new genus Scutiloricus.	Article in Journal	10.1371/journal.pone.0250403	Green
61	Sadogurska, Sofia S.; Neiva, João; Falace, Annalisa; Serrão, Ester A.; Israel, Álvaro	The genus Cystoseira s.l. (Ochrophyta, Fucales, Sargassaceae) in the Black Sea: morphological variability and molecular taxonomy of Gongolaria barbata and endemic Ericaria crinita f. bosphorica comb. nov.	Article in Journal	10.11646/phytotaxa.480.1.1	Green
62	Madeleine Emma Aase-Remedios; David E. K. Ferrier	Improved Understanding of the Role of Gene and Genome Duplications in Chordate Evolution With New Genome and Transcriptome Sequences	Article in Journal	10.3389/fevo.2021.703163	Green
63	Mariarita Caracciolo; Fabienne Rigaut-Jalabert; Sarah Romac; Frédéric Mahé; Samuel Forsans; Jean-Philippe Gac; Laure Arsenieff; Maxime Manno; Samuel Chaffron; Thierry Cariou; Mark Hoebeke; Yann Bozec; Eric Goberville; Florence Le Gall; Loïc Guilloux; Anne-Claire Baudoux; Colomban de Vargas; Fabrice Not; Eric Thiébaut; Nicolas Henry; Nathalie Simon	Seasonal dynamics of marine protist communities in tidally mixed coastal waters	Article in Journal	10.1111/mec.16539	Green
64	Pablo Heres; Jesús S. Troncoso; Estefania Paredes	Larval cryopreservation as new management tool for threatened clam fisheries.	Article in Journal	10.1038/s41598-021-94197-2	Green
65	Anthony Leon; Lucie Subirana; Kevin Magre; Ildefonso Cases; Juan J. Tena; Manuel Irimia; Jose Luis	Gene Regulatory Networks of Epidermal and Neural Fate Choice in a Chordate	Article in Journal	10.1093/molbev/msac055	Green

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	Gomez-Skarmeta; Hector Escriva; Stéphanie Bertrand				
66	Sachslehner, Attila; Zieger, Elisabeth; Calcino, Andrew; Wanninger, Andreas	HES and Mox genes are expressed during early mesoderm formation in a mollusk with putative ancestral features	Article in Journal	10.1038/s41598-021-96711-y	Green
67	Yacine Badis; Delphine Scornet; Minori Harada; Céline Caillard; Olivier Godfroy; Morgane Raphalen; Claire M. M. Gachon; Susana M. Coelho; Taizo Motomura; Chikako Nagasato; J. Mark Cock	Targeted CRISPR-Cas9-based gene knockouts in the model brown alga Ectocarpus	Article in Journal	10.1111/nph.17525	Green
68	Seila Diaz; Alicia L Bruzos; Daniel Garcia-Souto; Sara Rocha; Ana Pequeño-Valtierra; Camila F Roman-Lewis; Juana Alonso; Rosana Rodriguez; Damian Costas; Jorge Rodriguez-Castro; Antonio Villanueva; Luis Silva; Jose Maria Valencia; Giovanni Annona; Andrea Tarallo; Fernando Ricardo; Ana Bratoš Cetinić; David Posada; Juan Jose Pasantes; Jose MC Tubio	Mitochondrial genome sequencing of marine leukaemias reveals cancer contagion between clam species in the Seas of Southern Europe	Article in Journal	10.7554/elife.66946	Green
69	Saavedra, Carlos Felipe; Milan, Massimo; Leite, Ricardo B.; Cordero, David	Expresión génica diferencial asociada a la tasa de crecimiento en las branquias y la glándula digestiva de la almeja fina (Ruditapes decussatus)	Publication in Conference proceedings/Workshop		Green
70	Jessica Pazzaglia, Thorsten B. H. Reusch, Antonio Terlizzi, Lázaro Marín-Guirao, Gabriele Procaccini	Phenotypic plasticity under rapid global changes: The intrinsic force for future seagrasses survival	Article in Journal	10.1111/eva.13212	Green
71	S.Campos, J.Troncoso, E.Paredes	Major challenges in cryopreservation of sea urchin eggs	Article in Journal	10.1016/j.cryobiol.2020.11.008	Green
