Stazione Zoologica “Anton Dohrn”

National Institute of Marine Biology, Ecology and Biotechnologies

Vision 2021-2030

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Executive summary

Marine research offers concrete opportunities to respond to the emerging demands of our times, offering new knowledge, new opportunities and allowing the identification of solutions to the complex problems we currently face. Marine research is growing exponentially due to the opening of new research areas and industrial opportunities along with continuous technical advancements and applications. Italy, with more than 8000 km of coastline, gains essential benefits from marine ecosystems. The European Union has recognized the critical importance of the marine sector by identifying priorities and resources and has launched key initiatives to promote the development of the "Blue Economy".

Italian marine research still lacks a national strategy of cooperation between public research and the private sector, and the Blue Growth Cluster promoted by the Ministry of University represents a unique opportunity to fill this gap. The statement of the G7 Ministers of Science (Tsukuba 2016) indicates as one of the top priorities for international research "The future of the seas and oceans", whose health is threatened by multiple anthropogenic impacts, climate change, marine litter (plastic) and pollutants. The development of ongoing infrastructures such as EMBRC (European Marine Biological Resource Centre), EMSO (European Multidisciplinary Seafloor and water column Observatory), LifeWatch and others will offer unprecedented opportunities for top-level research. In this framework, the Stazione Zoologica Anton Dohrn in Naples (SZN), recently ranked within the 20 most influential research institution in the world, can have a central role as a model of international scientific cooperative research in the fields of marine biology and ecology.

Analysis of global "Research Trends" over the last 10 years clearly shows an exponential growth of research, led by Life and Environmental sciences. The OECD regards the sustainable development of the blue economy as one of the most important sectors of the global economy. Marine biological research is thus one of the fastest growing research sectors with great potential for further expanding in the future. Amongst the most promising research sectors, outlined in the present documents of Vision for the years 2021-2030 we include: i) Global dimensions of marine basic and applied ecological research; ii) Exploration of marine biodiversity, including the study of marine genomes, microbiomes, holobionts and species evolution; iii) Global impacts of single and multiple anthropogenic activities on marine ecosystems; iv) Novel impacts: new contaminants and their effects on marine ecosystems and humans; v) multidisciplinary research; vi) identification of marine resources across habitats, including extreme environments, for eco-friendly and eco-sustainable biotechnological applications; vii) Development and provision of conservation/ management tools and approaches to support nature and people.

The effort provided by SZN can be summarized as "Knowledge from the Sea, knowledge for the Sea", with the aim of "Providing innovative research for discovering, valuing, protecting and restoring marine life" for sustainable development, coherently with the new launched UN Decade of "Ocean Science for a Sustainable Development".

Aims for the years 2021-2030 include the increased ability to develop a holistic and cross-cutting approach to science, at all levels of biological organization, from molecular processes to ecosystems, from viruses to whales, from the poles to the tropics, at different scales of complexity, including deep-sea and extreme environments.

The SZN intends to expand collaboration with other disciplines (including socio-economic sciences and scientific communication), while enhancing its multidisciplinary expertise in the main fields of Marine Biology, including Biodiversity exploration, Marine Omics, Eco-Evo-Devo, Biological adaptation and evolution, Animal Cognition, Marine Biotechnology, Global Change

impacts, Conservation & Ecosystem Based Management and Renewable and sustainable Energy. SZN aims to develop innovative experimental and observational studies, able to include fully diverse biological and omic components for understanding biodiversity and functioning of Mediterranean and other marine ecosystems, their health status and vulnerability. Research priorities in the Mediterranean in the next decade are: i) Integrated experiments in the field and under laboratory conditions; ii) Mapping biodiversity across habitats also through innovative robotics iii) Development of models and collection of field data for understanding biodiversity and ecosystem functioning; iv) Research on invasive species; v) Conservation and rebuilding of endangered marine species and ecosystem restoration, along with goods and services they provide to people; vi) Speciation processes; vii) Deep appraisal of marine microbial diversity to discover novel species, genes, and enzymes; viii) Model organisms for fundamental and applied research; ix) Identification of key metabolic processes from marine organisms that might prove useful for several biotechnological application; x) Novel models for the sustainable use of marine resources xi) Contribution to the implementation of management models in the framework of Marine (maritime) spatial planning and according to an ecosystem based management. These sectors need the development of a network of bio-ecological observatories, enabling the long-term analysis of changes of marine ecosystems.

The priority for future development is also the establishment of a true marine research network of SZN marine stations, which reflects the initial objective of Anton Dohrn of creating several "zoological stations" conducting research in different habitats and seas. This reflects the PNR 2021-2027 and is now a real opportunity, as besides the historical seat of Naples and the laboratories in Ischia, the Stazione Zoologica has developed new seats in Messina-Palermo (Sicily), Amendolara (Calabria)) and Fano (Marche), which together provide access to different seas and ecosystems, including the Straits of Messina, the Adriatic Sea and Ionian Sea. It provides an unprecedented opportunity for becoming the first network of Mediterranean observatories to monitor relevant ecological variables, ready to provide early warning environmental change, with each node of the network nested in critical areas of the basin. It will be also an opportunity to realize models of monitoring and governance allowing to guarantee marine sustainability (Horizon Europe n. 36)

Meeting the objectives of scientific excellence and international leadership requires an appropriate critical mass to compete with the top scientific institutions worldwide. The guiding criteria for recruitment in the years 2021-2030 will follow those developed at EU level in terms of full transparency, maximum dissemination of information and guarantees of equal access to all candidates from Europe and beyond.

SZN aims to further increase Italian competitiveness in basic and applied marine research in the European context. The SZN conducts continuous monitoring of scientific performance based on objective criteria and promotes merit in all forms according to international standards. Based on analyses conducted on the Web of Science for the period 2010-2020, SZN contributes for ca 10% to the total number of scientific publications in marine science produced at national level and is currently the Italian institution with the greatest scientific expertise worldwide in the field of Oceans and seas (Expertscape 2020).

SZN scientists are committed to further improve their research outputs in terms of excellence and scientific impact. In this framework, the exponential increase in the number of national and international projects we experienced over the last 5 years represents a very promising result, conducive to stronger scientific production. Calling for an increase in funding from competitive calls, improving SZN infrastructure, increasing the participation of researchers in public communication of science, encouraging the hiring of highly qualified personnel, and promoting ongoing training and career development.

The SZN contributes to the consolidation of the European Research Area (ERA) and is committed to an increasingly competitive approach and to the merit-based acquisition of private and public funding. The recruitment and promotion of the best performing researchers will be crucial to attract and engage the human capital necessary to achieve the ambitious results envisaged and to foster innovation and leadership of research.

The Stazione Zoologica in the next decade will be also committed to consolidate its service provisions to provide easy and cost-effective access to cutting-edge infrastructure and facilities for research. This will be done also through the European Research Infrastructure (ERIC) EMBRC (European Marine Biological Resource Centre), which is expected to increase the SZN leadership in Italy and the overall impact of Italian marine research at European level. SZN will strengthen its research infrastructure through: i) investing in new technologies of high complexity to allow innovative investigations; ii) completing and strengthening existing infrastructures to make them up to date and competitive in the light of new research developments; iii) creating research hubs allowing SZNSZN researchers to access and investigate diverse marine habitats, thus increasing the potential development of some key regions in Italy.

The SZN aims to become the national reference point in the field of marine biological research and to further develop relationships with the private sector for improved dissemination and capitalization of its research results. The Stazione Zoologica is also renowned as the oldest marine Aquarium in the world still open to the public, which supports the outreach and the educational programmes for children and higher education students. The Aquarium has been restored and together with the new Darwin-Dohrn museum will represent a key tool for the dissemination and outreach of the research activities and history of the Stazione Zoologica. These infrastructures, along with the Turtle Point (the largest Research and Rescue Centre of the Mediterranean, in Portici-Naples) and the Marine Farm of Bagnoli (planned to become the largest European Centre for the production of marine organisms for research and industry) will be managed by the Department of Animal Conservation and Public engagement and will provide a strong platform for communicating the strategic importance of the marine research undergoing in the institute. SZN is very active in public outreach and the plan is to further increase dissemination of scientific information using public channels (news broadcasts, television programs dedicated to the environment, international programs, and newspaper articles and media to increase local, national and international awareness of the importance of the marine environment and the need for its protection.

The Stazione Zoologica hosts students for doctoral and master theses, training stages and specialization courses, either within the frame of the International masters course in Marine Biology in collaboration with the University of Naples Federico II, and in collaboration with several Italian and foreign Universities. SZN also provides hosts a PhD degrees acting as Associated Research Center of the Open University of Milton Keynes, UK. These higher education activities are a priority for the next decade in order to train a new generation of top scientists who could represent suitable candidates for future positions as researcher or technologist. The Stazione Zoologica also intends to further develop the provision of summer schools and advanced courses, contributing to new paths in high-level international coordination with international networks and European Research infrastructures (RIs).

Flagship Statement

Seas and oceans represent a global priority not only in economic terms but also for wellbeing of a large portion of the global population (see also Global Ocean Science Report, UNESCO IOC). The United Nations' Sustainable Development Goal #14 for 2030 (i.e., Conserve and sustainably use the oceans, seas and marine resources) represents one of the most important global missions.

The UN Decade of *Ocean Science for Sustainable Development* represents a once-in-a-lifetime opportunity for Nations to work together "to generate the Global Ocean Science needed to support the sustainable development of our shared ocean." The UN Decade statement: "The Science We Need for the Ocean We Want" is thus a cornerstone of the Stazione Zoologica targets for the present document of Vision 2021-2030. This means an unprecedent effort in accelerating Marine and Ocean Science for collecting new data and identify the solutions to protect human and ocean's health in a *One-Health* perspective.

The Stazione Zoologica in Naples (SZN), also thanks to the development of new territorial laboratories at a national scale, offers access to a number of different habitats and ecosystems and thus unique opportunities to discover diversity, complexity, functioning and evolution of marine organisms. Anton Dohrn intended the Stazione in a global perspective, and the seat of Naples was intended as one (the first) of many Marine Stations enabling scientists to conduct their research on different habitats and seas, and to disclose the secrets of life hidden in the blue planet. Charles Darwin inspired Anton Dohrn to embrace a new vision of the of evolution of life based on marine biology and ecology. As a visionary science manager, Anton Dohrn dedicated the Stazione Zoologica to search for the proof of evolution and of the origin of life in the oceans. Anton Dohrn was also a pioneer of scientific dissemination and public engagement on our oceans and thanks to this vision the Stazione Zoologica has always been a place where science meets oceans (and their enormous richness of physical, chemical and biological knowledge) with a multidisciplinary and holistic approach. For the reasons outlined above, the SZN has always been as the center for international collaborative networks.

Adopting a 4D perspective (i.e. dimensions of space and time), the SZN extended the study of the Mediterranean Sea to the Atlantic, Pacific and Southern Ocean for exploring marine biodiversity and ecosystem functions, as well as the immense variety of biological and physiological adaptations of the organisms inhabiting our seas. The SZN has given important contributions to zoology, botany, ecology, embryology, physiology, biochemistry, oceanography - to mention some. The SZN has also been at the center of important innovations for the development of research methods. This "permanent congress of scientists" the SZN has served as an example for many other institutions worldwide.

The "Stazione Zoologica Anton Dohrn" is nowadays the **"National Institute for Marine Biology, Ecology and Biotechnology"**, a Public Research Institution (one of the 14 of the Italian Ministry for University and Research) exclusively devoted to marine biology and associated disciplines, with the main headquarters in Naples and territorial seats in other regions on the country.

As such the SZN faces the competition and challenges offered by our times, and views the next decade as the years during which its contributions in innovation, discoveries and public engagement will further expand for the ultimate goal of educating our Society to a sustainable partnership with our planet and our Oceans.

A short overview

Marine research is growing exponentially, either because of the discovery of new research areas or for the development of innovative technologies and approaches. Coastal marine ecosystems provide more than 60% of the economic value of goods and ecosystem services offered by Nature and People, and provide a significant contribution to national economies, both in advanced and emerging countries. The oceans cover more than 70% of the planet and about half this area lies outside national jurisdictions. Italy has more than 8000 km of coastline and 40% of its territory is “underwater” (territorial waters). As stated by the PNR 2021-2027, the sustainable use/exploitation of marine resources represents the new frontier for international scientific, industrial, economic, and diplomatic interaction amongst countries.

Renewable energy sources and non-renewable resources (such as mining), along with the discovery of new molecules, bio-based products and bio-inspired solutions of biomedical or industrial interest, fishing, maritime transportation, tourism, and also the effect of ongoing climate and global change, depend critically on the oceans and on "marine resources". The potential and prospects for economic growth and employment in this sector largely exceed those of any other industrial sectors. The European Union recognizes the critical importance and the priorities of this sector and is devoting resources to the *Blue Economy*. In the "Blue" as in many other fields, Life Sciences will represent the sector with the highest perspectives of innovation and the strongest interests for the use of resources for the next two decades. Marine biological research has the advantage of combining “Life Sciences,”, “Environmental Sciences” and “Social sciences” in a unique way, thus providing a cultural bridge between the development of fundamental knowledge and solutions for sustainable growth of our prosperity. The global context sees a growing population, with increasing demand for food and new resources to ensure welfare, sustainable development and environmental quality, which are priority objectives in the EU Marine strategy Framework Directive.

