Lagoon hydrodynamics of pearl farming atolls: the case of Raroia, Takapoto, Apataki and Takaroa (French Polynesia)

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Abstract.

Between 2018 and 2022, four pearl farming Tuamotu atolls of French Polynesia were monitored with autonomous oceanographic instruments to measure the hydrodynamics of atoll lagoons and the ocean-lagoon water exchanges. These surveys were conducted in the frame of the ANR-funded MANA (*Management of Atolls*) project and its extensions to additional sites. The overarching goal was to improve knowledge on the processes influencing the spat collection of the pearl oyster *Pinctada margaritifera,* the oyster species used to produce black pearls. These data sets are also critical for the calibration and validation of 3D high spatial resolution hydrodynamic models used to study the oyster larval dispersal within lagoons. The observational strategies focused on the characterization of ocean/lagoon exchanges through passes and *hoa* (i.e., shallow reef flats), lagoon circulation, incident waves breaking on the forereef, water elevation inside lagoon as well as spatial temperature variability. Chronologically, the investigated atolls were first Raroia Atoll with 9 months measurements between May 2018 and March 2019 during which the MALIS1 and MALIS2 cruises on-board the R/V ALIS took place. It was followed by a 4-month deployment in Takapoto Atoll (November 2021 to March 2022). In late April 2022, Apataki Atoll was instrumented until end of July, followed by Takaroa measurements between July to October

2022. Apataki (Leg2) and Takaroa Atoll were conjointly instrumented during the MALIS 3 oceanographic cruise. Altogether, those multi-atoll data bring a worldwide unique oceanographic atoll data set, useful to address local pearl farming questions but potentially beneficial for other fundamental and applied investigations. Each data set was post processed, quality controlled and converted in NetCDF format. Files are available in open source into dedicated repositories in the SEANOE marine data platform with permanent DOIs.

1 Introduction

This ~~report~~ study focuses on hydrodynamic data collected between 2018 and 2022 on four pearl farming atolls of the Tuamotu Archipelago, in French Polynesia. French Polynesia (FP) is a French overseas collectivity located in the Central Pacific Ocean (134° to 155°W and 7° to 27°S). It consists of five archipelagos (Figure 1b) and 118 atolls and high islands spread on a vast ~~4.8 million km²~~ Exclusive Economic Zone (EEZ) with 4.8 million km² (Andréfouët and Adjeroud, 2019). The Tuamotu and Gambier Archipelagoes include a total of 77 atolls and several high islands that are found in the lagoon of Gambier. Five of the atolls are actually with dry or uplifted lagoons. The other 72 atolls all have an intertidal/partly emerged rim ~~which~~ surroundings the~~a~~ lagoon. Among the atolls with a deep (>20 m) lagoon, about 30 have been black pearl farming atolls since the beginning of this activity in the late 1980s.~~,~~ Currently, as in 2023, only 20 are active or operational~~although only about 20 are currently active as in 2023~~.

Black pearl farming is the second source of French Polynesia income after tourism. In 2021, it represented a 40 million € value in exports (Andréfouët et al., 2022a). This activity emerged as a major activity after nearly 60 years of trials and pioneer work. Since the 1980s and especially the 1990s, the number of exploitations boomed, ~~thanks~~ due to the presence of abundant oyster *Pinctada margaritifera* natural stocks. This stock has allowed to efficiently collect spats in several lagoons, and a sustained supply of oysters for pearl productions. The activity thus includes oyster production (through spat collection) and pearl production. In 2021, 8136 ha of lagoon concessions were ~~devoted~~ dedicated to these activities (DRM, 2021). Four islands and atolls (Gambier, Marutea Sud, Ahe, and Arutua) represent half of the concessions but many other atolls contribute to the activity (such as Apataki, Takapoto, Takaroa, Katiu, Kauehi, Raroia, etc.). However, ~~, although~~ there are ups and downs. For instance, Takaroa atoll lagoon suffered a major dystrophy event in 2014 (Rodier et al., 2019), resulting in a mass mortality of oysters and spats. Since then, the activity is moribund in this lagoon, and has not yet ~~revived~~ recovered as in 2023. Overall in French Polynesia, the numbers of farmers have decreased the past years and now stabilized at around 600 farmers, with 340 of them producing pearls.

