PROGRAMMES & PROJECTS

Service d'Observation CORAIL

A Long-Term Monitoring Program for the Coral Reefs of the South Pacific

http://observatoire.criobe.pf

Context, Motivations and Scientific Objectives

Since its inception more than 40 years ago, CRIOBE set out to establish a rigorous long-term scientific monitoring program to detect temporal fluctuations in the condition of the coral reefs of French Polynesia. Today, this multi-faceted program, spanning many sites and island states, is known as Service d'Observatoire CORAIL (SO CORAIL).

The first data were collected in 1971 on Tiahura reef, in the north-western part of Moorea. However only in 1983 was a long-term monitoring program was truly established. Today we have more than three decades of scientific observations and data not only from around Moorea, and the archipelagos of French Polynesia, but also more recently from the small neighbouring island states and territories of the Global Coral Reef Monitoring Network (GCRMN) that form the Polynesia Mana network. The taxa that are monitored include all fish encountered (down to species level), corals (down to genus level), benthic algae and other benthic invertebrates. Physico-chemical parameters are also monitored. In 2007, France's Institut National des Sciences de l'Univers (INSU) recognized CRIOBE for their efforts and successes in the South Pacific and formally integrated their monitoring work into France's portfolio of Scientific Observatories (SO).

SO CORAIL: CRIOBE's Long-Term Coral Reef Monitoring Program

The main objective of the SO CORAIL monitoring program, as conceptualized by INSU, is to better understand how physical and biological systems change through time. For biological systems, a focus is placed on exploring the drivers that regulate ecological processes over many generations. It is only long-term data sets with a specific comprehensive set of variables which can reliably document the natural evolution of a system, discover changes within this system, and, more importantly, determine whether these changes can be attributed to seasonal variability or are a part of long-term processes of change. A successful monitoring program considers all aspects of an ecosystem and uses methods that allow variability over time and space to be ascertained. A long-term approach is of particular importance for the study of marine ecosystems, where change typically happens slowly, but where the impacts of this change can have significant consequences for coastal communities and environments.

SO CORAIL has adopted this long-term view in its monitoring of the coral reef communities of French Polynesia and the South Pacific. The overall objective of SO CORAIL is the systematic and coordinated acquisition of a common set of **hydrological, climatic, chemical** and **biological** parameters across sites spanning more than 10 million km^2 throughout French Polynesia and the South Pacific. Through a systematic and coordinated approach across all sites, meaningful conclusions about how systems change over time and space can be drawn.

Results from long-term monitoring efforts are being used to:

1. Define a baseline at each site such that any deviations from this state can be investigated.
2. Identify inter-annual fluctuations, within and across sites.
3. Identify common fluctuations across sites to study how coral reef ecosystems respond to disturbance, of natural and anthropogenic origin, and to distinguish between these two sources of variability.

An important point especially worth mentioning now, when the world is deeply concerned about global warming and climate change, is that if we are to effectively monitor changes in an ecosystem, we cannot restrict ourselves to biological parameters. Rather it is important to couple biological observations with the collection of physical and chemical parameters, so as to acquire the data necessary for modelling scenarios used to study environmental change. Thus SO CRIOBE collects the following comprehensive set of data:

- Biological data (diversity, abundance, biomass for each of the different biological components of the ecosystem)
- Physical data (temperature, salinity, currents, swell, and climatology)
- Chemical data (concentration measurements and the flow of inorganic materials, nutrients, sedimentation, pollution, etc.)

Geographic Coverage

The SO CORAIL is the first monitoring network of its size, spanning an area of more than 10 million km^2 and extending across nearly 4700 km between Pitcairn Island and Tonga. There are currently 15 island sites within the SO CORAIL network (Figure 1). In French Polynesia itself, monitoring sites are spread across 10 islands belonging to four of the territory's archipelagos:

1. Society Islands: Moorea (3 sites), Tahiti (3 sites), Tetiaroa, Raiatea
2. Tuamotu Archipelago Gambier: Nengo Nengo, Marutea south, Rangiroa, Tikehau
3. Marquesas Islands: Nuku Hiva
4. Archipelago Austral: Tubuai