However, pressing environmental issues, related to global change and direct anthropogenic impact, are causing unprecedented loss of marine biodiversity and habitats, and consequently of the related ecosystems’ goods and services. Marine research offers efficient ways to respond to the emerging demands of our time by providing knowledge and new opportunities and identifying, for the complex problems we face, solutions that are also sustainable for future generations. Answering these social, scientific and cultural "challenges" in national and international contexts is the pillar of the activity of the Stazione Zoologica Anton Dohrn’ vision for the years 2021-2030.

Looking back to plan ahead

The Stazione Zoologica Anton Dohrn in Naples (SZN) founded by the German zoologist Anton Dohrn in 1872, is the first research institution created around the idea of a research infrastructure open to scientists from anywhere. It has been recognized as a "*Special Scientific Institution*" of public interest by Italian Law (no. 886 of 20 November 1982) and became a Governmental Research Institute under the control of the Italian Ministry of University and Research (MUR) in 1991. Its history and its location in the Gulf of Naples, one of the regions encompassing the greatest marine biodiversity in the world, have given this institute a key role in the Italian and international marine research context. Throughout its history, the SZN has maintained an international profile. Due to its vocation for marine research. Dohrn believed that the secrets of evolution could have been revealed by the study of marine biodiversity. The founding of the Stazione Zoologica in Naples was a choice dictated by the extraordinary biological richness and nature of the area. The decision came in 1870 and the creation of a public aquarium, one of the first in the world at the time, was a strategic invention to help fund research. The first building (1872) could accommodate twenty researchers; the aquarium opened to the public on January 26, 1874. In 1885 and in 1905 the building was expanded, increasing the overall space for research labs and infrastructures more than three times. The Stazione Zoologica of Naples was the first, by date of foundation, non-academic Institution devoted to Marine Research. It is among the most influential research organizations in the field of marine biology and ecology at the international level. With the original mission of providing access to independent scientists and offer them all facilities they may need to put a "bench" on the side of the sea and of marine organisms, the Stazione became historically the most famous place for high-level biological and marine research in the world.

Past editions of the SZN Document of Vision

Vision 2010-2020 - It was the first vision document produced by the SZN. It was based mainly on the importance and modernity of marine biological research, recognizing its potential development in various areas of application, such as the protection and conservation of the environment, and the management of fisheries and aquaculture. The Vision recognized the involvement of the SZN in the study of marine biodiversity and recalled that the "co-existence of biological and ecological research is essential for an understanding of the marine environment and of the basic mechanisms governing ocean functioning". The document also highlighted the ability of SZN to conduct research at different levels of complexity with expertise in different disciplines such as genetics, cell and developmental biology, physiology, ecology and oceanography, and to explore and develop methodologies and experimental protocols that represent important reference for marine research and that can be transferred to other systems and/or organizations. Finally, the document emphasized the potential of national and international interactions for SZN, with its ability to provide "access to marine organisms to the international scientific community", as well as advanced training. The document reported the SZN role as project coordinator of the preparatory phase of the infrastructure EMBRC (European Marine Biology Resources Centre), a network of research facilities dedicated to Marine Biology, and able to provide, in the future, access to the use of organisms and marine systems for researchers worldwide.

Vision 2015-2025 - The Vision Document 2015-2025 proposed the key topics for a ten-year research plan, organized in three main research lines: 1. Development of an integrated approach to the study of marine biodiversity; 2. Marine organisms as a source of knowledge; 3. Development of functional ecology. The development of an integrated approach to the study of

marine biodiversity was promoted. The previous Vision document identified possible 'gaps of knowledge' about the “biological mechanisms that underlie: i) the interaction between these organisms and their environment, ii) the interactions and trophic behaviors governing interactions among organisms iii) the adaptive processes that allowed the evolution of life in the sea". It outlined the key role of the use of model organisms in current marine science.

SZN is aware that the mission of facing global and local changes requires a combination of different approaches and that experimental ecology can have a critical role in the understanding of patterns of distribution of marine biodiversity and of the processes shaping marine biodiversity in this rapidly evolving time. The “development of a functional ecology” was indicated as crucial to recover the “delay of knowledge” on the functioning of marine ecosystems with the use of laboratory and *in situ* analysis and modelling. A consolidation of the role of the Long-Term Ecological Research sites was expected. SZN was committed with MareChiara (LTER-MC) for the systematic observation of the coastal ecosystem in the water column, including -omic analyses, with Lacco Ameno, Ischia (LTER Lacco Ameno, Ischia) for the observation of long-term trends in the *Posidonia oceanica* system, and with the site characterized by natural emissions of CO2 of volcanic origin (Castello Aragonese, Ischia),), that gives access to a ‘natural laboratory’ on the “effects of acidification on marine organisms at different hierarchical levels of biological complexity”. Another objective that was highlighted was the importance of identifying new bioactive substances from marine organisms.

International scientific research trends

As has become increasingly evident in recent years, basic and applied research should translate into solutions enabling the progress of humanity and improving the living conditions of human and non-human species on the planet.

Seas and oceans contain more than 98% of the world’s water resources and play a key role in the water cycle. It is estimated that over 50% of energy and mineral resources are stored in the deep ocean and oceans can be the main source for renewable energy. The marine environment occupies over 90% of the planet’s biosphere, regulates the global biogeochemical cycles, produces about 50% of the oxygen we breathe and sequesters about 50% of the carbon dioxide produced by man. Moreover, the global ocean provides basic food resources, especially in developing countries, and the production of more than 30% of the proteins available for human consumption. In other words, the “*Future of the Seas and Oceans”* is one of the top four missions (along with “Global research infrastructures”, the “Neglected Tropical Diseases and Poverty Related Diseases” and “Open Science - Big data”) that involve humanity in the next millennium. Moreover, a not sustainable use of marine resources and a deterioration of marine habitats, can have strong effects on the future economies of most countries, impacting on the fields covered by all the other targets indicated above.

Analysis of the global "Research Trends" of the last 10 years clearly shows exponential growth in the output of scientific research (expressed in terms of publications and scientific products). The impressive ability to generate data is leading to a huge flood of information. The ability to process this information and its transformation into knowledge remains limited, as these processes depend on human endeavor rather than scientific instrumentation. These elements allow understanding how great is the potential of data production, digitalization, storage and sharing by technological development, with the training and recruitment of researchers who can exploit these for "scientific progress and re-use".

Among the key research areas contributing to the development of global knowledge in the last decade, two appear to grow at particularly high rates: 1) Life sciences and 2) Environmental sciences and their relevance for human wellbeing. Marine research conducted at the Stazione Zoologica lies exactly at the intersection of these two areas of global research.

Analysis of marine research in the period 2010-2020 using the Web of Science, indicates a 10% growth rate per year in terms of both products (publications) and citations. In the last decade, most advanced countries doubled their annual productivity.

Within the field of marine research, the most important subject area is that of Marine Biology, with over 42% of products, followed by environmental sciences (with a strong ecological component) and finally oceanography and geo-sciences with less than 20% each. In the Marine Biology area, the sectors that contributed mostly to the scientific production of the last decade were: 1) marine biology and ecology (over 50% of the products of the area); 2) microbiology and biotechnology (20%) followed by 3) marine biochemistry (about 7%); 4) fishing, 5) evolutionary biology and 6) conservation biology with about 5% each.

The trend of the last decade indicates that even among these scientific areas, the growing sectors are those related to integrative, ecological and multidisciplinary sciences (2500% increase), and conservation (increase of almost 300%), followed by toxicology, fishery biology and microbiology, with increments of 100%.

The results of this decadal analysis at a global scale, clearly shows that marine biological research (*sensu lato*), in its various disciplines/areas, is one of the fastest growing research sectors with the greatest potential for further development.

Global priorities in marine research are:

1. Fostering global dimension of marine biological and ecological research.
2. Increasing relevance of the targets of the Sustainable Development Goals (SGDs) with a special focus of SDG 12-14.
3. Increasing impact of EU directives and Agenda, incorporating scientific information into decision-making and supporting policy implementation.
4. Advancing our knowledge on the impact of global changes and human activities on marine life and ecosystems, taking also into account multiple stressors, including by-products of human activities.
5. Expanding the potential of eco-friendly and eco-sustainable biotechnological applications.
6. Increasing cross-disciplinarity (biological, ecological, geological, physical, technological, microbiological, bio-medical research) for a holistic approach to the study of the marine environment.
7. Applying Global Safety and One Health Approach including the oceans.
8. Searching for Innovative solutions for marine sustainability missions, fostering scientists, policymakers, and funders involvement in interdisciplinary research transcending disciplinary boundaries.
9. Improving the adoption of principles: i. support female leadership; ii. forge partnerships outside the academia; iii. develop impact-based performance metrics; iv. focus on long-term funding; and v. cultivate a visible brand.

Vision for the years 2021-2030

Following the current prescriptions given by the EU Mission Board on Healthy Oceans, Seas, Coastal and Inland Waters, the **Mission Starfish 2030** (Restore our Ocean and Waters by 2030) has been proposed. This aims to know, restore and protect our ocean and waters by 2030, by reducing human pressures on marine and freshwater environments, restoring degraded ecosystems and sustainably harnessing the essential goods and services they provide (https://ec.europa.eu/info/publications/mission-starfish-2030-restore-our-ocean-and-waters_en). Inspired by the shape of the starfish, five overarching objectives for 2030 have been identified:

a. Filling the knowledge and emotional gap,
b. Regenerating marine and freshwater ecosystems,
c. Zero pollution,
d. Decarbonizing our ocean, and waters
e. Revamping governance.

These five objectives are mutually supportive and taken together, Mission Starfish 2030 will aim to enable the restoration of the water cycle as a whole. For each of the five objectives, a set of ambitious, realistic and measurable targets have been defined. They specifically address the actors, activities, tools and systems that need to be called upon to reach each objective. These are considered the indispensable components of a holistic approach to systemic change. Conservation efforts should be incorporated within an Ecosystem Based Management framework and should address the entire ocean and water system with a holistic approach, if they are to succeed. The future we must collectively create will be defined by how we perceive ourselves to be in relation to the natural capital of our oceans and waters, guiding the choices we now make.

The 2030 Agenda for Sustainable Development, adopted by the United Nations in 2015, identified 17 Sustainable Development Goals and 169 targets. Goal #14 "Life below water" aims to "*Conserve and sustainably use the oceans, seas and marine resources for sustainable development*". The SZN research priorities strongly align to this goal, including other Goals, such as #13 (Climate Action - "Take urgent action to combat climate change and its impacts").

The Stazione Zoologica achieved rapid growth in terms of personnel over the last 5 years. This trend should continue to be consolidated for the next decade, thus increasing the leading role at national and international level as reference for its expertise in the field of marine science and particularly of marine biology and ecology.

We believe that marine biodiversity is the greatest source of knowledge yet unexplored of the Planet and that further study is required to provide a major contribution to the advancement of human knowledge and acquiring new tools for sustainability.

The development of new technologies and expansion of current approaches allow us to study biodiversity at all levels of organization. The scientific outcomes and continue increase in SZN research capacity will allow to stimulate the growing capacity of turning research into data, and data into knowledge.

The SZN wants to seize this opportunity, challenging the inter-disciplinarity 'priority' by enhancing its expertise and further expanding the leading role in a global collaborative network. For the next decade we identify the following Research strategic areas.

SZN Research Strategic areas for the 2021-2030 decade:

a) Characterization of molecules, structures, physiology, adaptation, threats, resilience of marine organisms and assemblages to explore their capacity to adapt to extreme environments and conditions.
b) Genomics of marine organisms applying an eco-evo-devo integrated approach.
c) Exploration of the mechanisms of macro and micro-evolution from genomes to epigenetics epigenomes, from species to communities integrating different approaches.
d) Exploring and analysis of patterns and processes of marine biodiversity, adopting novel integrated, and holistic approaches.
e) Understanding impact of Global Change through marine observatories for answering to strategic needs.
f) Improve the conservation of marine biodiversity through an ecosystem-based management approach.
g) Exploiting marine organisms' potential for industry, food and medicine for developing eco-sustainable marine biotechnologies.
h) Supporting the eco-sustainable development of renewable energy resources from the sea.

By focusing on the strategic areas listed above, we will also incorporate the Blue Economy, exploring marine biotechnology for industry, food, medicine and biotech for bioremediation research, and explore alternative and renewable sources of energy from the sea.

a) Characterize molecules, structures, physiology, adaptation, fate, resilience of marine organisms and assemblages to explore their capacity to adapt to extreme environments and conditions

Marine environments offer a diversity of habitats and microhabitats vastly exceeding that of land environments, leading to adaptive radiation and evolution of great phenotypic variability. For this reason, the seas offer an invaluable and largely untapped reservoir for comparative and evolutionary studies, aimed at describing the adaptations that enable survival in these habitats.