72	Daniel Garcia-Souto, Alicia L Bruzos, Seila Diaz, Sara Rocha, Ana Pequeño-Valtierra, Camila F Roman-Lewis, Juana Alonso, Rosana Rodriguez, Damian Costas, Jorge Rodriguez-Castro, Antonio Villanueva, Luis Silva, Jose Maria Valencia, Giovanni Annona, Andrea Tarallo, Fernando Ricardo, Ana Bratoš Cetinić, David Posada, Juan Jose Pasantes, Jose MC Tubio	Mitochondrial genome sequencing of marine leukemias reveals cancer contagion between clam species in the Seas of Southern Europe	Article in Journal	10.1101/2021.03.10.434714	Green
73	Jeff C. Clements, Sam Dupont, Fredrik Jutfelt	"Urchin pinning": Behavioural observations reveal how hungry urchins actively prey upon their sea star predators	Article in Journal	10.1111/eth.13147	Green
74	Stephanie Bertrand, João E. Carvalho, Delphine Dauga, Nicolas Matentzoglu, Vladimir Daric, Jr-Kai Yu, Michael Schubert and Hector Escriva	The Ontology of the Amphioxus Anatomy and Life Cycle (AMPHX)	Article in Journal	10.3389/fcell.2021.668025	Green
75	Gordon T, Upadhyay AK, Manni L, Huchon D and Shenkar N	And Then There Were Three horizontal ellipsis: Extreme Regeneration Ability of the Solitary Chordate Polycarpa mytiligera	Article in Journal	10.3389/fcell.2021.652466	Green
76	Laurence H. De Clippele, Denise Risch	Measuring Sound at a Cold-Water Coral Reef to Assess the Impact of COVID-19 on Noise Pollution	Article in Journal	10.3389/fmars.2021.674702	Green
77	Elisabeth Zieger, Andrew D. Calcino, Nicolas S.M. Robert, Christian Baranyi, Andreas Wanninger	Ecdysis-related neuropeptide expression and metamorphosis in a non-ecdysozoan bilaterian	Article in Journal	10.1111/evo.14308	Green
78	Christina Pavloudi, Eleni Ioanna Yperifanou, Jon Bent Kristoffersen, Thanos Dailianis, Vasilis Gerovasileiou	Artificial Reef Monitoring Structures (ARMS) providing insights on hard substrate biodiversity and community structure of the Eastern Mediterranean Sea	Publication in Conference proceedings/Workshop	10.3897/aca.4.e64760	Green
79	Christos Katsaros, Sophie Le Panse, Gillian Milne, Carl J. Carrano, Frithjof Christian Küpper	New insights on Laminaria digitata ultrastructure through combined conventional chemical fixation and cryofixation	Article in Journal	10.1515/bot-2021-0005	Green
80	Jeff C.Clements, KirtiRamesh, JacobNysveen, SamDupont, FredrikJutfelt	Animal size and sea water temperature, but not pH, influence a repeatable startle response behaviour in a wide-ranging marine mollusc	Article in Journal	10.1016/j.anbehav.2020.12.008	Green

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81	Marcos A. L. Teixeira, Arne Nygren, Ascensão Ravara, Pedro E. Vieira, José Carlos Hernández, Filipe O. Costa	The small polychaete Platynereis dumerilii revealed as a large species complex with fourteen MOTUs in European marine	Publication in Conference proceedings/Workshop	10.3897/aca.4.e64937	Green
82	Tatyana Darienko, Cecilia Rad-Menéndez, Christine N. Campbell, Thomas Pröschold	Molecular Phylogeny of Unicellular Marine Coccoid Green Algae Revealed New Insights into the Systematics of the Ulvophyceae (Chlorophyta)	Article in Journal	10.3390/microorganisms9081586	Green
83	Miriam Ruocco; Marlene Jahnke; João Silva; Gabriele Procaccini; Emanuela Dattolo	2b-RAD Genotyping of the Seagrass Cymodocea nodosa Along a Latitudinal Cline Identifies Candidate Genes for Environmental Adaptation	Article in Journal	10.3389/fgene.2022.866758	Green
84	Russell J. S. Orr, aja M. Sannum, anne Boessenkool, manuela Di Martino, ennis P. Gordon, annah L. Mello, atthias Obst, ali H. Ramsfjell, bigail M. Smith, ee Hsiang Liow	A molecular phylogeny of historical and contemporary specimens of an under-studied micro-invertebrate group	Article in Journal	10.1002/ece3.7042	Green