Since the first mortality events in Takapoto atoll in the 1980s, pearl faming lagoons have been the objects of numerous scientific investigations related to the biology and ecophysiology of *P. margaritifera*, the estimation of natural stocks, or the characterization of the planktonic trophic web and food sources for oysters, among many other topics (Le Pennec, 2010; Andréfouët et al., 2012a, 2022; Gueguen et al., 2016). Lagoon hydrodynamics became a focus during the *Programme General Recherche sur la Nacre* 2 (PGRN2) in the late 1990s, using a comparative approach between atoll lagoons but with limited field measurements (Pagès et al., 2001; Andréfouët al., 2001a), in the wake of the comparative TYPATOLL program (Dufour and Harmelin-Vivien, 1997).

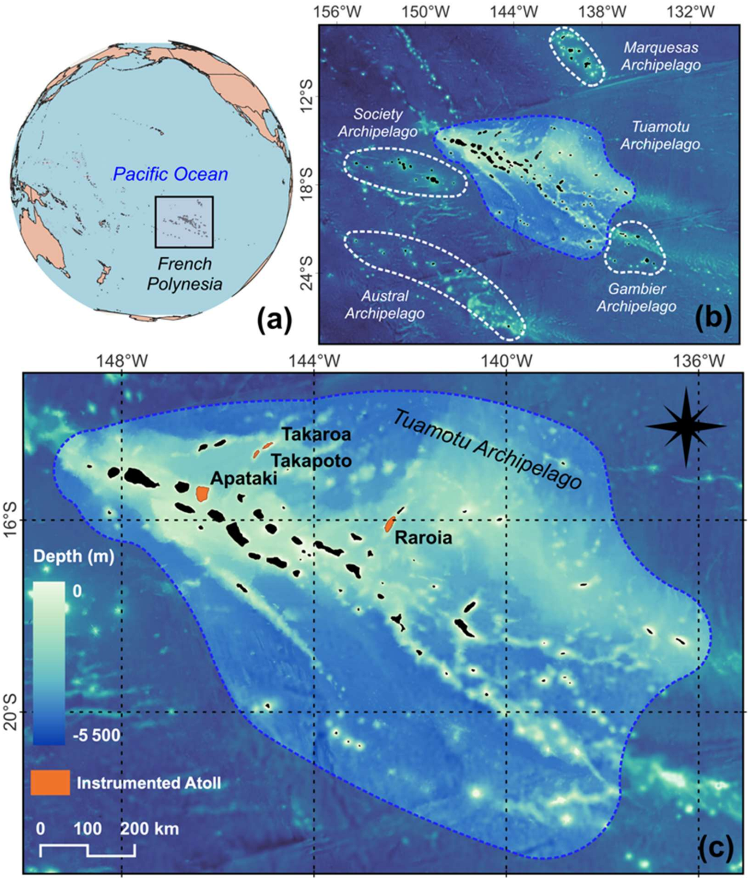

Figure 1: Map of French Polynesia Archipelagos and GEBCO bathymetry (GEBCO Compilation Group 2023). The instrumented atolls of Tuamotu Archipelago that are the focus of this study are colored in orange (Raroia, Takapoto, Apataki, Takaroa).

Following the first Tuamotu-Gambier atoll hydrodynamic modelling work by Tartinville et al. (1997) that investigated Moruroa aAtoll in the context of nuclear weapon tests consequences, a workshop in 2004 in

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Tahiti identified the main steps required to achieve 3D high spatial resolution numerical models to address pearl farming questions (Andréfouët et al., 2006). A high priority topic was to better understand spat collection variability, for which it was necessary to better characterize *P. margaritifera* larval dispersal phase in spat collection lagoons exposed to different oceanographic and atmospheric forcings.
Ahe atoll became the first atoll investigated for 3D hydrodynamical modelling, with for the first time a large array of *in situ* measurements (Dumas et al., 2012). Ahe atoll had a one-year dedicated field program in 2008-2009 (see Le Gendre, 2020a for sampling strategy), followed by a dedicated oceanographic POLYPERL cruise in 2013 (Andréfouët, 2013~~https://doi.org/10.17600/13100050~~). Ahe was followed by Takaroa atoll but only with a short field expedition in 2009 (see Le Gendre, 2020b for sampling strategy). Results from Ahe atoll model proved to be very useful to characterize larval dispersal variability (Thomas et al., 2012; 2014; 2016).