Extreme environments provide extraordinary opportunities to better understand: i) the limits of life; ii) the adaptation to extreme conditions; iii) the mechanisms of symbiosis; iv) the functioning of molecules and exploring for products of interest for pharmaceutical, or other industrial sectors; v) the effects of environmental forcing in structuring marine communities in the future.
The Gulf of Napoli offers unique opportunities to study extreme environments, from the acidified site of Ischia - Castello Aragonese capable of simulating the pH conditions in year 2100, to the deep-anoxic hypersaline basins that host unique life forms that can live in the absence of oxygen and light. Of particular relevance are the studies of active hydrothermal vents, only recently discovered in the Tyrrhenian Sea, and cold seeps with new communities whose operation is based on oil spills. Hypersaline environments, including brine pools, are extreme environments promoting the growth of those species able to cope with osmotic pressure. Hypoxic zones will be of increasing interest for their expansion predicted as a result of global climate change. Finally, the deep sea represents the most unexplored portion of the Planet. Here high pressure and low temperatures provide a unique opportunity to investigate the adaptation of marine organisms to these extreme conditions. This environment offers important opportunities also in the Mediterranean from the Ligurian sea to Gulf of Naples and their canyons. Studying organisms from the deep sea may provide unique insights also in mechanisms

promoting health and longevity. The study of these systems, whose operation is typically simpler than others, would allow the understanding of the mechanisms that structure biological communities in extreme environments. The ultimate goal will be understanding the complex molecular interactions among organisms and between organisms and the environment, exploring their physiological adaptations at individual, population and community levels, thanks also to metatranscriptomics and metagenomics which allow the simultaneous analysis of the biodiversity and function of the genes.

The mission for the years 2021-2030:
- to identify biochemical, molecular, cellular, physiological, ecological and evolutionary mechanisms that allow life in extreme conditions.

b) Genomics of marine organisms for an eco-evo-devo approach

Marine organisms are an important source of fundamental biological knowledge and of new models for experimental research that have contributed to key steps of modern science (e.g., tetrodotoxin from pufferfishes - Tetraodontidae - and conotoxin from marine snails). The Nobel Prizes Alan Lloyd Hodgkin and Andrew Huxley studied the axon of the Giant Squid (1963), Keffer Hartline studied the photoreceptor of Limulus polyphemus (1967), Martin Chalfie and Roger Y. Tsien studied the Green Fluorescent Protein (GFP) from the jellyfish Aequorea victoria (2008). The huge genetic diversity of marine life and of metabolic processes, control systems and production of compounds provides an extraordinary genetic potential that is largely unexplored. High-throughput sequencing technologies are nowadays commonly used for decoding and cataloguing marine genomes and the genes they encode. In the future, transcriptomic, metagenomic and metatranscriptomic approaches will be applied to all marine organisms.

The variety of organisms used as "models" in research is currently undergoing a massive expansion. The SZN aims, on one hand, to enhance the accessibility of the experimental marine species currently in use, on the other to create a new catalogue, diversified by type of use, with a new generation of species that can extend scientific research in new directions. The SZN is in a unique position in the national and international context, to offer availability and accessibility to the infrastructure and advanced technologies required for conducting experimental research. At present SZN maintains several marine models, including the protochordate *Ciona robusta*, echinoderms such as sea urchins (*Strongylocentrotus purpuratus* and *Paracentrotus lividus*), and starfish (*Patiria miniata*, *Astropecten aranciacus*), the cephalochordate amphioxus (*Branchiostoma lanceolatum*) and the mollusc *Octopus vulgaris,* just to name a few. Other models such as the hydrozoan *Turritopsis dohrni* (the immortal jellyfish) have also been studied at the SZN. The refurbishment and expansion of the Aquarium will also provide opportunities to maintain vertebrates such as cartilaginous- and bony-fishes that are of particular interest for embryological, immunological and neurobiological studies. For example, the eggs of the small and abundant galeomorph shark *Scyliorhinus canicula* can be easily obtained and maintained to study its embryonic development. In addition, the marine environment contains some of the most basal and contextually highly adapted/specialised forms of life at the neuro-sensorial level, such as the diversified group of cartilaginous fish, strongly represented in the Mediterranean. They represent the earliest branch of the vertebrate phylogenetic tree and the comparison among cartilaginous and other vertebrate species is a strategic approach to unravel novel mechanisms and genes, or the convergent/divergent role of some conserved pathways as well,

especially in the context of neurodegenerative processes, neuro-regeneration and aging. Indeed, the longest-lived organism currently known, the Greenland shark *Somniosus microcephalus*, is a dweller of the deep sea, and some shorter-lived cartilaginous species inhabit the deep-sea of the Mediterranean canyons in Ligurian and Campania regions (*Squalus acanthias, Etmopterus spinax*), representing ideal comparative species in this context. SZN is strategically positioned in key areas such as the canyon system of the Gulf of Naples, that, together with the unique upwelling events along the coasts of Sicily and Calabria regions caused by the peculiar regime of strong rising sea currents through the Messina strict, offer scientists easy access to meso- and bathypelagic species characterized by adaptations to this extreme habitat. Housing some of these animals is extremely complicated (or impossible), however physiological, behavioral and metabolic data collection, by underwater videorecording and the use of extremely specialized instrumentations can be developed at SZN, and their integration with the growing available genomic datasets on marine organisms will offer a solid base for comparative studies.

The use of a large variety of organisms will also be of fundamental importance for understanding the mechanisms that underlie human diseases. The high accessibility of these experimental organisms makes them particularly suitable for studying gene regulatory networks underlying cell differentiation, fertilization, stem cell biology, morphogenesis, regeneration and aging, both in physiological and in pathological conditions.

The use of marine models allows us also to investigate the effect of the environment on development and evolution. The integration of research from developmental biology and ecology into evolutionary theory has given rise to the ecological evolutionary developmental biology (Eco-Evo-Devo), which integrates the developmental symbiosis and plasticity of the genetic accommodation and niche construction. Developmental symbiosis can generate particular organs, can produce selectable genetic variation for the entire animal, provide mechanisms for reproductive isolation, and may have facilitated evolutionary transitions. Such non-genomic mechanisms of selectable and heritable variation will be investigated with specific reference to the model organisms utilized at the SZN and maintained in the new facilities of the marine farm.

The discovery of organism-specific biological processes and genetic pathways associated with them, will lead to the enrichment of potential "models" and will encourage the search for alternative methods for reducing the number of living organisms to be tested. The development of cell and organo-typic cultures of marine species will allow understanding of fundamental biological processes at the cellular and sub-cellular level, thus extending the potential of stable cell lines and stem cells and expanding research capacity in biomedical and ecotoxicological fields.
The Marine Farm (in Bagnoli) will be an outstanding facility for marine model organisms, including several facilities to host laboratory animals and produce massive cultures of aquatic animal models that will be available to scientists from all over the world. The Marine Farm will also include large aquaria for overhanging research and laboratory tanks where model animals will be exhibited to the public.

Genome sequencing is biased towards few taxonomical groups such as multicellular organisms and microbes of interest such as pathogens or parasites. Subsequently the proportion of genomes sequenced from marine microbes is typically lower than average. For example, diatoms, dinoflagellates and Haptophyta account for most marine primary production in the water column and very little genomic information is available from these taxa. Marine microbes exhibit a broad genetic and likewise metabolic diversity encompassing all the three domains of life, archaea, bacteria and eukaryotes. Archaea have been mostly described in extreme environments

although they are also present, and thought to play a non-negligible role in the oxygenated water column. Bacteria encompass a huge variety of metabolisms, carrying important aerobic and anaerobic processes and driving the cycling of a number of chemical elements eventually promoting the diffusion of nutrients and trace metals in the water column and in the sediment (e.g., iron and manganese reduction, nitrification, nitrogen fixation). Microbial eukaryotes possess a narrower metabolic versatility although they comprise both phototrophic and heterotrophic organisms and are also widespread in the water column and in the sediment. Eukaryotic microalgae are responsible for most marine primary production being thus crucial for both the food chain and the carbon cycle. Over 99% of marine microbes are uncultured, with key features of their life cycle and metabolism unknown. Different strategies aimed at bringing new species in culture are indeed required, in addition to a deeper sequencing of microbial genomes. Coupling massive culturing efforts with large genome sequencing might improve our knowledge on marine microbes in the coming decade. There is no doubt that the next decade will see a huge increase of genomic resources, with the production of new high-quality genomes and transcriptomes of marine organisms completely sequenced and functionally annotated. In these large-scale studies there will be the development and promotion of systems and methodologies aimed to study the gene function, similar to the approaches used in the traditional model organisms (banks of mutants, gain and loss of function, methods to study protein-protein and protein-DNA interactions).
In particular, the possibility to study gene functions will be crucial for understanding the role of a fraction of those sequences that show no homology with any known gene, and to define the cellular context in which they act. It will also be possible to select genes with specific functions and study the consequences of their disruption in the cell and in the interactions with other components of the ecosystem of origin, with the real prospect of discovering new mechanisms or new combinations of known strategies. The possibility of carrying out genetic manipulations also results in the possibility to produce transgenic lines for application purposes. Attempts in this direction are, for example, performed on microalgae, promising source of various compounds, or ecto-parasites copepods that pose serious threats to aquaculture.

The missions for the years 2021-2030:
- to identify novel marine organisms to replace the traditional species for the study of evolution-
- to complete genome sequencing of key-marine species and model organisms of the Mediterranean for discovering and valuing their characteristics and potentials.

c) Exploring the mechanisms of macro and micro-evolution in the Anthropocene from genomes to epigenetics, from species to communities integrating different approaches

Anton Dohrn was a fervent evolutionist who firmly embraced Darwinian theory and promoted the comparative study of animal embryological and morphological diversity as essential for understanding the processes governing biological evolution. Marine ecosystems are now facing global and local threats and environmental conditions are changing at unprecedented rate. In this context, SZN scientists study the response to global and local human driven impact and stressors, and micro-evolutionary changes from single organisms to communities. Studies integrate organismal biology, physiology and ecology with population genetics and dynamics, through advanced genetic/genomic approaches.

The results of several years of experimental biology made evident that the differences among individuals living in nature are far larger than those detectable in the laboratory, which undergo frequent inbreeding. The study of marine organisms confirmed that the diversity of the processes at various levels of biological organization is far greater than in terrestrial organisms. This body of evidence makes even more pressing the study of the evolution of the genomes in their complexity (individual, population, behavioural or ecological).

Ecological processes are inter-connected and the complexity of their interactions must be investigated, considering, for example, the selective forcing factors operating on the multiple stimuli to which organisms and populations are continuously subjected, in part also due to increased anthropogenic pressures.

Various "stressors" affect important biological processes (fertilization, development, physiological and behavioural responses, interactions between species and between organisms and their environment), altering the ability of species to survive. 'Stress' can be considered an evolutionary accelerator because it can alter specific molecular processes resulting in an increase of genomic mutation frequency. Also transmissibility, through the gametes, of stress responses by epigenetic modifications acquired following the interaction with the environment, in ways independent from the mutations, adds another layer of complexity that appears to contribute significantly to the success of a population.

SZN will investigate these aspects, exploiting the present historical context of "global change" and increased pressure due to multiple stresses. In particular the study of fertilization, development, evolvability and behaviour with the most modern approaches to molecular and cell biology, functional genomics and bioinformatics, neuroscience and behavioural biology will open new frontiers to the understanding of the evolutionary process. The multi-scale and multi-system studies enable an integrated approach to biological evolution. New technologies are enabling the study of evolution at different levels: i) reproductive capacity, development and differentiation; ii) the variability of genomes and components that enable the evolution of the novelty and complexity, particularly with regard to the non-coding and mobile part of the genome; iii) biological and behavioural plasticity and genetic and epigenetic processes that allow diversification; iv) plasticity to stressors, allowing species resilience to environmental changes; and v) the evolution and diversification of proteins and metabolites involved in the fundamental processes of aggregation, mating or predation in model species.

Habitat-forming species, such as seagrasses and some seaweeds, rank among the most valuable ecosystems on earth and sustain biodiversity and ecosystem functioning. Seagrass meadows, for example, fulfill a series of important ecosystem services worldwide, including oxygen production and CO2 sequestration. Although they occupy only 0.1% of the ocean surface, it is estimated that seagrasses can store 27–44 Tg organic carbon (C_{org}) year–1 globally, corresponding to the 10–18% of the total carbon stock in the oceans. Moreover, habitat forming species sustain biodiversity and ecosystem functioning in harsh environments through the amelioration of physical stress. Nevertheless, meadows of the Mediterranean species *Posidonia oceanica*, one of the most valuable seagrass species worldwide, are disappearing at an alarming rate.