85	Silvia Mercurio, ilvia Messinetti, aoul Manenti, entile Francesco Ficetola, oberta Pennati	Embryotoxicity characterization of the flame retardant tris(1-chloro-2-propyl)phosphate (TCPP) in the invertebrate chordate Ciona intestinalis	Article in Journal	10.1002/jez.2446	Green
86	Brandon Weissbourd, Tsuyoshi Momose, Aditya Nair, Ann Kennedy, Bridgett Hunt, David J. Anderson,	A genetically tractable jellyfish model for systems and evolutionary neuroscience	Article in Journal	10.1016/j.cell.2021.10.021	Green
87	Christian Galasso, Xabier Lekube, Ibon Cancio, Antonio Dell'Anno, Christophe Brunet, Clementina Sansone, Michael Tangherlini	Marine Fungi as Potential Eco-Sustainable Resource for Precious Metals Recovery from Electronic Waste	Article in Journal	10.1007/s12649-021-01587-8	Green
88	Alwin Hylkema, Adolphe O. Debrot, Ronald Osinga, Patrick S. Bron, Daniel B. Heesink, Ayumi Kuramae Izioka, Callum B. Reid, Jorien C. Rippen, Tali Treibitz, Matan Yuval, Albertinka J. Murk,	Fish assemblages of three common artificial reef designs during early colonization	Article in Journal	10.1016/j.ecoleng.2020.105994	Green
89	Mary W. Carrano, Carl J. Carrano, Matthew S. Edwards, Hanan Al-Adilah, Yann Fontana, Martin D.J. Sayer, Christos Katsaros, Andrea Raab, Joerg Feldmann, Frithjof C. Küpper,	Laminaria kelps impact iodine speciation chemistry in coastal seawater	Article in Journal	10.1016/j.ecss.2021.107531	Green
90	Flora Rendell-Bhatti, Periklis Paganos, Anna Pouch, Christopher Mitchell, Salvatore D'Aniello, Brendan J. Godley, Ksenia Pazdro, Maria Ina Arnone, Eva Jimenez-Guri	Developmental toxicity of plastic leachates on the sea urchin Paracentrotus lividus	Article in Journal	10.1016/j.envpol.2020.115744	Green
91	Jessica Pazzaglia, Alex Santillán-Sarmiento, Miriam Ruocco, Emanuela Dattolo, Luca Ambrosino, Lazaro Marín-Guirao, Gabriele Procaccini	Local environment modulates whole-transcriptome expression in the seagrass Posidonia oceanica under warming and nutrients excess,	Article in Journal	10.1016/j.envpol.2022.119077	Green
92	Érica Caroline Becker, Maria Grazia Mazzocchi, Luis Carlos Pinto de Macedo-Soares, Manoela Costa Brandão, Andrea Santarosa Freire	Latitudinal gradient of copepod functional diversity in the South Atlantic Ocean	Article in Journal	10.1016/j.pocean.2021.102710	Green
93	Geslaine Rafaela Lemos Gonçalves, Ana Clara Denadai, Aline Nonato Sousa, Antonio Leão Castilho, Marleen De Troch,	Fatty acid profiles of three commercial shrimp from southeastern Brazil	Article in Journal	10.1016/j.rsma.2021.102032	No
94	Reem, E., Douek, J., & Rinkevich, B	A critical deliberation of the 'species complex' status of the globally spread colonial ascidian Botryllus schlosseri	Article in Journal	10.1017/s0025315422000029	Green
95	Medrano, A., Hereu, B., Mariani, S. et al. Ecological traits, genetic diversity and regional distribution of the macroalga	Ecological traits, genetic diversity and regional distribution of the macroalga Treptacantha elegans along the Catalan coast (NW Mediterranean Sea)	Article in Journal	10.1038/s41598-020-76066-6	Green
96	Lopes, A.F., Faria, A.M. & Dupont, S.	Elevated temperature, but not decreased pH, impairs reproduction in a temperate fish	Article in Journal	10.1038/s41598-020-77906-1	Green
97	P. Heres, J. Troncoso & E. Paredes	Long-term study on survival and development of successive generations of Mytilus galloprovincialis cryopreserved larvae	Article in Journal	10.1038/s41598-022-17935-0	Green