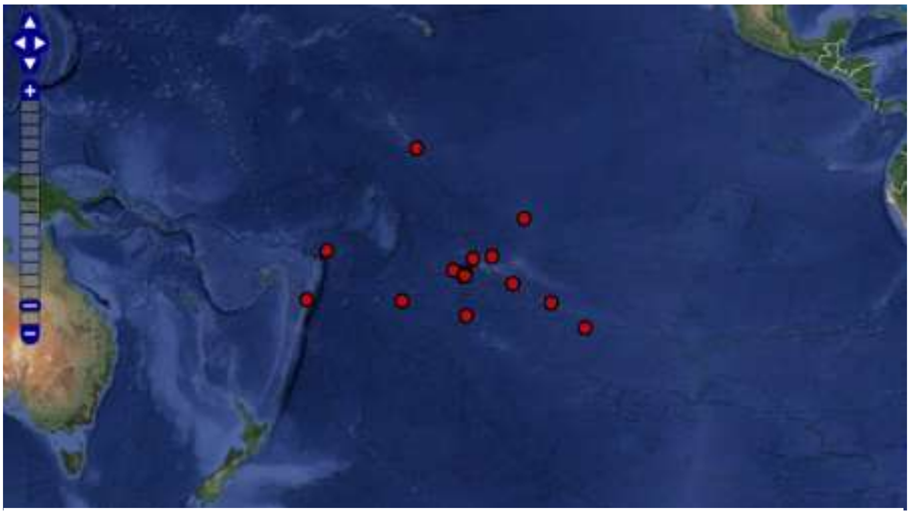

Figure 1. Location of the 19 monitoring sites (red dots) within the current CORAIL LTMP Network

In 1999, SO CORAIL was transformed into a wider regional network, with one new site added in each of the following 5 countries: the Cook Islands (Rarotonga), Kiribati (Christmas Island), Pitcairn Island (UK), Samoa (Apia) and Tonga (Tongatapu).

What began over 40 years ago as the work of one researcher, focused on the biology of corals and fish at a single site on the island of Moorea, has now expanded by many orders of magnitude, to create a network that now spans multiple countries and is integrated within the Global Coral Reef Monitoring Network (ICRI-GCRMN). The details of this expansion are documented in the table 1. Notably, in 1992, Clive Wilkinson (GCRMN) and Bernard Salvat (EPHE) established 'Polynesia Mana', a coral reef monitoring network spanning French Polynesia and the small neighbouring island states and territories of the Cook Islands, Kiribati, Tokelau, Tonga, Pitcairn, Niue, Wallis and Futuna. Polynesia Mana is managed by CRIOBE in partnership with CRISP, SPREP and AFD.

Context	Target	Location	Start	Duration
Galzin Research	Fish, Benthic Communities	Tiahura/Moorea	1983	28 years
CRIOBE Research (ATPP)	Fish, Benthic Communities	Tiahura/Moorea	1990	25 years
GCRMN, Polynesia Mana	Corals, Fish	French Polynesia, 10 Islands	1992	23 years
GCRMN, Polynesia Mana	Corals, Fish	Cook, Kiribati, Niue, Tokelau, Tonga, Wallis and Futuna, Pitcairn, Samoa	1999	16 years
PGEM Moorea	Fish, Benthic Communities	Moorea, Marine Protected Areas	2004	11 years

Table 1. A summary of the history of CRIOBE's long-term biological monitoring efforts

Biological Data

Polynesia Mana has adopted the methods and objectives developed by the GCRMN. It aims to monitor and to understand how populations of corals and fish change through time, particularly in response to natural and climate-change related disturbances (Fig. 2). Each site is surveyed, at a minimum, on a biennial basis. Biological measurements are made at a depth of 7 to 12 m, and carried out according to several techniques and at differing spatial scales:

