



Marine Stations Helgoland and Sylt operated by the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research

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Abstract: The Marine Stations Helgoland and Sylt are permanent coastal stations in the German Bight operated as one joint research infrastructure by the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI). Using both stations, the south-west region of the North Sea and its ecosystem features are tightly monitored via ecological time series, which are recorded and made available to government offices, professional associations, and research institutes world-wide. The stations are a hub for national and transnational access for guest researchers and visiting scientists in the German Bight. For over fifty years, the stations have served as centres of student education by providing facilities for university courses. The stations operate the coastal research vessels Mya II, Uthörn and Aade. The Biologische Anstalt Helgoland (BAH) is home to the AWI Centre for Scientific Diving, which conducts, promotes, and supports diver-related underwater science within the framework of all AWI research themes. The BAH is also home to the school laboratory OPENSEA, which offers high school students a scientific environment to explore marine science. The Wadden Sea Station on the island of Sylt offers 24 seawater mesocosms for ecological studies of future climate scenarios. Public outreach centres are associated with both locations (BLUEHOUSE and Erlebniszentrum Naturgewalten).

1 Introduction

The Marine Station Helgoland (“Biologische Anstalt Helgoland”) and the Wadden Sea Station Sylt (“Wattenmeerstation List, Sylt”) together form a large-scale research infrastructure operated by the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI). Since 1892 on Helgoland, one of the oldest marine stations in the world, scientists have been investigating shelf seas and unique coastal environments. In 1892 the “Biologische Anstalt Helgoland (BAH) was founded, and together with the “Meeresstation” on Helgoland, the first facility was opened (Salewski 2017). In 1924, the BAH was extended to include Wadden Sea and oyster research, with the addition of the “Wattenmeerstation” in List. In 1998, the BAH became an integral part of the AWI.

The marine stations on Helgoland and Sylt house key infrastructure for fulfilling scientific, educational, societal and logistic obligations according to the statutes of the AWI and the Helmholtz Association. The BAH has a long tradition of generating, archiving and analysing marine, ecological time series. The first temperature and salinity time series were started in 1873. The earliest macroalgal data were also collected in the 19th century. In 1962, one of the most important time series globally, the so-called Helgoland Roads time series on plankton was initiated. The time series Helgoland Roads and Sylt Roads are characterized by a unique combination of length, temporal resolution, and level of detail (range of parameters).



Figure 1: Building A of the Marine Station on Helgoland (Picture: Uwe Nettelmann, AWI).



Figure 2: Wadden Sea Station on Sylt (Picture: AWI, GSMH)

2 Research capacities for work at the marine stations Helgoland and Sylt

The portfolio of the stations comprises personal, remote and virtual access to field samples and data, as well as the provision of modern infrastructure for advanced work in the context of coastal research (laboratories, testing devices, standard sampling procedures, seawater supply, temperature constant rooms, research vessels, accommodation etc.). In addition to the basic facilities, visiting scientists have access to nutrient analyses, micro- and molecular biology laboratories through cooperation with on-site scientists and, uniquely, to outdoor mesocosms capable of simulating ocean warming and acidification under various tidal conditions. The research vessels can be requested for short research cruises to take pelagic or benthic samples.

User get access to the facilities for service requests in the user portal www.accessinfra.awi.de.

Both Marine Stations contribute to national and international projects and networks as e.g. the German Marine Research Consortium, German Marine Research Alliance, European Marine Research Network, European Network of Marine Stations and the World Association of Marine Stations.

2.1 Long-term observatories

Helgoland Roads

The Helgoland Roads time-series, located at 54°11'N and 7°54'E, is one of the richest temporal marine datasets available. It is registered in the Dynamic Ecological Information Management System - Site and dataset registry (DEIMS) as an information management system powered by [eLTER](#). The data set comprises a phytoplankton time series (started in 1962 and sampled daily during the work week) and a zooplankton time series (started in 1975 and sampled three times a week), along with time series for inorganic nutrients (nitrite, nitrate, phosphate, silicate, ammonium), salinity and temperature. Also, several shorter time series (e.g. Chlorophyll a and other data from ferrybox systems) and spatio-temporal datasets exist, and Helgoland scientists are jointly setting standards by linking these data through detailed documentation, quality control and data management to facilitate detailed analyses of long-term ecological change and their societal consequences. In addition to these core time series, bacterial counts have also been carried out for over 40 years, although this time series has recently been discontinued (Gerdtts et al. 2004, Lucas et al 2015, Lucas et al 2016, Banos et al 2020). An overview of the microbial parameters acquired at the sampling station “Kabeltonne”, Helgoland Roads from 1962 until today is given in Gerdtts et al 2004. The macroalgal and macrobenthos communities were investigated periodically (Bartsch & Kuhlenkamp 2000, Franke et al. 2004). However, the fact that the 'Helgoländer Felswatt' is the only habitat of this type in Germany, makes this data set all the more valuable. The high sampling frequency of the Helgoland Roads time series has provided a unique opportunity to study long-term trends in abiotic and biotic parameters (Raabe and Wiltshire 2008, van Beusekom et al. 2009, Wiltshire & Manly 2004, Wiltshire et al 2010), but also ecological phenomena, such as seasonal interactions between different food web components (Boersma et al 2015, Freund et al 2012, Kraberg et al 2019), niche properties, and the dynamics and timing of the spring bloom (Brüwer et al 2023, Meunier et al. 2018, Scharfe et al. 2019, Teeling et al 2012, Wiltshire et al. 2008). It has also facilitated close examination of the dynamics of new species appearing in the local ecosystem.