98	Roberta Piredda, iana Sarno, aniele De Luca, Wiebe H.C.F. Kooistra	Biogeography of six species in the planktonic diatom genus Bacteriastrum (Bacillariophyta)	Article in Journal	10.1080/09670262.2021.2021591	Green

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99	Daniel Grzebyk, Vanina Pasqualini, Marie Garrido, Yann Quilichini, Clément Pereto & Philippe Cecchi	Insight into the morphology and genetic diversity of the Chaetoceros tenuissimus (Bacillariophyta) species complex	Article in Journal	10.1080/09670262.2022.2029949	Green
100	Stoimir Kolarević, Margareta Kračun-Kolarević, Jovana Jovanović Marić, Jelena Djordjević, Branka Vuković-Gačić, Danijela Joksimović, Rajko Martinović, Oliver Bajt, Andreja Ramšak	Single and combined potential of polystyrene microparticles and fluoranthene in the induction of DNA damage in haemocytes of Mediterranean mussel (Mytilus galloprovincialis)	Article in Journal	10.1093/mutage/geac017	Green
101	Dominik Forster, uillaume Lentendu, abine Filker, lyssa Dubois, homas A. Wilding, horsten Stoeck	Improving eDNA-based protist diversity assessments using networks of amplicon sequence variants	Article in Journal	10.1111/1462-2920.14764	Green
102	Rafath Chowdhury, Agnès Roure, Yann le Pétillon, Hélène Mayeur, Vladimir Daric & Sébastien Darras	Highly distinct genetic programs for peripheral nervous system formation in chordates	Article in Journal	10.1186/s12915-022-01355-7	Green
103	BARICHE, M., AL-MABRUK, S. A., ATEŞ, M. A., BÜYÜK, A., CROCETTA, F., DRITSAS, M., EDDE, D., FORTIČ, A., GAVRIIL, E., GEROVASILEIOU, V., GÖKOĞLU, M., HUSEYINOGLU, F. M., KARACHLE, P. K., KLEITOU, P., TERBIYIK KURT, T., LANGENECK, J., LARDICCI, C., LIPEJ, L., PAVLOUDI, C., PINNA, M., RIZGALLA, J., RÜŞTÜ ÖZEN, M., SEDANO, F., TAŞKIN, E., YILDIZ, G., & ZANGARO, F.	New Alien Mediterranean Biodiversity Records (March 2020)	Article in Journal	10.12681/mms.21987	Green
104	Lydvina Meister, Hector Escriva, Stéphanie Bertrand	Functions of the FGF signalling pathway in cephalochordates provide insight into the evolution of the prechordal plate	Article in Journal	10.1242/dev.200252	Green
105	MONTESANTO, F., CHIMIENTI, G., GISSI, C., & MASTROTOTARO, F.	Polyclinum constellatum (Tunicata, Ascidiacea), an emerging non-indigenous species of the Mediterranean Sea: integrated taxonomy and the importance of reliable DNA barcode data	Article in Journal	10.12681/mms.28311	Green
106	Simon C Dailey, Iryna Kozmikova, Ildikó M L Somorjai	Amphioxus Sp5 is a member of a conserved Specificity Protein complement and is modulated by Wnt/beta-catenin signalling	Article in Journal	10.1387/ijdb.170205is	Green
107	Ildikó M L Somorjai	Amphioxus regeneration: evolutionary and biomedical implications	Article in Journal	10.1387/ijdb.170219is	Green
108	Sébastien Darras	En masse DNA Electroporation for in vivo Transcriptional Assay in Ascidian Embryos	Article in Journal	10.21769/bioprotoc.4160	Green
109	MARCELO P. HERNANDO, IRENE R. SCHLOSS, FLORENCIA DE LA ROSA, MARLEEN DE TROCH	Fatty acids in microalgae and cyanobacteria in a changing world: Contrasting temperate and cold environments	Article in Journal	10.32604/biocell.2022.017309	Green
110	Paola Olivo, Antonio Palladino, Filomena Ristoratore, Antonietta Spagnuolo	Brain Sensory Organs of the Ascidian Ciona robusta: Structure, Function and Developmental Mechanisms	Article in Journal	10.3389/fcell.2021.701779	Green
111	Anne Tourneroche, Raphaël Lami, Gaëtan Burgaud, Isabelle Domart-Coulon, Wei Li, Claire Gachon, Marc Gèze, Dominique Boeuf, Soizic Prado	The Bacterial and Fungal Microbiota of Saccharina latissima (Laminariales, Phaeophyceae)	Article in Journal	10.3389/fmars.2020.587566	Green