Most seagrasses and seaweeds rely on clonal growth for propagating, resulting in dense and productive meadows and forests that can be genetically depauperate. Old and persistent *P. oceanica* meadows rely on mechanisms other than genetic recombination for ensuring the minimum genetic potential for fostering plasticity and allowing response to changes. The study of the genetic make-up of seagrass meadows and seaweed forests, the investigation of the role of somatic and epigenetic mutations in conferring plasticity, the full understanding of genes and gene pathways involved in the modulation of the adaptive response at a transcriptomic level,

will allow predicting the fate and anticipating the effect of different sources of impacts on these valuable ecosystems. The identification of physiological and molecular mechanisms responding to target stressors will allow the selection of a new generation of stress indicators, able to detect the organismal response before the effect of stressors will not be reversible.

The provision of new genomic resources, such as genomes, methylomes and transcriptomes, together with new population genomics approaches will further support this research line where SZN is already recognized in its leading role.

The mission for the years 2021-2030:
- to identify the genetic and molecular mechanisms, and the epigenetic and behavioural factors driving micro- and macro-evolution of marine life.
- to understand the plasticity of iconic species and habitat formers and to identify a new generation of early warning indicators of regime shifts

d) Explore and analyze patterns and processes of marine biodiversity, adopting novel integrated approaches and technologies.

The Mediterranean is a heterogeneous system that, despite its oligotrophic nature, has high diversity of marine species and high rate of endemism, making it one of the world hotspots for marine biodiversity. The basin is also among the most impacted Large Marine Ecosystems in the world due to the combined multiple stressors, such as fishing pressure, habitat loss and degradation, climate change, pollution, altered trophic state and the introduction of invasive species.

One of the priorities of SZN for the next ten years will be the study of marine biodiversity (including native and invasive species) at different hierarchical levels of organization, through integrated approaches that include genetics, genomics (NGS and metagenomics), morphology, taxonomy, ecology by experimental approaches and modelling. The evolution of biodiversity through time will be studied by exploiting platforms of long-term monitoring (decadal scale), museum collections and archives (centennial scale) and by cooperating with archeologists and paleobiologists (millennial and geologic time scales). Taxonomic research will be enhanced by morphology, phylogeny, life cycle study, physiology, and functional trait analysis for a comprehensive understanding of organisms, their relations and positioning in the ecosystem.

The integrated definition of species and their boundaries that taxonomy can provide is important for the interpretation of their distribution in space and time, but will also provide information on their bio-ecological, structural and functional differences and therefore the possibility of their exploitation through biotechnology.

The analysis of biodiversity based on molecular tools will include the analysis of Environmental DNA, which is an emerging sector of marine biology enabling the simultaneous analysis of all phyla of organisms present in one sample, based either on metagenomic approaches or meta-barcoding. The challenge is to couple classical methods for censusing biodiversity with these novel approaches encompassing the entire assemblage. This requires the implementation of current genomic databases. The use of molecular tools allows us to develop an end-to end approach, from viruses to whales, and to include the analysis of microbiomes, either associated to organisms (holobionts) and/or to specific habitats of biomes.

A future priority will be also connecting the species with their genes and genomes. Currently, in GenBank, the accuracy of taxonomic identifications is very questionable, with the risk that sequences found in an environment are used to identify species that, because of misidentification, may actually not be present. In addition, a significant number of microalgal species, especially diatoms do not have any gene sequenced. Studies coupling morphological and genetic data on living cultures are slowly filling this gap. A number of databases, that usually includes a subset of GenBank sequences deriving from better identified species, have been made available. The SILVA database includes ribosomal sequences for all three domains of life, whereas the Protist Ribosomal Database focuses on microbial eukaryotes with a significant presence of sequences from marine microalgae. Linking morphological and genetic traits of organisms will improve the accuracy of genetic databases making DNA barcoding approaches more useful. The future mission is to address the complex phenotypic and genotypic biodiversity with an integrated approach.

The missions for the years 2021-2030:
- to identifying new species and biodiversity patterns and trends
- to map marine habitats for their protection and efficient management

e) Understanding global change impacts through marine observatories for answering to strategic needs

The ongoing global warming of the oceans, accompanied by rising sea levels, by changing ocean currents and extreme climate events, the substantial loss of Arctic ice, ocean acidification and deoxygenation are problems universally recognized by the international scientific community. These changes will have direct effects on the physiology and phenology of marine species and also significantly influence their spatial distribution and ecological interactions. These changes will also have impacts on habitats and on the structure and functioning of ecosystems, while altering the connectivity between populations. These perturbations can interact with other threats (multiple stressors) exacerbating the effects and hitting not only the individual species or functional groups, but also the network of interactions in which they live. Specifically, resilience and/or resistance of marine ecosystems to perturbations depend on the degree of acclimation and adaptation of organisms, on the diversity of ecosystems and on the degree of isolation from contiguous ecosystems.

Understanding marine ecosystems and their dynamics and functions is a long-term priority of marine research. Such systems are subjected to environmental pressures acting individually or together, profoundly changing the interactions between species, the population dynamics and community structure. SZN will develop an end-to-end approach, the integration of data on varying spatial and temporal scales and the development of innovative methods and technologies aimed at obtaining an accurate and efficient measurement of the health of ecosystems. These will allow us to measure, monitor, understand and predict impacts of global change, needed for the sustainable management of oceans and coastal areas. Given the complexity of marine ecosystems, compounded with the complexity of the climate system as a whole, the commitment of the research in this area should be to:

> "*Understand the structural and functional processes at the local scale to act at the global level*".

The approach to be favored must therefore be highly integrated, systemic and multidisciplinary, have full coverage of trophic levels and functional groups (i.e., from viruses to mammals) and should investigate a large range of processes and mechanisms going from gene expression (*in situ* and in the laboratory) to regulatory mechanisms at different levels of biological organization.

The future of research and priorities in this area are:

1) ***Developing networks of biological and ecological observatories*** to:
   a) Support technological innovation to implement *in situ* biological observing systems and develop smart technologies for cost-effective automated monitoring of biological variables;
   b) Promote long-term monitoring of physical and chemical conditions, relevant to the biology (structure and dynamics of the water column, renewal of nutrients and export to deep sea, terrigenous inputs, the role of micro-nutrients, etc.);
   c) Describe the *in situ* metabolic state of the organisms (metagenomics and metatrascriptomics and other omics) in combination with a detailed description of their diversity, including identification of indicator species, at the regional level, of the undergoing change, with an emphasis on non-native species;
   d) Achieve a define the regulatory mechanisms of intra- and interspecific biotic interactions and the resulting emerging structures, taking into account the seasonal and inter-annual variability and the biological cycles of the species and their associations.

2) ***Investigating functional groups***, including habitat formers with particular emphasis on their ability to adapt to environmental local and global change, under controlled conditions in the laboratory and *in situ* so to investigate the responses of marine organisms to "multiple stressors".

3) ***Highlighting the relevance of the local vs global processes*** through the investigation of the inter-annual and decadal changes of ecosystems at a hierarchy of spatial scales.

4) ***Integrating the knowledge gained into new ecological models***, in order to assess and predict the scope and impact of the changes on the ecosystems and on society.

5) ***Investigating the stability and resilience of ecosystems***, o their functions and services in response to climate forcing across different ecological scales and exploring biodiversity variation from within species to across landscapes

In this context, the SZN will strive for greater integration of the different approaches (from observation to simulation through process studies *in situ* and laboratory experiments) in order to create a fully integrated and multidisciplinary network of marine observatories, in coordination with European and global initiatives.

The mission for the years 2021-2030:
- to develop networks of ecological observatories for integrating biological (including -omic) components into the environmental variables.

f) Conservation of marine biodiversity through an ecosystem-based management approach

The biological diversity of the oceans has an essential role for the maintenance of goods and services offered by marine ecosystems, but the pressure that human activities produce on seas and oceans has grown dramatically in recent decades. The need to preserve biodiversity has been clearly established by the European Union. The EU "Biodiversity

Strategy to 2030" stresses that to put biodiversity on the path to recovery by 2030, we need to step up the protection and restoration of nature. This should be done by improving and widening our network of protected areas (30% of the sea) and by developing an ambitious EU Nature Restoration Plan.

Appropriately designed monitoring programmes can determine the effectiveness (or otherwise) of spatial planning interventions and inform adaptive management. The exploitation of biological resources and mining, the human coastal settlements, maritime transport and climate change (among others) undermine the capacity of marine ecosystems to provide essential goods and services to people. The gradual depletion of coastal resources has led people to develop technologies for the exploitation of offshore areas previously inaccessible. All the forecast models suggest that the stressors will increase significantly in the near future, and if no measures will be taken, by 2050, most commercially exploited fish stocks will collapse.

Fishing is one of the main drivers of change in Mediterranean marine ecosystem; a key step for sustainability is to foster an ecosystem approach to fisheries (EBFM) to: i) support the resilience of the ecosystem minimizing the negative impacts of fisheries; ii) recognize the physical, biological, economic, and social interactions among the affected fishery-related components of the ecosystem, including humans; iii) seek to optimize benefits among a diverse set of societal goals. The Mediterranean Sea is one of the mostly exploited Large Marine Ecosystem of the world where a fleet of about 75,000 fishing boats. The high fishing pressure has led to a general overexploitation status of commercial stocks, with more than 80% of the stocks assessed out of safe biological limits, and an alarming decline of sharks and rays. According to the IUCN, the Mediterranean region is the area in the world with the highest proportion of threatened species of elasmobranchs, i.e., species classified by the International Union for Conservation of Nature (IUCN) as Vulnerable, Endangered and Critically Endangered. Unregulated fishing pressure represents a threat for populations making them more fragile and less resilient to other pressures and changes, and ultimately increasing the risk of collapse for the fisheries themselves.

The increasing global fish production from aquaculture will pose risk of pollution. The extraction of gas and oil is already shifting from the continental shelf at depths of between 3000m and 5000m and mining of the deep ocean is rapidly expanding. All these stressors may synergistically or cumulatively interact, depending on the dynamics of processes that are still little known, thereby eroding further the resilience of marine ecosystems. It is now clear the need to improve our understanding of the functioning of marine ecosystems and the comprehension of how they respond to human pressures.

> "*Biodiversity and the ecosystem services must be protected, valued and duly restored, for their intrinsic value and for their essential contribution to human wellbeing and economic prosperity*" (Convention on Biological Diversity, Vision 2050).

Despite the efforts to reduce habitat destruction through the mitigation of human pressures or the implementation of conservation measures, the natural recovery of coastal habitats is rare, even when the proximate drivers of loss are removed. In addition, recovery potential may be compromised by limited connectivity of the degraded system with healthy ecosystems, which could act as vital sources of propagules. In this scenario, restoration is increasingly acknowledged as a necessary path to actively trigger or accelerate the recovery of degraded coastal habitats, recognized by the recently announced UN Decade on Ecosystem Restoration (2021-2030).

Marine Protected Areas (MPAs) are crucial for the conservation of the Mediterranean Sea, since they protect biodiversity and regulate human activities. The Marine Strategy Framework Directive (MSFD) clearly defines MPAs as a main tool for implementing marine biodiversity conservation and promoting healthy ecosystems, while providing opportunities for sustainable local development. Also Natura 2000 Sites are at the core of the biodiversity conservation strategy of the EU. They are based on the Habitats and Birds Directives (EC, 1992, 2009) and do not usually include strictly protected zones, having the main target of regulating and managing human activities, contributing to an ecosystem-wide conservation with other national and supranational initiatives. MPAs play a critical role in the achievement of GES in European seas, even though it is assumed that Good Ecological Status (GES) should be attained also in unprotected areas: MPAs should be considered sentinel observatories of the effects of multiple human activities, and more broadly of the status of the marine environment as a whole.

The rapidly increasing demand for maritime space for the production of renewable sources, shipping and maritime exploration, fishing activities, aquaculture, tourism and recreation has led to the need for an integrated planning and managing approach for European waters, with MPAs implemented and integrated in a planned marine space. The Maritime Spatial Planning Directive18 2014/89/EU (MSP) works across borders and sectors and aims to ensure that human activities take place in a safe and sustainable way.

Science needs to bring together all users of the ocean on how to make informed and coordinated decisions on the use of marine resources. MSP aims to promote the Blue Economy, enabling sustainable use of marine areas and resources, taking into account social, economic and environmental aspects. Its effective implementation requires long term data on ecosystem changes associated with combinations of multiple proposed activities and the pressures they exert.
However, good ecological and environmental data collected at appropriate spatial and temporal scales are simply missing. More investments are needed on mapping the distribution and status of ecosystems, habitats and species and setting observation platforms to improve our knowledge of biodiversity, abiotic variables and ecosystem functioning. Monitoring only inside MPAs is not enough. SZN is investing firmly in this direction also in terms of innovative infrastructures (ROV, side scan sonar) to improve the knowledge about the distribution and extent of marine habitats, their integrity and potential.
Thanks to its tradition and competence, the SZN will take a leading role in documenting and understanding the changes of marine environments, building knowledge on past and present distribution of habitats, their connectivity providing a scientific basis for MPA institution and management in a MSP perspective. MSP can be a solution to the spatial management of multiple stressors and the potential for rebuilding of overexploited populations and achievement of good environmental status, as required by the EU Marine Strategy Framework Directive. SZN research will focus on enhancing restoration strategies and also developing new approaches.