Sylt Roads

The Sylt Roads time series is closely related to the Helgoland Roads time series and comprises an almost identical parameter set. Sylt Roads was initiated in 1974. Its main station located in the Sylt-Rømø bight close to List/Sylt (55°03'N and 8°46'E) is generally sampled twice a week ([ID in DEIMS](#)). The measured parameters comprise phytoplankton, zooplankton, water temperature, salinity, pH, Chlorophyll a and nutrient (nitrite, nitrate, phosphate, silicate, ammonium) analyses (Balkoni et al 2023, de Amorim and Wiltshire et al 2023, van Beusekom et al 2019). The plankton time-series is augmented by gelatinous zooplankton, meroplankton, primary productivity, fish monitoring, macroalgae, macro- and microzoobenthos, providing a unique opportunity to investigate long-term changes at an ecosystem scale (Armonies et al. 2023, Martens et al 2008; Rick et al. 2023).

Monthly transect cruises

Additionally, monthly transect expeditions from Helgoland to the Elbe (Cuxhaven) and Eider rivers have been carried out continuously since the beginning of the 1980s, monitoring the coastal transition zone (Lucas et al 2016). Increasingly, time-series data are generated with the assistance of autonomous measuring systems, like e.g. a Ferry Box system on the passenger vessel HELGOLAND.

Description of the time series are given in the Dynamic Ecological Information Management System - Site and dataset registry (DEIMS-SDR) and LTER-D.

The ecological time-series research at Helgoland and Sylt Roads produces extremely valuable data used by science, public authorities, educational institutions, and national/international organizations. The data are archived in the World Data Centre [PANGAEA](#) and can be accessed via the [marine-data-portal](#). To make information about and the knowledge resulting from the HR and SR LTER time series findable and accessible for the scientific community and other interested stakeholder groups meaningful and reproducible data products were already compiled for selected parameters of the LTER time series of HR and SR. The resulting data products are presented on two dashboards ([Helgoland Roads Dashboard](#), [Sylt Roads Dashboard](#)), where information about the time series, near-realtime data and the data products are consolidated.

The coastal long-term observatories contribute to the analysis and knowledge transfer of long-term environmental trends and marine processes in cooperation and exchange with local authorities (e.g. Bundesamt für Seeschifffahrt und Hydrographie/BSH, Umweltbundesamt/UBA) and national and international institutions (e.g. Sir Alister Hardy Foundation for Ocean Science/[SAHFOS](#), National Oceanic and Atmospheric Administration/[NOAA](#)), boards (e.g. International Council for the Exploration of the Sea/[ICES](#) Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization/[IOC-UNESCO](#)), and networks (e.g. Long-term ecological Research Germany [LTER-D](#), European Marine Observation and Data Network/[EMODnet](#), World Register of Marine Species/[WORMS](#)).

2.2 Guest research and education

The stations' educational infrastructure - course and seminar rooms - is regularly used for university practical courses and field excursions, scientific workshops and seminars. Technical support and service for visiting scientists and university courses are complemented by access to biological material at both stations. The supply of marine-sourced material is possible both on-site and by shipment. Capacities for university courses include two course rooms for 20-25 participants including supervisors on Helgoland, and one course room for 18 participants including supervisors on Sylt. All course rooms are equipped with microscopes, binoculars, a taxonomic library, wet lab area with running seawater and equipment for field work. Access to the field is assisted by the guest research team.

Sampling within the nature reserve Helgoland is regulated according to the "Landesverordnung über das Naturschutzgebiet "Helgoländer Felssockel" of April 24, 1981 in §5. However, research activities and teaching at the Biologische Anstalt Helgoland (including necessary experimental arrangements) are allowed. Sampling in the Schleswig-Holstein Wadden Sea National Park (according to the "Gesetz zum Schutz des Schleswig-Holsteinischen Wattenmeeres" of December 17, 1999, last amended by ordinance of January 16, 2019) is regulated in §6 "Permitted measures and uses, exceptions, exemptions". Within the national park, research is permitted pursuant to § 2 para. 2: protection, maintenance and development measures of the authority responsible for the national park and the long-term observations approved by it, including research work.