112	Ferrieux Mathilde, Dufour Louison, Doré Hugo, Ratin Morgane, Guéneuguès Audrey, Chasselin Léo, Marie Dominique, Rigaut-Jalabert Fabienne, Le Gall Florence, Sciandra Théo, Monier Garance, Hoebeke Mark, Corre Erwan, Xia Xiaomin, Liu Hongbin, Scanlan David J., Partensky Frédéric, Garczarek Laurence	Comparative Thermophysiology of Marine Synechococcus CRD1 Strains Isolated From Different Thermal Niches in Iron-Depleted Areas	Article in Journal	10.3389/fmicb.2022.893413	Green
113	Rahlff, J.; Giebel, H.-A.; Stolle, C.; Wurl, O.; Probst, A.J.; Herlemann, D.P.R	Overlooked Diversity of Ultramicrobacterial Minorities at the Air-Sea Interface	Article in Journal	10.3390/atmos11111214	Green
114	Ruocco, M.; Ambrosino, L.; Jahnke, M.; Chiusano, M.L.; Barrote, I.; Procaccini, G.; Silva, J.; Dattolo, E.	m6A RNA Methylation in Marine Plants: First Insights and Relevance for Biological Rhythms	Article in Journal	10.3390/ijms21207508	Green
115	Sabine Keuter, Jeremy R. Young, Gil Koplovitz, Adriana Zingone, Miguel J. Frada	Novel heterococcolithophores, holococcolithophores and life cycle combinations from the families Syracosphaeraceae and Pappohaeraceae and the genus Florisphdera	Article in Journal	10.5194/jm-40-75-2021	Green
116	MULAS M., NEIVA J., SADOGURSKA S. S., BALLESTEROS E., SERRÃO E. Á., RILOV G. & ISRAEL Á.	Genetic affinities and biogeography of putative Levantine-endemic seaweed Treptacantha rayssiae	Article in Journal	10.5252/cryptogamie-	Green

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		(Ramon) M.Mulas, J.Neiva & Á.Israel, comb. nov. (Phaeophyceae)		algologie2020v41a10	
117	Maria Valeria Ruggiero, Wiebe H.C.F. Kooistra, Roberta Piredda, Diana Sarno, Gianpaolo Zampicinini, Adriana Zingone, Marina Montresor	Temporal changes of genetic structure and diversity in a marine diatom genus discovered via metabarcoding	Article in Journal	10.1002/edn3.288	Green
118	Catriona Munro, Hugo Cadis, Sophie Pagnotta, Evelyn Houliston, ean-René Huynh	Conserved meiotic mechanisms in the cnidarian Clytia hemisphaerica revealed by Spo11 knockout	Article in Journal	10.1101/2022.01.05.475076	Green
119	Román M, de Los Santos CB, Román S, Santos R, Troncoso JS, Vázquez E, Olabarria C.	Loss of surficial sedimentary carbon stocks in seagrass meadows subjected to intensive clam harvesting	Article in Journal	10.1016/j.marenvres.2022.105570	Green
120	Océane Seudre, Francisco M Martín-Zamora, Valentina Rapisarda, Imran Luqman, Allan M Carrillo-Baltodano, José M Martín-Durán	The Fox gene repertoire in the annelid Owenia fusiformis reveals multiple expansions of the foxQ2 class in Spiralia	Article in Journal	10.1093/gbe/evac139	Green
121	Hugo Doré, Jade Leconte, Ulysse Guyet, Solène Breton, Gregory K. Farrant, David Demory, Morgane Ratin, Mark Hoebeke, Erwan Corre, Frances D. Pitt, Martin Ostrowski, David J. Scanlan, Frédéric Partensky, Christophe Six, aurence Garczarek	Global phylogeography of marine Synechococcus in coastal areas reveals strikingly different communities than in the open ocean	Article in Journal	10.1101/2022.03.07.483242	Green
122	Guido Bonthond, nastasiia Barilo, o J. Allen, ichael Cunliffe, tacy A. Krueger-Hadfield	Fungal endophytes vary by species, tissue type, and life cycle stage in intertidal macroalgae	Article in Journal	10.1111/jpy.13237	Green
123	Alessandra Petrucciani, Peter Chaerle, Alessandra Norici	Diatoms Versus Copepods: Could Frustule Traits Have a Role in Avoiding Predation?	Article in Journal	10.3389/fmars.2021.804960	Green

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