The missions for the years 2021-2030:
- *to protect biodiversity and ecosystem functioning and services.*
- to support the achievements of the objectives of the Marine Strategy.
- to assume a leading role in marine conservation research in Italy
- to contribute to the targets of the UN Decade on Ecosystem Restoration.

g) Marine organisms for industry, food and medicine for developing eco-sustainable marine biotechnologies

In the context of the global economic crisis, countries are now facing complex challenges, including the supply of sustainable food, water and energy, climate change and

environmental degradation, human health and the population aging. Marine biotechnologies can give an increasingly important contribution to face these social challenges and support the recovery and economic growth, providing new knowledge, products and services, as also pointed out by the Horizon 2020 Framework Programme of the European Commission about the potential of the "Blue Growth".

Sustainable supply of healthy and high-quality marine products. Biotechnology has contributed significantly to increase production efficiency and product quality of sea food, as well as to the study of new species for intensive aquaculture. Marine biotechnologies can help in coping with the current mission of commercial aquaculture, including the control of reproduction, development, growth, nutrition, disease management, animal health, environmental interactions and sustainability. Furthermore, the loads of organic materials and the potential chemical and/or biological contamination associated with aquaculture activities can have negative impacts on the pelagic and benthic marine ecosystems, thus hampering the sustainability of this economic sector. Marine biotechnologies applied to the remediation of the marine ecosystems affected by aquaculture activities can thus help to support sustainability and represent a promising research field.

Improve welfare and human health. Marine organisms are an untapped source of secondary metabolites with interesting biological activities. One example is ilimaquinone, a sea sponge metabolite with promising anticancer and anti-SARS-CoV2 properties and that has been used in basic cell biological research. This implies that biotechnological exploitation of marine compounds of interests will require identification of their biosynthetic pathways and their "transplant" into producer organisms such as bacteria and yeast that can be grown industrially for "biofarming", as is the case for insulin, for instance. In recent years, the chemistry of natural products derived from marine organisms has received growing interest in the scientific area, with 14 approved pharmaceutical products in clinical use, and more than 20 marine natural products in various stages of clinical development (i.e., 4 compounds in Phase III, 12 in Phase II and 7 in Phase I clinical trials), especially in the field of oncology. The main challenges for drug discovery from marine biological resources are related to legal aspects (secure access to marine resources, intellectual property rights), quality of marine resources (identification and variability), and costs of drug discovery from marine natural products.

Decontaminating polluted marine ecosystems: Marine biotechnologies are playing an increasingly important role in the protection and management of the marine environment (e.g., biosensor technology for high-resolution in situ monitoring of coastal water quality, control of harmful algal blooms, the development of advanced eco-friendly antifouling products). The marine environment is an unexplored resource for the discovery of new enzymes, biopolymers and biomaterials for industrial applications. Biopolymers of marine origin will attract increasing attention from pharmaceutical industries, biomedical and biotech industry for their numerous applications ranging from biodegradable plastics to food additives, polymers, pharmaceuticals, medical dressings, bio-adhesives, dental biomaterials, tissue regeneration and 3D tissue scaffolds. New biobased products will be based on criteria of sustainability, also thanks to ecotoxicity approaches.

Identification of marine microbes for the bioremediation of degraded marine ecosystems: these include bacteria, fungi and microalgae with effective degradation/detoxification abilities, to be exploited affected by different types of contaminants (e.g., heavy metals and petroleum hydrocarbons), also through bio-stimulation and bioaugmentation.

The mission for the years 2021-2030:

- to identify new marine organisms, microorganisms and/or their products useful for industrial, food, medical and environmental decontamination purposes.

h) ***Supporting the eco-sustainable development of renewable energy resources from the sea***

The ocean is the largest source of sustainable energy. There *is enormous potential for* ***obtaining renewable energy from offshore wind farms, currents,*** *and* ***waves. Among the most promising renewable energy resources, offshore wind farms (OWFs) are those showing the most widespread planning due to the recent technological developments enabling the use of floating systems.***

ItIt is likely that in the future OWFs will be deployed at all depths including the deep seafloor. Given their huge potential expansion, criteria to site the farms and descriptors to assess their ecological impact are needed. These depend upon the biological components for two main reasons: 1) these structures should not cause impacts on marine life and ecosystems; 2) marine life can impair their functioning, thus reducing the impact of organisms on these structures is a further mission for Marine Research.

The mission for the years 2021-2030:
- to provide eco-sustainable solutions for expansion of the renewable energetic resources from the sea.
- to identify areas and tools for the sustainable development of energy industries at sea

Priority areas for marine research

The Mediterranean is a “miniature ocean”, where the impact of global change is stronger and faster than in all other oceans. For this reason, it is a natural laboratory for investigating the effects of these changes on biodiversity and functioning of marine ecosystems. Numerous environmental emergencies in the Mediterranean need to be addressed, including: habitat destruction, overfishing, pollution, introduction of alien species, the progressive acidification and warming of seawater, combined with episodic extreme phenomena and mass mortality events, and proliferation of non-indigenous species. The development of innovative experimental and observational studies are a priority to understand the biodiversity and functioning of ecosystems, their health status and their vulnerability. It also requires systemic and holistic approaches that can integrate interactions at varying spatial scales - between molecules, organisms, populations, assemblages and ecosystems. For example, the analysis of the function and dynamics of marine ecosystems at the basin scale may benefit from the use of satellites to be integrated with field data and functional observations at different levels of biological organization, from viruses to large mammals.

These objectives also require significant international cooperation between SZN, countries of North Africa and the Middle-East who insist on the Mediterranean Sea.

The priority areas that need the development of marine research actions are:

Tyrrhenian Sea, a key sub-basin of the Mediterranean Sea. Volcanoes, seamounts, canyons and deep water close to the coast require a plan of integrated and multidisciplinary research to understand the interaction between biodiversity and functioning, both in terms of mineral resources or potentially available energy. Moreover, the Tyrrhenian Sea is an ideal site to integratively investigate the effects of extreme climatic events and the synergistic impact of volcanic, hydrothermal, regime shifts, climate change and others.

Gulf of Naples: as an example of areas under multiple stressors, the Gulf of Naples is of great biological value, since it encompasses submerged ecosystems (e.g., precoralligenous seabeds and marine phanerogams), pelagic communities and a multitude of higher marine animals from fishes to large mammals. Furthermore, it hosts two stations of the international long-term ecological research community (LTER), active in monitoring planktonic communities (LTER-Marechiara) and *Posidonia* prairies (LTER-Lacco Ameno). The Gulf of Naples is also a pollution hotspot, with part of its coasts unsafe for bathing. The high population density of the Naples metropolitan area exerts a strong anthropogenic impact on coastal and offshore marine ecosystems. In addition, the Gulf of Naples includes Bagnoli Bay that has been seriously affected by pollution from a former metallurgical industry during the last century and is now considered a national interest site for decontamination by the Italian government. Another significant source of pollution in the Gulf of Naples is the Sarno River; it is the most polluted European river, seriously affected by inefficient treatment of wastewaters contaminated by municipal, agricultural and industrial discharges.

Ionian Sea and Straits of Messina and Sicily: the Stazione Zoologica in Naples will expand its research action in the new territorial seats established in the Ionian Sea (Amendolara - Calabria) and in the Sicilian coastal area (Milazzo-Palermo). These seats will allow to investigate a set of unique ecosystems, such as the Messina and Sicily Straits, that inspired Anton Dohrn since the beginning of the foundation of the Stazione Zoologica, and provide access to peculiar and fragile ecosystems and communities of key scientific interest, such as the hard bottoms of the Calabrian margin and the hydrothermal systems of the Aeolian arc.

Adriatic Sea – is likely to be the region most impacted by the ongoing climate changes in the entire Mediterranean basin and likely one of the most impacted worldwide. The Adriatic marine habitats are facing major impacts from overexploitation and pollution, and the dramatic changes occurred over the last 30 years have affected components of biodiversity that are critical to ecosystem functioning. The Fano Marine Center (Marche Region), on coast of the mid-Adriatic Sea offers crucial opportunities for investigating ecosystem shifts in this area as well as logistic support for several research activities and institutional programmes.

Eastern Mediterranean – is one of the priorities of the research in the Mediterranean that is undergoing unprecedented changes in its history since the last 5 million years. Here the impact of global climate change, episodic events (e.g., transient) and alien species invasion from the Suez channels are causing changes that make this region a laboratory for global change of international relevance.

Improving the contribution to the national research

Positioning within the National Research

Based on the analysis conducted on the Web of Science for the period 2004-2014, the SZN contributes by 12% to the total marine research carried out by national research institutes. In the decade 2010-2020 the SZN produced ca 10% of the total number of "marine" publications in Italy. Ranking second after the CNR (ca 30% of the marine publications in Italy):

1) CONSIGLIO NAZIONALE DELLE RICERCHE CNR
2) STAZIONE ZOOLOGICA ANTON DOHRN DI NAPOLI
3) UNIVERSITY OF NAPLES FEDERICO II
4) UNIVERSITY OF GENOA
5) UNIVERSITY OF BOLOGNA
6) UNIVERSITY OF PISA
7) SAPIENZA UNIVERSITY ROME
8) MARCHE POLYTECHNIC UNIVERSITY
9) UNIVERSITY OF PALERMO
10) UNIVERSITY OF PADUA

When the analysis is restricted to specific areas of expertise, the Stazione Zoologica is the institution with the greatest scientific impact in the field of marine biology (Area 05, more than any other scientific or academic institution in Italy).

The role of leadership in marine biological research must, however, be considerably enhanced in both quantitative (i.e., number of publications in international journals) and qualitative terms (i.e., number of citations per article and the relative impact on the international scientific community). Moreover, in the future the cultural leadership on the scientific products (i.e., position in the Author list as first, corresponding author or chief school in the last position) will become even more important.

In the last years, the rate of ISI publications per SZN author per year has remained fairly constant (on average about 2,6 publications per author per year), compared with a significant upward trend globally. Over the next years it is set an average target of 3 publications per author per year, to reach the rate of 4 ISI publications at the end of the decade, in accordance with the top international standards.

The impact on the international scientific community can be even more profitably rated as number of citations per author per year. In this case it is possible to indicate targets for improvement in the number of citations of doubling overall citations of the SZN in the next 5 years.

The missions for the years 2021-2030:
- to produce at least 4 publications in ISI journals per SZN scientist per year at the end of the decade,
- to double the total number citations per year in the next 5 years.

Linking the SZN strategy for marine research to the National Research Programme - Italy

SZN is member of the European Marine Board and is part of the "National Coordination Body" and member International Oceanographic Commission-IOC of the UNESCO. SZN is also contributing to the JPI Oceans that launched a new Strategy Framework 2021-2025 and discussed its contributions to Horizon Europe, the UN Ocean Decade and other initiatives.

Italy lacks of a National institute of marine research and research activities are still divided among at least 5-6 research institutions. This makes difficult to identify a single strategic perspective, national priorities, as well as managing research infrastructures (such as research vessels and top-class robotic tools).

The Cluster *Blue Italian Growth*, linking research institutions, universities, industries, stakeholders and policy/decision makers provides a crucial contribution to the need of a greater integration between the industrial production system and marine research. The "national blue strategy" should tend to offer more opportunities for economic development and employment, while preserving the marine ecosystems. The National Research Plan, seas and oceans, including polar research, are priorities that need appropriate strategies and investments.

From this perspective, the Stazione Zoologica can play a role of primary importance at a national level and contribute significantly to the Italian leadership in these and other areas of marine research. This role can become useful in a social perspective in areas such as research devoted to the implementation of the marine monitoring with advanced approaches, including the Marine Strategy applied to deep-sea ecosystems, which in Italy will be assigned to the Research Institutions by the Ministry of Environment (instead of to the Regional Agencies for the Environment).

The Stazione Zoologica has also the chance to become a reference point for the identification of marine biological models for biomedical experimentation, suitable for the progressive replacement of traditional models (e.g., mouse, dog, rabbit, guinea pig) and the strengthening of research in the field of marine biotechnology (Blue biotechnologies).

The missions for the years 2021-2030:
- to become the national reference point for marine research
- to become the Italian leader of marine biological research at an international level.