To build on these first results, the ANR-funded MANA (*Management of Atolls*) project was launched in 2017 (Andréfouët et al., 2022a) and was completed in September 2022. The project overarching goals were to provide new spatially explicit products useful for the management of geomorphologically diverse pearl farming atolls (namely Ahe, Takaroa, Raroia in French Polynesia and Manihiki in the Cook Islands). Focus was still on understanding spat collection on different sites, but also provide guidelines for stock management and restocking (André et al., 2022, Violette et al., 2023). Funds and instruments provided by the local *Direction des Ressources Marines* (DRM) in charge of the management of pearl farming lagoons expended the ~~ANR~~ MANA project to two new sites (Gambier Islands and Takapoto Atoll). Finally, the *Commission Nationale de la Flotte Côtiere* also supported the project with ship time (R/V ALIS) for 2 cruises in Raroia Atoll in 2018 (Andréfouët, 2018) and one cruise targeting in particular the Apataki and Takaroa Atolls in 2022 ~~(respectively, https://doi.org/10.17600/18000582 and~~ Andréfouët and Le Gendre, 2022~~https://doi.org/10.17600/18001644~~).
This paper reports on the *in situ* data collected in the frame of the ~~ANR~~ MANA project and its derivatives on Raroia Takapoto, Takaroa and Apataki atolls between 2018 and 2022 (Figure ~~2~~1). It is organized as follow: Section 2 briefly presents the French Polynesia climate to draw the regional context, and the general sampling strategy applied to atolls during the MANA project considering the typical geomorphology of atolls and their lagoons and the hydrodynamic processes at stake. Then, the sampling strategy specific to the different study sites are developed in Section 3. Oceanographic instruments used during all surveys are detailed in Section 4 and data processing specificities are provided in Section 5. Examples of results are provided in section 6. Section 7 finally informs on data availability followed by Section 8 which concludes this paper.

2 The French Polynesia atolls context: climate, geomorphology and hydrodynamic processes

2.1 French Polynesia climate

Due to the large latitudinal and longitudinal variations, there are local weather differences between French Polynesia archipelagoes, but overall, the French Polynesia climate has two seasons (Laurent and Maamaatuaiahutapu, 2019). The wet and warm season ranges from November to April (Austral summer) with weak trade winds (northeast to southeast) and moderate waves including distant swells born in the northern hemisphere. Then, a cooler and dryer season occurs from May to October (Austral winter), with stronger trade winds and high energy distant swells from southern hemisphere. The weather is influenced by the proximity of the South Pacific Convergence Zone (SPCZ) leading to higher rainfalls during December to March, albeit with significant spatial and interannual variations between archipelagoes (Laurent and Maamaatuaiahutapu, 2019).

The interannual El Niño-Southern Oscillation (ENSO) affects the French Polynesian climate and particularly precipitations and trade wind regimes. ENSO influences the position of the SPCZ which leads to increased precipitations, higher occurrences of tropical cyclones and changes in wind regimes during the El Niño phase (Laurent and Varney, 2014). Conversely, the La Niña phase exacerbates the main features of the neutral years, with lower precipitation and drought especially in the north (Marquesas Archipelago), and lower east to southeast trade winds overall.

The wind and wave regimes of French Polynesia with a focus on pearl farming sites was recently revisited at different temporal scales (Dutheil et al., 2020; 2021). The wave regime is much more spatially variable and atoll-dependent than the wind regime considering the shadowing effects on the propagation of wave trains created by the position of atolls relative to each other (Andréfouët et al., 2012b, 2022a).

2.2 Atoll geomorphology and hydrodynamic process: the clues for the MANA project field data collection strategy

During the MANA project and its extensions, a total of four atolls (Raroia, Takapoto, Apataki and Takaroa, Figure 2, Table 1) have been instrumented with physical instruments to better understand the processes influencing *Pinctada margaritifera* spat collection variability. Instruments were also needed~~,~~ ~~by helping~~ for the calibration and validation of 3D high spatial resolution hydrodynamical models and to improve the realism of existing models. The deployments took place between 2018 and 2022, with an interruption due to the COVID pandemic (Figure 3). We describe in this section the general features encountered on all atolls and the principles used for the sampling strategy to capture the main hydrodynamic processes. The Section 3 provides the sampling specifics per atoll.

High resolution bathymetry data were collected by private sub-contractors using a mono-beam (Takaroa atoll) or multibeam (Takapoto, Raroia atolls) sounders (Andréfouët et al., 2020). Soundings were resampled and interpolated to achieve a 10 m resolution bathymetric grid for Raroia and Takapoto and a 60m resolution grid for Takaroa Atoll, prior to the development of hydrodynamic models. Conversely, the Apataki lagoon has not been entirely mapped yet as in 2023.