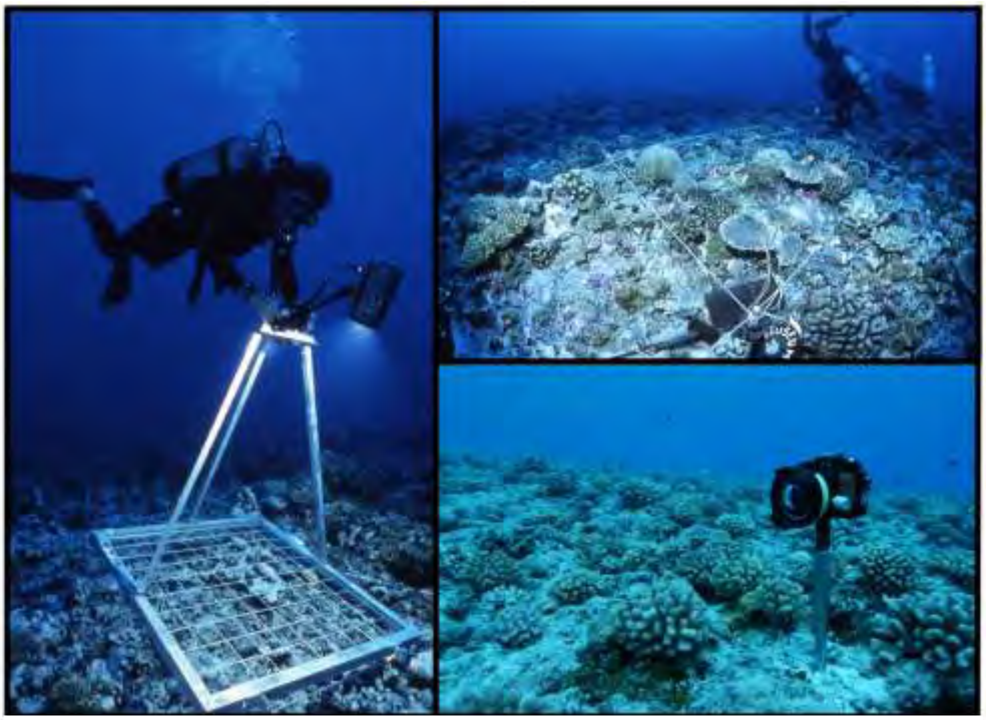

Figure 2. Some of the different techniques used to collect benthic biodiversity data.

- Coral populations are studied in great detail over an area of 20 m^2 using a photographic technique (20 permanent quadrats).
- Broadscale Manta tows are conducted along the outer reef slope for semi-quantitative assessment of coral cover.
- Landscapes are monitored using photographic surveys along on a fixed transect.
- Fish are censused along transects on which the species and size of each individual is recorded.

Further information on sampling methods can be found at http://observatoire.criobe.pf.

Physicochemical Parameters

The need for physical and chemical data to be collected in parallel with biological surveys has led to the deployment of permanent measuring devices across the network of study sites. Table 2 provides details on the equipment deployed at each site. The physical and chemical parameters selected for inclusion into the SO CORAIL monitoring protocol (temperature of the sea water, hydrodynamics of mineral salts and dissolved gases) yield valuable data with respect to direct and indirect impacts of natural disturbances or global climate change, as well as local anthropogenic pressures (waste water, urbanization, changes in the coastline, exploitation of resources).

Figure 3. View of the data logger as set out on the reef to collect environmental parameters.

There are 3 types of automated instruments currently used to measure physicochemical parameters (see Fig. 3). These are:

SBE56 Sea-Bird Thermographs. Today, SBE56 Sea-Bird thermographs are installed at all SO CORAIL sites. Prior to the Sea-Bird, several other models of thermographs were used, including the Stowaway and Pro V2 models by ONSET (accuracy: 0.2 ° C resolution 0.02 ° C to 25 ° C). Through trial and error, the Sea-Bird model has proven to be more efficient and stable than other models, so starting in 2010 older models were phased out and replaced with the Sea-Bird. They have proven reliable at significant depths from 1-55m at the SO CORAIL site in Moorea-Tiahura, and across vast geographies in the GCRMN Polynesia Mana Network. Data is automatically recorded at hourly intervals for all sites, and data reports are generated twice a year.

Sea-Bird SB26plus Probes. The Sea-Bird probe precisely measures conductivity (precision 0.0005, resolution 0.00005), temperature (precision 0005, resolution 0.0001) and pressure associated with depth and swell (precision 0.02%, resolution 0.002%). Probes are strategically placed on each archipelago of French Polynesia, and one in each additional territory or state within the GCRMN Polynesia Mana network. Tide is automatically measured every 15 minutes, waves are measured every hour, and data reports are generated twice a year.

Sea-Bird SB16plusV2 / SBE18 / SBE43 Probes / WET Labs ECO FLNTU. These probes can measure not only temperature and conductivity (like the Sea-Bird SB26plus), but also dissolved oxygen (precision 2%) and pH (precision 0.1 pH). These probes are also equipped with turbidity and chlorophyll sensors. However, the lifespan of these probes is limited, generally from 6-9 months, and, because of the need to replace them frequently, they are installed at locations close to the CRIOBE laboratory (within 60km) and at sites where they can be easily accessed. Two sites in Moorea and Tahiti are currently equipped with these probes. Data is collected automatically every 3 hours and data reports are generated twice a year.