Laboratories

Well-equipped laboratories are offered to individual guest researchers and university courses at both marine stations.

Lab specification	Equipment	Helgoland	Sylt
Wet lab	Aquaria, scales, pumps, sieves	2	1
Dry lab	Microscopes, binocular	4	1
Chemistry lab	Centrifuges, dry cabins	1 (muffle furnace, freeze dryer)	1
Scientific cold storage	Freezer -20°C, -60°C, -80°C	2 (-20°C, -60°C, -80°C)	2 (-20°C, -80°C)
Temperature constant rooms	Defined temperature between -2°C and 22°C, running seawater, fresh water, pressure air	1	1
Constant running seawater supply		X	X



Figure 3: A university course takes plankton samples (Photo: AWI)



Figure 4: Students determining species with binoculars in the course room (Photo: AWI)

School laboratory

The school lab OPENSEA offers a scientific environment to explore marine science, thereby promoting young peoples' scientific thinking. In close cooperation with the scientists, OPENSEA offers experiences outside the classroom for high school graduates with special interests in natural science and marine biology. With hands on experiments in the field and in the lab (Höfble et al 2021, Thiel et al 2023), OPENSEA provides add-ons to the syllabus for high school graduates, and encourages the scholars to actively ask scientific questions, conduct practical biological and chemical experiments, collect field data to find conclusive answers, and to foster scientific thinking. Scholars are introduced to ecological processes very close to current research topics and learn more about the urgent need to protect the oceans.



Figure 5: School lab OPENSEA taking samples in the intertidal (Picture: Uwe Nettelmann, AWI)

2.3 Material Dispatch

Institutes and universities from all over Germany (and increasingly Europe) have a high demand for living and/or fixed biological material for teaching purposes. The Biologische Anstalt Helgoland operates a material dispatch and supply service that enables researchers and course leaders to acquire such material. The BAH Material Dispatch tries to process all inquiries, but strictly adheres to existing species protection regulations. Accordingly, species that are on the red list cannot be supplied. Conserved and living zoological material, botanical material (living macroalgae), seawater, as well as sediment are offered on a material list and shipped to the requesting institution.



Figure 6: Conserved specimens in glass jars for university usage (Picture: Uwe Nettelmann)

2.4 Mesocosms

The AWI Sylt Outdoor Mesocosms (AWISOM) consist of 24 identical mesocosms, each with 1800 l sea water volume and a light-permeable cover. Each mesocosm can simulate tides and currents to recreate conditions as natural as possible for the experimental communities contained within (Pansch et al 2016). Furthermore, it is possible to precisely regulate temperature, carbon dioxide concentration and nutrients within each basin. A multiparameter probe continuously monitors and automatically records pH, salinity, oxygen content and temperature. The mesocosms are operated seasonally from April to October to study the influences of simulated environmental changes (IPCC climate scenarios) on species communities of the Wadden Sea. In winter, AWISOM is shut down to protect the electronics and technology from cold-related damage. However, in addition to the 24 outdoor tanks, there are six further tanks in a large greenhouse, where it is possible to conduct experiments in winter e.g. to study the effects of warmer winters. The AWI team has used this facility to test, among other things, the impact of various future scenarios released by the IPCC (Intergovernmental Panel on Climate Change) on marine life (Di Pane, 2022; Fuxjager et al. 2019; Moreno et al. 2022).



Figure 7: AWISOM mesocosms (Picture: Esther Horvath, AWI)