Improving Italian contributions to European research and infrastructures

European Research Infrastructures
it is clear that, within the European Research Area (ERA), high-level research, technological development and innovation (RTD & I) depend not only on the scientific capacity of the individuals, but also from the availability of research infrastructure. Major breakthroughs in the life sciences, such as the deciphering of whole genomes, are the result of both new technologies and joint efforts of biologists, physicists, mathematicians and computer scientists. Moreover, these accomplishments would not be possible without support infrastructure that provides specific technologies and expertise to face also new missions like the deep-sea exploration or metadata analysis from augmented observatories. Such high-end research infrastructure, often organized as core facilities, have helped to foster a collaborative research environment that is crucial for competitive interdisciplinary science and have become an integral part of life science research. The current third biomedical (r)evolution, manifested by the ever-increasing speed of technological innovations, means that an individual researcher can no longer afford and master all state-of-the-art techniques. In the current life sciences ecosystem, Research Infrastructures and core facilities are essential and the only means of providing cutting-edge technologies and expertise in an affordable manner.

Some of these are possible in a transnational framework allowing the development of pan-European research (RIS). The systems to be set up pointing to:

1) internal and external users from Universities and the private sector who need platforms, and data services on a competitive basis;
2) internal staff that will have access to cutting-edge infrastructure and share best practices, information, knowledge, and personnel, increasing the standard levels of European research;
3) resource sharing on a supranational scale, which enables better planning and management of large systems and their use more efficient and coordinated.

EMBRC (European Marine Biological Resource Centre) is a distributed research infrastructure spread over different countries, including Italy. EMBRC provides access to a wide range of ecosystems and marine organisms, expertise and services needed for both the exploration and sustainable exploitation of marine biological resources and to be used as models for basic research and applied industrial purposes. Interoperability between EMBRC and its nodes at pan-European level will make connections between regional seas and latitudes, as well as assessing and predicting the impact of climate change on marine biodiversity and ecosystem functioning. As a founding member of EMBRC, SZN coordinates and manages the Joint Research Unit in Italy, opening up new opportunities for interdisciplinary collaborations. The Joint Research Unit (JRU) EMBRC-IT will coordinate the participation of Italian EMBRC and EMBRC user access to Italian marine resources for research, encouraging research activities and joint training among EMBRC partners, increasing the international visibility of Italian researchers. For the development and management of such infrastructure, SZN contributing important investments of human resources and technologies thanks to two impressive grants it has obtained for a total of about 20M€.

EMSO is another collective European infrastructure with the aim of monitoring environmental phenomena relevant to the understanding of the complex interactions between the geosphere, hydrosphere and biosphere, with particular reference to the deep environments. The SZN is partner of the Joint Research Unit (JRU EMSO), sharing expertise, databases and resources with other partners to promote the training and joint research and technology transfer in this area of

marine science. The years 2021-2030 will be crucial to develop the next generation of marine observatories and in particular to exploit the potential of the new technologies.

LifeWatch is a pan-European e-infrastructure deployed for the study of biodiversity and ecosystems. Its goal is to provide researchers with tools and databases useful for the understanding and management of ecosystems. The SZN is one of the Italian partners and contributes to the Italian JRU of LifeWatch. SZN is the co-coordinator of the Biomolecular Topic Centre (BTC) within the service centre providing access to the tools for analysing genomic, metagenomics, phylogenetic and DNA-barcoding, as well as to existing databases. The research communities associated to SZN will benefit from the infrastructure through the use of tools and on-line service centres and through the participation of the topic centres and user groups.

ELIXIR is a pan-European e-Infrastructure leading managing and safeguarding research data generated in Europe that supports research in different fields: medicine, agriculture, bio-industries and society. This Research Infrastructure manages the data that are generated by publicly funded research and provides the necessary services for researchers in the life sciences. It ensures open access to biological datasets rapidly expanding. SZN is not a member of ELIXIR,but collaborates with EMBRC-IT Next Generation Sequencing and aspires to future increases in the use of existing datasets for its own scientific purposes.

Euro-Bioimaging is a pan-European RI for the development of biological imaging technologies. This RI allows the user to access to state-of-the-art biological and molecular imaging and provides image data support and training for users and providers and updates the new imaging technologies to provide cutting edge services. The cooperation with Euro-Bioimaging and with the Italian node will allow SZN to maintain its microscopy platforms and service provision associated with the forefront of their ability.

SZN has started a process of cooperation among EMBRC, Euro-Bioimaging, LifeWatch, EMSO and ELIXIR, developing joint strategies for the best use of data useful for the development of marine research. Research activities at the SZN produce huge amounts of data, requiring data storage, i.e., the e-infrastructure. Moreover, research at SZN necessitates free access to different sets of data and associated services available in these data stores. SZN must maintain a bridge between EMBRC-IT and EMBRC-ERIC, to promote interoperability through these RIS with regard to marine biological data and participate in the development of data standards. These data streams require fast connections, and a staff of specialized personnel to support the scientific community that works with the SZN. The improved ability to use information and technologies expected in the next decade will work at unprecedented observational, spatial and temporal scales, and to increase the capacity of both observation of molecular processes and at different scales of complexity and biological organization with end-to-end approaches. In addition, the development of these infrastructures will develop a new era of research in deep environments and extremes for which activities are needed, and joint efforts at a pan-European level.

The missions for the years 2021-2030:

- to implement the Joint research unit EMBRC – IT in order to enable the entire Italian research community to exploit the potential of this ERIC.
- to create synergies between international research infrastructure for improving their use for marine research.

To increase the capacity of observation of molecular processes at different scales of complexity and biological organization.
To start a new era of research based on bio-ecological observatories.

SZN Research infrastructure

An additional value for the SZN will be the development of two main facilities:

Marine Farm of Bagnoli – this is planned as the largest marine farm facility in Europe for the production of model organisms for research and industry. The production and search of model organisms will need the implementation of Animal Welfare criteria (including application of 3R) in order to meet the national and international regulations. The animal welfare committee of SZN (OBA) has started its activity in 2020 and already analysed most of the projects currently ongoing on vertebrates and cephalopods. OBA also aims to train the researchers in the application of the methodology identified and to allow proper use of wild living organisms.

Research vessel for offshore research – The new 35-m and 350,000 tons research vessel (that will be named A. Dohrn) will be operational in 2024 and will support offshore studies to an unprecedented spatial scale and with state-of-art equipment and instrumentation, including an ROV for exploring the deep sea down to over 2000 m.

The missions for the years 2021-2030:

- to open the MARINE FARM in BAGNOLI: open the labs in 2022 and open the marine farm to the public in 2024.
- to implement the animal and organism welfare principles in handling, caring for and studying species and individuals.
- to educate scientists and collaborators to comply with overarching principles of organismal welfare, to support a sustainable management of resources and to reduce impact on the environment, in full application of the 3R principles (Replacement, Reduction, Refinement).
- to increase SZN and national potential for large-scale oceanographic studies, thanks to the new A. Dohrn vessel

International initiatives @SZN

The huge amount of data available from national and international projects makes it increasingly necessary to recruit researchers that can transform this information into knowledge. A recent international trend also sees the creation of centres of ecological data analysis and synthesis.

MEDAS. The SZN will strengthen the Centre for Marine Ecological Data Analysis and Synthesis (MEDAS) in collaboration with the Stanford University, US. The SZN intends, with this centre, to promote the formation of working groups, summer schools, research activities, visiting scientists and PhDs. MEDAS will focus on marine systems, ecosystem-based management, and the definition of new research policies and management of marine resources. SZN intends to improve its expertise in the field of meta-analysis of ecological data and knowledge and technology transfer, thus providing new opportunities for development regionally and nationally.

MARS is a network grouping and organizing European marine research institutions and is a meeting place for the definition of policies and strategies of marine research in the long term, to lobby the heads of European research, and to ask for greater attention to the unique role of

marine research institutes. SZN is a major partner of this network that allows a wide range of international collaborations.

TARA Oceans and Ocean Sampling Day: the Tara Oceans expedition (SZN is among the leaders of this consortium) and the Ocean Sampling Day (OSD) have brought together international teams of scientists, including those of SZN, to collect data and samples of marine biodiversity. They provide new advanced technologies for measurement, sampling, study of marine organisms, their biodiversity (through the Next Generation Sequencing Meta-barcoding and meta-transcriptomics and high-throughput bio-images) and mark a crucial point for advancement of knowledge on marine biodiversity. These initiatives underscore the importance of promoting and participating in the coming years in scientific initiatives of a global nature that allow to enhance the skills of scientific SZN personnel, providing new opportunities for collaboration. The SZN is firmly dedicated to support the process of globalization of scientific research initiatives over the next decade.

Decade of Ocean Science for a sustainable development – SZN is taking part of different EUEU and international initiatives for launching marine research during the UN decade of the oceans. The future of research in Europe will depend upon the "blue response" to these major aims, which include social connotations and SZN intends to provide its contribution.

The missions for the years 2021-2030:
- to promote top-level marine scientific initiatives.
- to contribute to the European targets of the Agenda 2030.
- to contribute to the Decade of Ocean Science for a sustainable development.

SZN contribution to International Organizations

OECD

The SZN following its participation in the OECD project "Fostering innovation in Ocean economy" and "The ocean economy: Preparing the innovation of tomorrow" contributes to the OECD project "The Ocean Economy: preparing the Innovation of Tomorrow 2019-2020", "and will participate in the next 2021/2022 work program. This effort aims at understanding and improving innovation policies for science and technology for seas and oceans, providing guidance in the use of economic instruments to enrich innovative and integrated management of seas and oceans, developing and refining an OECD industry database for the sea and ocean, and analyzing the economic value of marine and oceanographic research and observation

UNESCO

SZN participates in the working group on Ocean Literacy promoted by UNESCO. The oceans (Atlantic, Pacific, Indian; Mediterranean, Baltic, Northern) function as a single system that is globally connected and fundamental to life on earth: the ocean provides oxygen, absorbs anhydride is a source of food, regulates temperatures and weather. The first forms of life on our planet arose from the sea. Dealing with Ocean Literacy means to spread the understanding of the influence that the ocean has on our life and the influence that our choices and our actions have on the ocean (and therefore, again, on our lives). The need for the spread of Ocean Literacy, as a fundamental educational theme, emerged about twenty years ago in the United States, when scientists, scholars and educators noted that in the guidelines for teaching there was no trace of ocean and science. Since then the topic has been studied, debated, planned,

regulated and the Ocean Literacy has become a basic element of educational programmes in many countries, including Europe, from seven very simple and clear principles. But it is not yet in Italy. The construction of an Italian network for Ocean Literacy has the objective of spreading also in our country, surrounded by the sea and historically, culturally, economically linked to the sea, the culture of the ocean, sharing these principles starting from the schools and the civil associations. It will thus be simpler and more natural to protect what is the fundamental element for life on Earth. SZN scientists contribute to the UN "Pool of Experts of the Regular Process" and contributed to the "Use of Marine Genetic Resources" in the First assessment. SZN will contribute also to the second World Ocean Assessment (WOA II).

MSP Global initiative

SZN also participates with UNESCO, MAECI, MIT in the MSP global Initiative (Maritime Spatial Planning). The overall objective of the project is to support international marine/maritime spatial planning (MSP) for the sustainable development of the blue economy, by enhancing cross-border and transboundary cooperation where it already exists as well as through the promotion of MSP processes in areas where it is yet to be put in place. The specific objective aims at improving planning of sustainable economic activities at sea by promoting the establishment of MSP plans and by creating an environment conducive to transnational cooperation through the development of international guidance for cross-border and transboundary MSP.

Scientific Journals

The contribution of the SZN to the international scientific literature is crucial, both for historical reasons and for the prestige that derives from such activity. SZN was the founder of the journals

- *Marine Ecology: an evolutionary perspective* (previously *Publications of the Stazione Zoologica in Naples* and then *PSZNI: Marine Ecology*), and
- *History and Philosophy of the Life Sciences*, an international journal

Recently, SZN, in collaboration with the Italian Society of Limnology and Oceanography (AIOL), has supported the development of the open access journal: *Advances in Limnology and Oceanography (AIOL Journal)*.

In the future the international impact of the SZN scientific journals will be further supported and enhanced with appropriate actions. The SZN researchers are members of the Editorial Board (Chief Editors, Associate Editors, Review Editors, Editorial Board members) of prestigious journals of Web of Science, such as: *Environmental Conservation*, *European Journal of Phycology*, *Frontiers in Ecology and Evolution*, *Frontiers in Marine Science*, *Functional Plant Science and Biotechnology*, *Genome Biology and Evolution*, *Harmful Algae*, *Marine Drugs*, *Marine Ecology Progress Series*, *Marine Genomics*, *PLoS ONE*.

The involvement in the international board from this point of view is essential. The strategy of the years 2021-2030 should focus more and more on the strong involvement of the staff of the Stazione Zoologica in editorial boards of prestigious international journals.

The missions for the years 2021-2030:
- to increase the impact of international journals of SZN.
- to increase the role of SZN researchers in the editorial boards of top-ranked international journals.