The collection of nutrient data is not currently automated and is performed on a monthly basis through the collection of sea water samples for analysis of phosphate, nitrate, nitrite, carbonate, silicate and ammonium. This sampling is done solely for the Moorea/Tiahura site, with samples taken from each of the three primary geomorphologic reef structures: fringing reef, barrier reef and outer reef slope.

Island	Prof (m)	Position (°, mn, 100° mn), WGS 84	Fre-quency	Instrument	Parameters	First Record	Frequency of Sampling
Apia (Samoa)	35	13°48,354S/172°01,915W	15 mn	Sonde SB26	T°, waves, sea level	15/05/13	F sampling routine, 2 years
Apia (Samoa)	10	13°48,354S/172°01,915W	1 heure	Thermographe SB56	T°	15/05/13	F sampling routine, 2 years
Christmas Island (Kiribati)	10	01°57.398N/157°29.368W	1 heure	Thermographe SB56	T°	10/11/10	F sampling routine, 2 years
Christmas Island (Kiribati)	26	01°57.418N/157°29.459W	15 mn	Sonde SB26	T°, waves, sea level	09/11/10	F sampling routine, 2 years
Marutea sud	10	21°29.628S/135°38.489	1 heure	Thermographe SB56	T°	15/09/99	F sampling routine, 2 years
Moorea Moorea Tiahura Bouée Jaune	25	17°28.940S/149°53.985W	1 heure	Sonde SB16	T°, S°/°°, O2, pH, nephelo, chl a	03/07/08	F sampling routine, 6 month
Moorea Moorea Tiahura P14	14	17°28.980S/149°53.985W	1 heure	Thermographe SB56	T°	29/01/98	F sampling routine, 2 years
Moorea Moorea Tiahura P25	25	17°28.960S/149°53.985W	1 heure	Thermographe SB56	T°	29/01/98	F sampling routine, 2 years
Moorea Moorea Tiahura P3	3	17°29S/149°53.985W	1 heure	Thermographe SB56	T°	03/04/98	F sampling routine, 2 years
Moorea Moorea Tiahura P35	35	17°28.940S/149°53.985W	1 heure	Thermographe SB56	T°	25/03/98	F sampling routine, 2 years
Moorea Moorea Tiahura P35	35	17°28.940S/149°53.985W	1 heure	Sonde SB16	T°, S°/°°, O2, pH, nephelo, chl a	01/12/08	F sampling routine, 6 month
Moorea Moorea Tiahura P35	35	17°28.940S/149°53.985W	15 mn	Sonde SB26	T°, waves, sea level	02/01/09	F sampling routine, 2 years
Moorea Moorea Tiahura P55	55	17°28.890S/149°53.985W	1 heure	Thermographe SB56	T°	15/05/99	F sampling routine, 2 years
Moorea Moorea Tiahura P8	8	17°28.996S/149°53.985W	1 heure	Thermographe SB56	T°	29/01/98	F sampling routine, 2 years
Moorea Taotaha	65	17°32.614S/149°54.720W	1 heure	Sonde SB16	T°, S°/°°, O2, pH, nephelo, chl a	01/04/09	F sampling routine, 6 month
Nengo	10	18°42.420S/14152.020W	1 heure	Thermographe SB56	T°	31/08/02	F sampling routine, 2 years
Nuku Hiva	10	08°54.930S/140°00.982W	1 heure	Thermographe SB56	T°	02/10/08	F sampling routine, 2 years
Nuku Hiva	40	08°55.367S/140°01.197W	15 mn	Sonde Sea Bird SB26	T°, waves, sea level	02/10/08	F sampling routine, 2 years
Pitcairn	10	25°03.821S/130°07.254W	1 heure	Thermographe SB56	T°	03/10/09	F sampling routine, 2 years
Pitcairn	36	25°03.361S/130°07.596W	15 mn	Sonde SB26	T°, waves, sea level	03/10/09	F sampling routine, 2 years
Raiatea	12	16°44.230S/151°30.240W	1 heure	Thermographe SB56	T°	06/01/98	F sampling routine, 2 years
Rarotonga (Cook Islands)	12	21°12.920S/159°49.976W	1 heure	Thermographe SB56	T°	01/02/09	F sampling routine, 2 years
Rarotonga (Cook Islands)	35	21°12.906S/159°50.067W	15 mn	Sonde SB26	T°, waves, sea level	01/10/08	F sampling routine, 2 years
Tahiti Motu Uta	52	17°31.334S/149°34.354W	1 heure	Sonde SB16	T°, S°/°°, O2, pH, nephelo, chl a	01/01/10	F sampling routine, 6 month
Tahiti Taapuna	55	17°36.111S/149°37.548W	1 heure	Sonde SB16	T°, S°/°°, O2, pH, nephelo, chl a	01/04/09	F sampling routine, 6 month
Takapoto	9	14°42.24S/145°15.20W	1 heure	Thermographe SB56	T°	24/06/09	F sampling routine, 2 years
Tetiaroa	12	17°01.787S/149°33.322W	1 heure	Thermographe SB56	T°	13/02/03	F sampling routine, 2 years
Tikehau	13	15°00.860S/140°17.290W	1 heure	Thermographe SB56	T°	11/06/02	F sampling routine, 2 years
Tikehau	35	15°00.860S/140°17.290W	15 mn	Sonde SB26	T°, waves, sea level	03/07/09	F sampling routine, 2 years
Tongatapu (Tonga)	12	21°04.046S/175°20.256W	1 heure	Thermographe SB56	T°	20/10/09	F sampling routine, 2 years
Tongatapu (Tonga)	35	21°04.046S/175°20.256W	15 mn	Sonde SB26	T°, waves, sea level	19/10/09	F sampling routine, 2 years
Tubuai	14	23°20.66S/149°24.22W	1 heure	Thermographe SB56	T°	24/01/02	F sampling routine, 2 years
Tubuai	35	23°20.66S/149°24.22W	15 mn	Sonde SB26	T°, waves, sea level	01/12/09	F sampling routine, 2 years