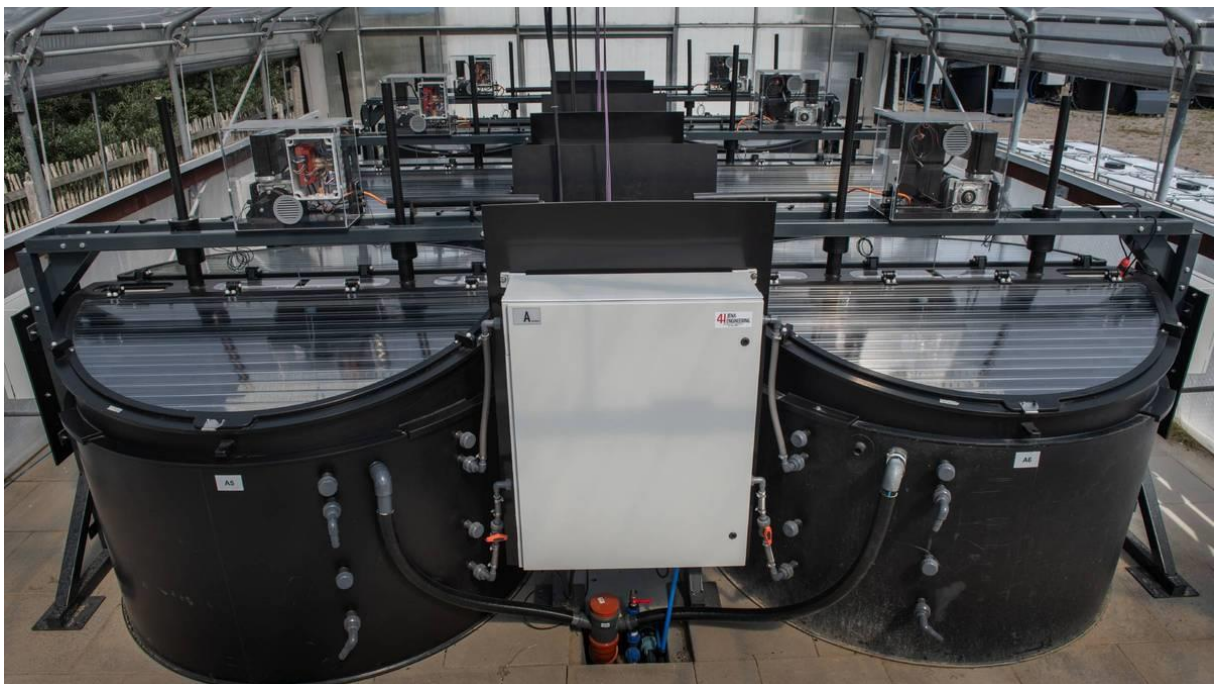


Figure 8: Six additional mesocosms in a greenhouse can be used for experiments studying the effects of warmer winters (Picture: Esther Horvath, AWI)

2.5 AWI Centre for Scientific Diving

With more than 1300 scientific dives per year, the Centre for Scientific Diving (AWI-CSD) is the central platform for all scientific diving related activities at the AWI. The CSD is located on Helgoland where excellent training and research facilities are available in combination with the Biologische Anstalt Helgoland. In addition, the AWI-CSD operates permanent dive bases in Bremerhaven and Sylt, as well as temporary dive bases. With currently 12 certified "Dive Mission Leaders", the AWI CSD is one of the main scientific diving facilities in Europe and conducts professional underwater research in all oceans of the world. The main goals of the AWI Center for Scientific Diving are to conduct, promote and support diver related underwater science within the framework of the AWI research topics. As an official education centre for Scientific Diving in Germany (certified by the German Examination Board for Scientific Diving), all scientific dives at the Alfred-Wegener-Institute are done within the framework of the German regulations for Scientific Diving DGVV Rules 101 023 released by the Statutory Accident Insurance in close cooperation with the German Commission for Scientific Diving.

The AWI-Centre for Scientific Diving provides highly-trained year-round scientific diver support for the set-up and maintenance of sensors and experimental equipment within the MarGate underwater experimental area off Helgoland (Fischer al 2020, Fischer et al 2021). The area is about 270 x 100 m in size, located between 5 and 10 m water depth, and is officially classified as a maritime exclusive zone for ship traffic. Six tetrapod-fields have been installed in 5 and 10 m water depth to study the effects of artificial breakwaters on the shallow water fish and macro-invertebrate community. Since summer 2012, the MarGate field contains the first German underwater node system developed in the framework of COSYNA. This system provides continuous and manageable power and network access at 10 separate underwater mutable docking ports, each providing 48V/200W and 100 MBit/1 GBit network connection. Each port can be individually addressed and managed by its registered user (sensor owner) from anywhere in the world to remotely control and manage even complex sensor units. As well as basic hydrographical parameters from the area, the AWI operates multiple sensor systems for the main abiotic and biotic variables (temperature, salinity, depth, tide, turbidity, oxygen, chl-a fluorescence, 3D-current) in near real time (about 1 h delay).



Figure 9: Diver with photo equipment (Picture: AWI)

3 Concluding remarks and future development

The Marine Stations Helgoland and Sylt have excellent facilities with a long-term institutional and governmental commitment. They promote a wide range of research topics and experimental approaches. On-site, scientists jointly set standards by providing these data for research and science. This entails detailed documentation, quality control, and data management to facilitate analyses of long-term ecological changes and their societal consequences. The Marine Stations Helgoland and Sylt will continue

- operating long-time data series and improve the services provided to internal and external users
- and extend the support for use and decision-making by science, society, and politics
- and improve the provided services to external visitors
- supplying educational institutions and universities with material and providing the best possible service and information
- providing a hospitable environment for education and ongoing capacity development building, and for more intensified international (transnational) cooperation

Besides continuation of their operational function, both marine stations will intensify their international collaborations. Joint strategies and developments provide a strong infrastructure with immense future potential. Facilitating engagement with stakeholders and governing bodies in discussions, as well as providing pivotal data products is a priority.

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