Institute Profile: The Centre Scientifique de Monaco—A Reference in the Study of Coral and Polar Biology

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The Principality of Monaco has a long tradition in Science. Indeed, Prince Albert I, the great-great grandfather of the current Prince of Monaco, HSH Prince Albert II, is regarded as one of the fathers of modern oceanography. He conducted 24 research expeditions onboard his four oceanographic vessels, each of which returned with a harvest of new species and scientific data, with one that contributed to the Nobel Prize awarded to Charles Richet in 1913 for his discovery of anaphylaxis. Prince Albert I created the Oceanographic Museum, the "temple of the sea," to showcase the results of His expeditions for the public.

Perpetuating the tradition of his great grandfather, Prince Rainier III founded in 1960 the "Centre Scientifique de Monaco" (CSM or Scientific Center of Monaco) to provide the Principality with the means to conduct more scientific research. Since 1990, the CSM has then become a reference in the study of coral physiology and ecophysiology in relation to global climate change. After more than 50 years spent in the development of the Oceanographic Museum of Monaco, the CSM moved 1 year ago to a new home with larger laboratories, specially designed for the research carried out by the center. Overlooking the harbor of Monaco, the new CSM labs are built on the terrace of an existing building that also hosts the United Nations IAEA Environmental laboratories as well as artists' studios. Covering an area of about 2300 m^2, they are home to a broad range of environmental research activities (coral biology, environmental economics, and polar biology) as well as a new department of medical biology, dedicated to cancer research and gene therapy.

One of the major successes of the Monegasque center of research has been the development of coral culture and propagation methods under controlled conditions. It is now home to more than 60 species of tropical, temperate, and cold-water corals that are cultured in the lab for experimental purposes. Tropical coral species are maintained in an aquarium room containing five large (10,000 L) aquaria, whereas the temperate and deep-sea coral species are kept in two other rooms supplied with cold water (5000 L). In addition, five experimental rooms containing a total of seventy-eight 30-L aquaria, allow testing the effects of various environmental parameters on coral biology. All aquaria are equipped with pH, temperature, and oxygen sensors and are supplied with fresh seawater (about 10 m^3/h) supplied by a pumping system drawing water from 50 m deep in the sea in front of Monaco-Ville. After circulating through the aquaria, the seawater is UV-sterilized before

CSMLabs: The new lab located above the harbor of Monaco on the terrace of an existing building, close to the old town of Monaco. Picture by Éric Tambutté © CSM

CSM Aquariums: The new aquarium facilities at the CSM. Storage aquariums to cultivate mother colonies and prepare experimental microcolonies. Picture by Éric Tambutté © CSM

being returned to the sea. The sensors are connected to a central alarm to signal problems in their regulation and are remotely monitored via the web. In total, the aquaria hold more than 20 tons of seawater on the top floor of the building! Among species cultured in the aquaria, the CSM regularly champions the use of the tropical coral, *Stylophora pistillata,* which has become the "coral lab rat" model species since used by many other research teams.

Coral reefs, cold-water reefs and their temperate counterparts, Mediterranean coralligenous organisms, play a major role in maintaining marine biodiversity. Coral reefs are thus considered oases of life in the open ocean and the marine equivalent of primary forests: although representing less than 0.2% of the ocean surface, they are home to more than 30% of all known marine life! They protect shorelines from erosion and are a major economic resource for more than 500 million people. Coralligenous organisms are very important for many species and their landscape is a major attraction for divers. Unfortunately, these ecosystems are highly threatened: mass mortalities in the Mediterranean, bleaching episodes in tropical environments, ocean acidification, etc. Research at CSM aims to determine, in normal conditions or during environmental stresses, the biological mechanisms underlying coral biomineralization and symbiosis, two key processes supporting tropical and Mediterranean coral ecosystems. The research performed in Monaco on coral biology are then mainly done under controlled lab conditions using unique methods of coral culturing and to the use of modern scientific equipment in the field of Ecology, Physiology, Biochemistry, Molecular Biology, or Genomics. To achieve these missions, the department of Marine Biology has two teams of marine biology research whose skills are complementary and a topic in Environmental Economics.

- *Team Physiology and Biochemistry: using molecular and cellular approaches*. This team is studying physiological and molecular processes involved in coral calcification and symbiosis from the molecule to the organism. The study of the effects of environmental parameters such as ocean acidification on these processes complements the fundamental component of this research.
- *Team Ecophysiology and Ecology: using an environmental approach*. This team is studying the impact of global change (global warming, acidification, increased UV radiation) on the functioning of coral reef ecosystems and coral growth. The importance of the energetic status of corals, as well as their relationships with microorganisms, is also considered.
- *Environmental Economics*. Due to societal concerns related to ocean acidification, the CSM has developed a program of environmental economy in order to help decision-makers and international organizations since 2009. In particular, studies are carried out on the socio-economic impacts of climate change, particularly on ocean acidification in coastal environments. In close collaboration with the International Agency for Atomic Energy (IAEA), this topic aims to stimulate multidisciplinary research between scientists and economists, to better understand socio-economical impacts of ocean acidification on coastal ecosystems.

Coral Reef systems and Polar Environments are obviously quite dissimilar. However, they are similar in that both are extremely vulnerable to environmental changes. In 2010, a new field of research on polar biology was established within the CSM to link expertise in reef environments and polar areas for better overall management and protection of biodiversity. It was therefore natural that leading international experts in polar research from the "Institut Pluridisciplinaire Hubert Curien" of Strasbourg (UMR 7178, Centre National de la Recherche Scientifique & University of Strasbourg) and the CSM, known worldwide for their respective work on the biology of penguins and reef-building corals, are now working together to better understand the adaptive capacity of susceptible species and their limits to changes in their environment, both natural or anthropogenic. Thus, the main objectives of the polar team of the "Laboratoire International Associated Biodiversity and areas sensitive to climate change" (LIA 647 *BioSensib* supported by the CSM, the Ecology and Environment Institute of the CNRS, and the University of Strasbourg) is not only to assess how phenotypic flexibility and plasticity enable Antarctic and sub-Antarctic penguin individuals and populations to adapt to ecosystem changes, but also to evaluate potential micro-evolutionary processes, to ultimately model population trajectories and extinction risks of these populations under projections of environmental change scenarios forecast, for instance, by the Intergovernmental Panel on Climate Change. To do so, technological innovations are developed by the team to monitor and track animals while reducing/avoiding human-induced disturbance and resulting biases.

Polar biology: Field work using a rover camouflaged with an emperor penguin chick model "huddling" with chicks in a crèche.The rover was able to infiltrate the emperor penguin crèche without disturbance, thus demonstrating the possibility to use such a camouflaged rover to collect data from locations within a colony that are not accessible to a human investigator. Picture by Frédérique Olivier © John Downer Production

The CSM welcomes within its teams, and within the framework of the programs elaborated above, post-doctoral visitors funded by international programs, such as National Science Foundation grants. The CSM also periodically has openings for doctoral and post-doctoral financing, generally announced on its website.

To know more about the research and facilities at CSM, visit our website: www.centre scientifique.mc

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