Priorities for the recruitment of SZN personnel

Role of the SZN researchers and technologists

Researchers and technologists at the SZN contribute to the development of scientific and technological research and carry out specific tasks for research activities of national and international interest. The primary objective of the researchers and technologists is the continuous advancement of knowledge translated into scientific production in order to contribute to the competitiveness of the national research in the international arena. The tasks of the researchers and technologists also include field and/or laboratory activities and/or participation in the testing of new procedures and technologies related to research activities. The tasks of the researchers and technologists include a major effort in the drafting of research projects for national and international competitive calls, aimed at attracting external resources. Researchers and technologists have direct access to the funds for scientific research, at all international, national and local levels. Researchers and technologists perform tasks of scientific research on topics of their choice, in the context of the mission of their Research Institute. Researchers and technologists can freely avail themselves of the funds allocated, within the terms of the current internal and legislation rules. They can also carry out industrial research, teaching and mentoring, including internal or external lectures for university courses, specializations or doctorates. They can also attend examination boards and can access all the management positions on a competitive basis. The researcher/technologist is also required to ensure her/his commitment to the various work activities of the SZN. The technologists at SZN are engaged in the improvement of scientific and technological research for 50% of their time and in the implementation activities for services and infrastructures of the SZN for the remaining 50%.

The missions for the years 2021-2030:
- to improve research quality and exploring new research directions, both in basic and applied research fields.
- to increase the income of external funding from competitive calls and/or local/regional/national commitments.
- to implement the services and infrastructures of the Stazione Zoologica.
- to foster the contribution of scientists to public engagement.

Role of the technical staff in research

The technical staff plays a key role in research. Highly skilled personnel are essential to the production of quality data, the management of equipment, procurement and maintenance of the materials and consumables necessary for the research. The technicians support the tasks assigned by the staff responsible for research with standardized procedures and measurable goals. As with the research staff, technical staff is obliged to provide continuous cultural and technical training to better use all available resources.

In the Vision 2021-2030 these objectives can only be fulfilled if we invest in life-long training of staff already in the SZN. Flexibility and inter-exchangeability of the roles of the technical staff are also indispensable to the proper functioning of the activities of the organization. The core activities of "technical staff dedicated to support the research" are carried out in laboratories, or in the field, because a marine research institution needs to work at sea. Given the increasing complexity of research and instrumentation necessary for it, it is necessary to think about a process of lifelong learning and the recruitment of highly qualified specialists and providing

further high-level training, while allowing adequate career opportunities. A similar target must also be programmed for personnel with different abilities that will be enhanced in the future in activities of particular complexity such as those required by the research support.

The missions for the years 2021-2030:
- to provide highly qualified and continuously updated technical support staff for research.
- to standardize procedures to make them more qualified and efficient.
- to improve the quality and efficiency of services provided.
- to increase recruitment of highly qualified technical staff

Research personnel in the years 2021-2030

To meet the objectives of scientific excellence and international leadership the SZN requires an appropriate critical mass to compete with the top scientific institutions. The overall personnel (ca 260 units according to the 3-yrs Plan of 2020-2022) plus ca 150-200 units of temporary staff/post-docs or PhD students, with overall 400 units, is the carrying capacity of the institution.

Other research institutions in the EU and elsewhere with similar missions have typically higher dimensions in terms of personnel. To give some examples: *Station de Biologie Marine de Roscoff* (France, founded in 1873, which has increased from around 50 to more than 200 units over a decade), *Woods Hole Oceanographic Institution* (WHOI, USA, with currently ca 1000 units), Hellenic Centre for Marine Research (HCMR, Greece, with the incorporation of IMBC its foundation in 1989, today has grown to more than 200 units), the NOCS (National Oceanographic Centre, Southampton, UK, founded in 1995, which now has about 540 employees and is the 30th institution in the world in Earth and Marine Sciences, QS Ranking).

According to the platform Expertscape, in the period 2010-2020, the most important research institutions worldwide were:

1. Centre National de la Recherche Scientifique (CNRS)
2. Chinese Academy of Sciences
3. Ministry of Education China
4. University of Queensland
5. University of Washington
6. Sorbonne University
7. Woods Hole Oceanographic Institution (WHOI)
8. Ocean University of China
9. University of California San Diego
10. Scripps Institution of Oceanography
11. University of Hawaii
12. Institut Francais de recherche pour l'exploitation de la Mer (IFREMER)
13. CSIRO Australia
14. Oregon State University
15. Universite Paris 6 Pierre et Marie Curie (which includes the Station de Biologie Marine de Roscoff)
16. University of the Chinese Academy of Sciences
17. Stazione Zoologica Anton Dohrn Napoli

The SZN is the second most productive research institution in Italy (after the CNR), but is the most influential in terms of citations and research outputs.

The SZN staff makes the Institute flexible, dynamic and competitive in terms of research activities at national and European level, but not enough to take on a leadership role in the management of major projects and infrastructure such as ERIC - ESFRI, the role which could aspire on the basis of the excellent international reputation of the SZN.

In general, the limited number of researchers (either in absolute and in relative terms) makes our country less competitive in the capability to obtain financing from international tenders and the EU. Thus, the return to the country's share of contribution to the European research (14%), the portion dedicated to marine research which is consistent, does not exceed 8%. The difference between Italian contribution to EU research and recovery of these funds is a "gift" for other countries: UK, Germany, Holland and France in particular.

The goal for the period 2021-2030 is to increase competitiveness of research by increasing the staff, reaching approximately 260 units. Firstly, the expansion will cover the researcher area, but it is clear that in order to face this expansion it will be necessary to find resources and ways to enhance technical staff.

Aims for the years 2021-2030:
- to recruit top scientists from abroad
- to attract top scientists through calls for excellence and for reversing the brain drain

Criteria for future recruitment

Italy invests only 150 Euros per year in research for each citizen, compared to 250 and 400 in France and Germany, respectively, and has a limited number of scientists when compared to other top leading countries. There are only 75,000 researchers, against 110,000 in France and 160,000 in Germany. In US and Japan (or Israel) there are 2-3 times more scientists than in Italy when normalized to the population. With a halved “army of researchers” compared to that of our competitors, we cannot grow in the ability to collect more EU resources or to lead international research.

The criteria for recruitment in the years 2021-2030 should be guided by the principles of excellence and full transparency in procedures, maximum dissemination of information and guarantees of equal access to all candidates, including foreign candidates.

The goal for the next decade is to maintain the SZN as an International Research Institution (currently it is the Italian research institution with the highest percentage of international researchers) and to attract the top scientists from Europe and elsewhere, including the return of Italian scientists that have started their career abroad.

Recruitment must always be guided by the principles of scientific merit and excellence that are inspired by established international approaches (see the section on the promotion of merit). This will be conducive to the recruitment of staff demonstrating high records of publication in international journals, leadership in the co-authored publications, use of advanced and

innovative technologies, membership of international networks and ability to work in international research teams.

Recruitment must be guided by the research priorities identified by the Institute, and research calls must be directed to complement and expand the existing expertise, and in order to replace expertise considered pivotal to the institute Vision but are going to be lost due to retirement.

Special attention will be given to the maintenance of skills in the areas of excellence considering the retirement of current research staff and the research sectors they cover. Priority will also be given to recruitment in areas of strategic interest for which there is a lack of expertise.

The missions for the years 2021-2030:
- to make the Stazione Zoologica the most international research institution in Italy.
- to apply EU guidelines for the recruitment of researchers,
- to expand the strategic areas of the SZN.

Strengthening research

Evaluation of research performance

The SZN conducts yearly monitoring of scientific performance, based on unbiased criteria, normalized to the field of research, scientometric criteria, with advanced and integrated approaches to all possible merit indicators. In any case, it is clear that the greatest weight in evaluating the results in the years 2021-2030 will be given to:

- ***publications*** *with particular emphasis on top quality papers, defined as publications in top international journals with a high rate of citations (eg, publications included in the top 10% of the citations for the specific area).*
- *international* ***patents****.*
- *competitive* ***projects****.*
- *activities for* ***third parties****.*
- *other activities that allow a better placement of SZN in innovation and competitiveness of international research.*
- *High level education (PhD, MSc).*

The missions for the years 2021-2030:
- to improve assessment of scientific performance of research.
- to self-assess research results through the application of objective criteria.

Technology Transfer

Technology transfer activities are aimed at the promotion and development of knowledge and its application to environmental protection and the improvement of quality of life. These aims are pursued to develop and promote economic, social and cultural development of the country. For this purpose, the SZN plans a policy of development and promotion of intangible assets, relaunching evaluation activities, marketing and protecting the intellectual property of the results obtained in research projects and institutional activities funded by public and private companies.

The main activities will be:

- ***management and licensing of patents***;

- ***valorization of research results*** through the participation and / or incubation of spin-off companies;
- ***promotion of industrial partnerships*** for the development of research skills and the transfer of results of research activities;
- ***act as an intermediary*** between scientific and entrepreneurial interests, and those of the institutional system.

The missions for the years 2021-2030:
- to increase the economic and social impact of the SZN researchers
- to enhance the research products of SZN
- to organize annual entrepreneurship courses.

Promoting quality and the excellence

The SZN contributes to the creation of the European Research Area (ERA) and is committed to an increasingly competitive approach and merit-based acquisition of private and public funding it receives. The selection and promotion of best performing researchers are crucial to attract and engage the human capital necessary to achieve the ambitions of the next decade. For this purpose, it will be built and used a system of recruitment, career progression and promotion of researchers based on open, transparent and purely meritocratic procedures, applying to the guidelines defined by the Carta of European Researchers of the European Commission. The system will be used for all staff involved in the research. In line with the criteria of evaluation of research defined at national and international level, the merit of the researchers will be evaluated by applying scientometric criteria supported by indicators on:

- innovation and leadership of research, with analysis of the impact on the international scientific community of reference;
- ability to attract funding and leadership in national and international research projects, selected on competitive calls and under peer review;
- promotion and coordination of international research networks;
- direction or participation in editorial boards of international journals of recognized prestige;
- participation in scientific committees and programming of recognized prestige, both nationally and internationally;
- attribution of teaching positions at universities or official fellowship and research institutions, foreign and international, highly qualified;
- direction or scientific responsibility / coordination of highly qualified national or international bodies or public or private research institutes ;
- prizes and awards for scientific activities;
- ability to improve research results and to carry out outreach activities;
- participation in program committees, and those of national and international policy and strategies.

All procedures will be open and transparent and will ensure the enhancement of researchers and technologists who have actually contributed to the objectives of SZN.

The missions for the years 2021-2030:
- to reward researchers and technologists who have significantly contributed to the objectives of SZN.

Facilities and Resources for Research

The SZN has been characterized since it was founded by the development of facilities and resources for research. The modern challenges of science and an increasingly competitive search of funds can no longer be addressed by individual research groups. Organized research groups (the core facilities) become today essential for each research institute to sustainably address management needs, the preparation required, and the costs associated with access and development of modern technologies. The ongoing process of reorganization of the Institute has seen the creation of two Departments dedicated to technological research and management of the infrastructures for the marine living resources (RIMAR and CAPE) designed to:

- **develop** and provide services for the marine biological research;
- **promote** technological development and support the research activities of the SZN;
- **support** international collaborations with particular reference to the Italian contribution to research infrastructures of European ESFRI roadmap;
- **provide** internal and external users with a number of services based on specific technologies and expertise;
- **Increase** SZN's competitiveness and ability to attract funds;
- **contribute** to the expansion of the role of SZN for industry and the society at large.

Research facilities are among the pillars of the Stazione Zoologica activities. The Department of Research Infrastructures for marine biological resources (RIMAR) provides high technology services and access to infrastructure and research platforms to the national and international scientific community, as well as support third mission activities such as third-party contracts. At the same time, RIMAR conducts applied research and technological development in the field of marine biology and in the specific fields of interest of the units of which it is composed. The services are available to universities and to other public and private institutions. The SZN in the next decade will be committed to consolidate its services, to enable its researchers and the scientific national and international community the access easily and at low costs to the different facilities, which include (but are not limited to):

- Environmental Monitoring & Analysis
- Infrastructure for Marine Research
- Technological upgrading & Robotic development
- Advanced Microscopy Center
- Bioinformatics, Computational Analysis & Data Management
- Classic and Molecular Taxonomy
- Sequencing and Molecular Analysis Center

The missions for the years 2021-2030:
- to increase the exploitation of top-level infrastructure and facilities.
- to strengthen the portfolio of research services.
- to improve the quality of research services.

Contribution of SZN Research to the national cultural and socio-economic framework

Marine research should contribute to shape the future of our society, providing opportunities and tools for improving the quality of life, the economy and sustainability of human activities, locally and globally. In this sense, SZN is committed to assess the impact of its research in the socio-economic and cultural county/regional and national level and to start the process to publish the annual social report of the SZN.