Table 2. Location and measurement details for probes and thermographs deployed throughout SO CORAIL network (* = sites located outside of French Polynesia)

Sampling Duration
Collection of physico-chemical data began officially in 2007, but it was not until 2010 that the network had the full suite of equipment and processes in place. It is considered that two decades (2010-2030) of physicochemical and biological data will be required to run an analysis powerful enough to deliver results providing insight into the impacts of global climate change on reefs. Twenty years is considered a 'magic number' in the context of coral reefs, where biological cycles are typically of this order of magnitude.

Data Storage and Security
Two types of data are archived as part of SO CORAIL. First, there is the metadata. Metadata provides a detailed description of the study sites, the methodology for collecting data on corals and fish, details pertaining to the instrumentation used (deployment and technical specifications), the structure of the data collected, and details of the observers or individuals responsible for data collection. Second, there is the data itself. Data are stored in raw Excel file format. Metadata and data are stored in duplicate on computers that are physically located at CRIOBE in Moorea, French Polynesia and Perpignan, France (CRIOBE). In addition, all data is stored online in a virtual Cloud storage setting. Metadata is currently accessible on the Internet at http://observatoire.criobe.pf. Access is unrestricted and the metadata is downloadable in PDF format.

Use of Data by Interested Scientists
All raw data is available through an online infographic available at http://observatoire.criobe.pf. Interested parties must submit a signed application form (located on the website) to gain access to the data. The form simply asks for the name of the person making the request, the data they are interested in and a brief description on how the data will be used. To date, there have been no restrictions on the use of data. By signing the form, users also agree to acknowledge SO CORAIL in any publications resulting from the use of the data. All these projects fall under the auspices of the INSU (Institut National des Sciences de l'Univers) of the CNRS.

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GREEN BUBBLES

The European Project on Sustainable Diving

www.greenbubbles.eu

Recreational SCUBA diving has become a mass leisure activity engaging millions of divers worldwide. The diving industry generates large direct and indirect revenues for local communities and Marine Protected Areas (MPAs). Other benefits linked to diving include the promotion of environmental and ocean stewardship, contribution to scientific research, fostering social inclusion and personal development. Yet, diving has also negative impacts, due to damage or disturbance of habitats and organisms and to conflicts with local communities for the access to/use of the same resources, equity issues, or cultural clashes. These aspects clearly relate to the three pillars of sustainability, covering environmental, economic and social dimensions and can only be addressed by a systemic approach.

The central objective of Green Bubbles is to maximise the benefits associated with diving, whilst minimising its negative impacts, thus achieving the environmental, economic and social sustainability of the system. This will be done by:

Carefully assessing and modelling the system itself;
Developing innovative products based on the issues and needs highlighted by assessment and modelling;