Connections with the territory and the public institutions

In the future, research institutions must increasingly become a cultural, ethical and technical reference for the national and local public administrations (e.g., Minister of the Environment, Municipalities) and the territory, and citizens (especially young people). They must support policy/decision makers and contribute to the protection of the territory and to the improvement of the education of citizens about sustainable practices and choices. In this sense the role of SZN is already evident for the research activities in the field of potentially toxic algae, sources of contamination, sustainable exploitation and consumption of seafood, sustainable tourism, and participation in consultations (e.g., marine protected areas etc).
The prospects for greater regional involvement are however large, both in the local area, in the Campania region (e.g., the new Marine Observatory in Portici, Naples), and outside the regional context. There are important areas or entire regions of the South, such as the Calabria region, that do not have access to local research institutions to support policy/decision makers, for monitoring and for the research at sea. The SZN aspires to become the main reference in marine biology for the public institutions of Southern Italy in particular, as well as for the entire country.

The SZN is coordinating the JRU-EMBRC-IT and cooperating with other national marine research institutions, such as INOGS, INGV, CNR, ENEA, INFN and ISPRA. Here the priority is to further expand the network to other Universities that can combine the best human skills and potential instrumental and infrastructural resources, creating new opportunities for synergies and strengthening scientific research.

The missions for the years 2021-2030:
- to Become the benchmark for Italy in the field of marine sciences.
- to Cooperate and networking with other marine research institutions.

Linking SZN research to private entities and industries

The SZN also collaborates with research institutions and private companies with the aim at contributing to the development of knowledge for environmental protection, improving the quality of life, and to develop and promote economic, social and cultural development of the country (Statute Art. 2). In the next decade, the SZN aims to further develop connections with enterprises and all activities of dissemination and capitalization of research results.

One of the restrictions on the competitive potential of our country is the limited industrial investment and, more generally, of the private sector into the scientific and technological research. While this is understandable in the light of the overwhelming dominance of very small (even individual) and small enterprises (SMEs) that have limited resources to invest in research, this appears difficult to understand for the medium and large enterprises. The public research institutions, however, have the potential to support the research needed to boost industrial

competitiveness and entrepreneurship in general. It is important to pursue these objectives in the coming years, identifying the business sectors of interest and growth potential in Cluster Blue growth and providing maximum support. Apart from this, it is necessary to promote the role of reference for the activities for third parties to support the activities of the companies.

It is therefore also necessary to implement an Grant Innovation Office to provide support to qualified researchers in the search of opportunities for collaboration with external parties, in the preparation and management of legal and contractual arrangements, in the patenting procedure, the creation of spin off and monitoring of their activities. This structure can create more effective relationships between SZN and world production and business. The connection with business in the next decade will be oriented to:

- active management of the portfolio of patents from SZN, pursuing a policy of exploitation of the patent to facilitate as much as possible the commercial exploitation of the patent;
- continuous encouragement of SZN researchers to pursue the commercial application of research findings, so as to encourage and support the creation of spin-off with a good chance of development;
- more opportunities for agreements with institutions and contracts with companies to do commissioned research, performance and tariff benefits and services account third party thanks to a specific line of activity of the ILO and the availability of equipment and highly techno-scientific qualified expertise;
- active participation in research infrastructure (for example, EMBRC, EMSO, Lifewatch) and intermediary effective and efficient structures (for example, Cluster Blue Italian Growth, incubators, foundations) in order to guarantee access to a network of companies and centres research potentially interested in the services offered by SZN.

The missions for the years 2021-2030:
- to develop and value the patent portfolio of SZN.
- to double the income from external contracts and agreements.
_ to develop business networks and relationships with research centres involved in research infrastructures.

Public engagement, outreach and communication

The SZN is internationally renowned for its expertise and results of research in the marine environment and has always seen public involvement as crucial. With the increasing global challenges that oceans are facing, it becomes ever more essential that scientists and experts communicate about relevant marine science with audiences beyond the scientific community. This is one of Animal Conservation & Public Engagement (CAPE) department goals since its birth at the end of 2020.

The correct transmission of research lines and related results to the public is essential in the 21st century. We live in a critical era, in which the public's distrust of scientists is very high, and often borders on hostility. This is also partly due to the lack of communication from the scientific establishment, due to antiquated and/or inadequate methods of information transmission. Communication cannot and must not be a one-way only, but a binary exchange of information; to obtain these results it is necessary to update communication models that are more than thirty years old, and the Department of Animal Conservation and Public engagement will lead the SZN to the new frontiers of scientific communication.

Presenting the data correctly is the priority, but using language that most people understand comes as a close second. The correct construction, preparation and presentation in every public outreach event and meeting, from a conference to a lecture, correct messaging is fundamental for successful transmission of information. This represents the main path for the Department of Animal Conservation and Public engagement in the future. Considering the dramatic speed and expansion of the communication tools nowadays available, is to bridge the growing gap between the public and science.

Effective science communication and dissemination have become crucial and mandatory in all European projects. Moreover, in UNESCO's program "Ocean decade" communication to the public is considered a backbone. Being properly equipped for such dramatic changes becomes a necessary step to keep our excellence. Following the rules of communication becomes vital: successful stories are created by using the acronym S.U.C.C.E.S.. This means Simple, Unexpected, Concrete, Credible, Emotional, Story.

Communication in SZN will be therefore considered no longer a secondary activity but a priority, and Department of Animal Conservation and Public engagement department will be central in this process. This Dept. will realize connections between the science community and society by designing strategic communication plans for SZN projects. It will apply multidisciplinary languages (novel, stories and storytelling, comics, movies, documentaries, journalistic and so on) on different social media, and interdisciplinary approach (such as arts, literature, anthropology, history, theater, etc), multimedia languages and all available media technologies. "Data analytics" will be applied to all types of communication to measure efficiency and effectiveness of the spread, in order to correct, improve and measure the society's transposition.

Scientific transparency and an easy, understandable and approachable communication strategy is required to build and sustain public trust (i.e. "why the research of SZN is important for individuals and society? Why it is it right spend money in such research?) to promote behavioural changes and engage broader audiences in understanding natural processes. Consciousness and acknowledgment are not a goal but a path that need to be built day after day with all strategies and methods: multisensorial, verbal and non-verbal communication. etc. So the facilities of SZN such Darwin Dohrn Museum, the Aquarium, Turtle point and future marine farm and scientific aquaria, are places where public experience, and consequently engagement, can become not only a lesson but also a call to action. One of the great aims of scientific communication is to change the point of view: move an audience that listens passively and often bored by the inexperienced speakers, to an audience that feels like an active participant. Arousing emotions is essential in communication. Without emotions, doors to people's mind will be closed and communication will be an effort doomed to failure (pathos, logos and ethos). Therefore, organizing and promoting continuous exchange, learning and public engagement through actively visiting the incredible richness historical SZN heritage cannot be postponed anymore.

In this perspective, communication training for scientists becomes critical and urgent. The majority of practicing scientists have acquired limited communication skills and knowledge. CAPE will promote evidence-based science communication training programs for SZN scientists to improve and enhance public communication. Building collaborative, interdisciplinary teams with diverse expertise aims at a unified aim of effective science communication.

Dedicated programs for training and facilitation of scientific education of children of primary and secondary school classes and increasing their interest in science and technology is a priority. They will become the researchers of tomorrow and contribute to a scientifically-literate society.

Darwin – Dohrn Museum, Historical Archive and Marine Library

The SZN holds an exceptional array of historical collections and documents uncovering the past of the Gulf of Naples, one of the most biodiverse ecosystems of the Mediterranean Sea. Preserved and dry samples of organisms, fishermen logbooks recording the daily catch and old maps dating back 150 years are just a few examples of the unique sources to reconstruct this ecosystem before the acceleration of human impacts that has characterized the second half of the 20th century.

This core collection represents the ideal foundation for the development of a museum of national relevance and international standing on marine biodiversity with the mission to:

1. preserve historical collections and archives, and enable their access by the international research community;
2. constitute the national repository of marine biological collections assembled by present-day scientists and advanced amateurs, including type specimens;
3. be pivotal for the development of a center of expertise on the taxonomy of marine organisms;
4. apply and further develop state-of-the-art approaches to the exploration of marine ecosystems (e.g. ancient DNA, ancient and modern environmental DNA, museomics);
5. contribute to large-scale international projects on the digitalization and distribution of scientific collections.

Historical and educational Aquaria, Turtle point, Marine Farm and Center for Conservation of large marine vertebrates

These facilities accessible to tourists and citizens are strategic tools for disseminating marine science and knowledge to the general public. Darwin-Dohrn Museum will facilitate communication of the concepts of biological evolution, by showing marine organisms to a large audience. Through these facilities the SZN will offer culture, science education and edutainment. The goal for the next decade is to increase tenfold the number of visitors and students, creating a steady stream of visitors from local schools, of tourists and citizens. The engagement of Stazione Zoologica in outreach and education will further expand with the realization of an educational aquarium in the new site of Fano Marine Center. This aquarium will host Mediterranean and non-indigenous species and promote active conservation of local marine organisms.

The objective of the SZN is to be identified by the general public as a reference point for all marine scientific aspects. In order to create a visible and recognizable sign of trustworthy approach, SZN has recently created a new logo system for each facility. This joint project with ABANA (*Accademia delle Belle arti di Napoli*) and the Museo di Capodimonte is a visionary and pioneering approach to spread SZN brand names and images and achieve a global perception.

The missions for the years 2021-2030

- to disseminate the results of SZN research and projects through all possible media tools
- to define an annual communication plan.
- to plan and promote communication training and support for the SZN scientific community.
- to use communication strategies at the forefront and groundbreaking to promote scientific communication projects.
- to increase awareness of human impact on the environment.

The SZN contribution to Higher Education

Research organizations should contribute to the advanced training of future generations of researchers. In the past, the SZN has hosted students for internships and thesis work carried out in its laboratories (mentoring), also in the framework of international programs (e.g. IMBRSea). This role will be enhanced in the next decade.

In 2014 the SZN also launched a new Master of Science in International English in *Marine Biology*, currently running, in collaboration with the University of Naples Federico II, whose mission is to train highly specialized Marine biologists and to develop skills in the management and conservation of the marine ecosystem. The SZN also offers the possibility of stages designed to provide advanced skills and professional skills in the field of marine scientific research and offering the opportunity to students of a second (Master of Science) and third level (Italian Doctorate and International PhD – Open University) to develop their skills and improve their employment prospects. Thanks to its international reputation, the SZN acts since 1998 as Associated Research Center for the Open University (UK), giving an internationally recognized PhD title, as well as has several joint educational initiatives with Italian doctorates in collaboration with several universities.

The SZN PhD program, including OU and other Universities, is organized in three scientific curricula: Integrative Marine Ecology, Biology and Evolution of Marine Organisms, Marine Biotechnologies and Marine Biological Research Technologies.

New opportunities are emerging from the cooperation with the University of Messina (Sicilian seat) and the University of Cosenza (Calabrian seat). The SZN presence within the Fano Marine Centre also offers the opportunity to develop doctoral programmes alongside the Universities of Urbino, Bologna, and the Polytechnic University of Marche.

PhD students have the opportunity to develop research of the highest scientific level and improve their personal skills in the laboratories of SZN. The International PhD in Life Sciences of SZN is based on the principles of excellence, internationality, dedicated mentoring and development skills relevant to the scientific career of young researchers. Currently there are doctoral programs in: i) Model organisms for Biomedical Sciences and Veterinary Research, ii) Computational Biology and Bioinformatics, iii) Applied Biology; iv) Veterinary Science; v) Biology; vi) Bio-Engineering.

The SZN intends to further develop the advanced education sector, offering new paths in high-level international cooperation with international networks (e.g., MARS) and European infrastructure (e.g., EMBRC, EMSO, LifeWatch).

Particular attention should be given to the planning and organization of international workshops and advanced courses (including Summer Schools) to be organized annually, together with prestigious seminars from leading scientists from around the world. These activities will require adequate implementation of the structures devoted to these activities.

The missions for the years 2021-2030:
- to expand master degree education in marine biology in cooperation with national and international universities;
- to organize seminars, workshops, summer schools and courses of the highest level.

Training of young researchers

A key component to the success of a research institution is its ability to train and to increase the value of young researchers. Since its foundation, the SZN has an international leadership role in the training of young researchers, activities implemented by giving its support to various national and international initiatives, following the vocation of its founder Anton Dohrn. The next decade will see a special effort in this direction.

The SZN aims to attract young researchers from around the world, train them, and eventually select them to strengthen their research activities. In this perspective, we need to implement investments in research grants, European grant (e.g., Marie Curie) and positions for fixed-term researchers (e.g., tenure tracks).

The missions for the years 2021-2030:
- to attract young research talent from around the world.
- to strengthen the procurement of funding for brain gain.

Life-long learning

Continuing education is one of the keys to a knowledge society. The SZN intends to contribute to the process of expansion of permanent training offered through some of the initiatives listed above (e.g., highly specialized schools for research staff), and to enhance the SZN staff.

Technological and methodological evolution impose the relaunch of training activities for the technical staff, both in the laboratory, and linked to other functional activities of the Institute. The advanced training is also essential for researchers and technologists. In this case, it is implemented through specialized courses, workshops and conferences, but it is a vital objective for the personnel connected to research and technological services.

The missions for the years 2021-2030:
To expand the training for permanent staff and for external personnel