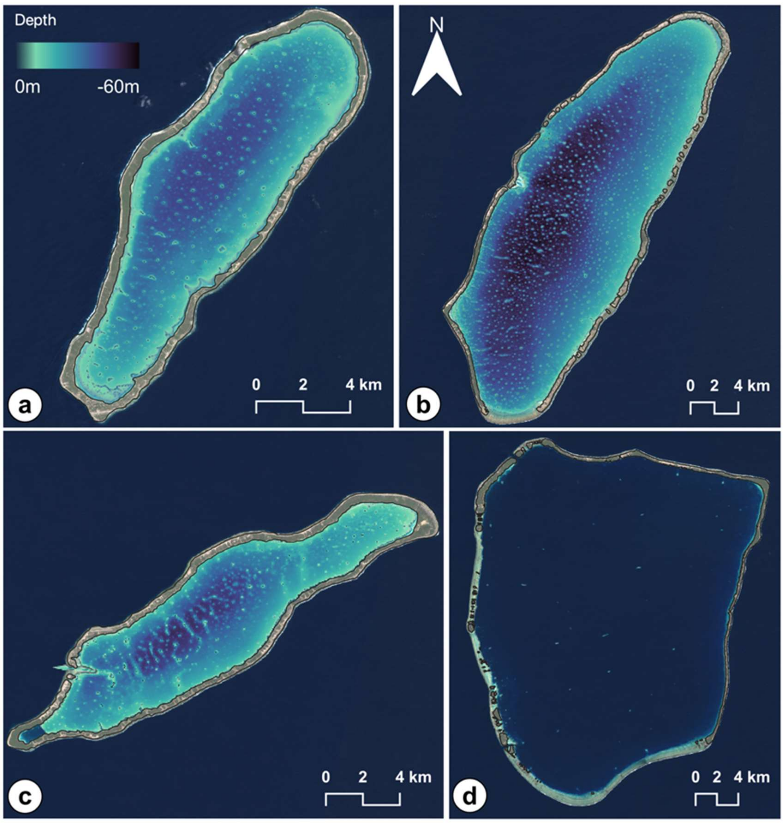

Figure 2: Bathymetry (described in Andréfouët et al., 2020) and *motu* contours for (a~~A~~) Takapoto Atoll, (b~~B~~) Raroia Atoll, (c~~C~~) Takaroa Atoll. Depth color-scale is identical for the three atolls. For Apataki Atoll (d~~D~~), there are no complete lagoon bathymetry data available yet. Background satellite images are from Sentinel-2 (Copernicus Sentinel 2, 2021)~~, European Space Agency (ESA)~~.

Table 1: Additional information about instrumented atolls (from Andréfouët et al. 2020).

Atoll	Type	Perimeter (km)	Area (km^2)	Mean depth (m)	Maximum depth (m)	Number of pinnacles
Raroia	Semi-open	93.70	367.95	32.2	68	1434

Takapoto	Closed	49.50	78.64	24.8	43	194
Apataki	Semi-open	109.23	678.45	NA	NA	63
Takaroa	Semi-closed	61.52	85.96	25.8	48	246

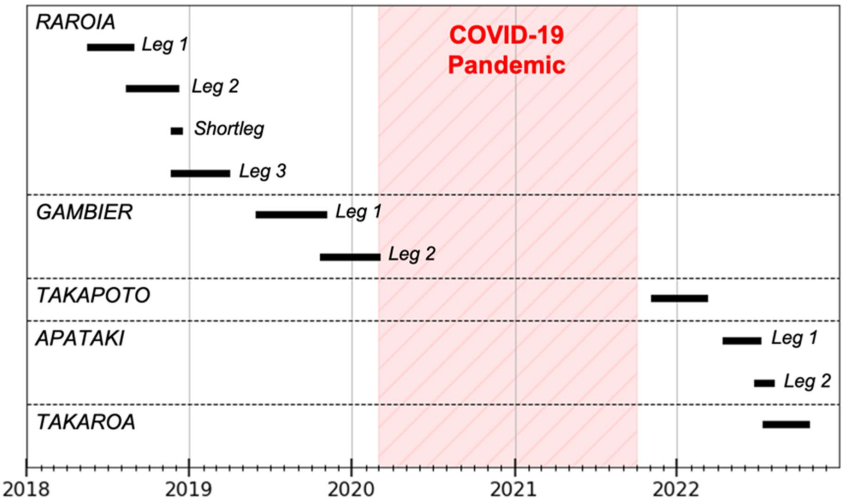

Figure 3: MANA project deployments between May 2018 and November 2022. Gambier Islands are another site studied from mid-2019 to February 2020. It is a group of high islands and data will be presented elsewhere (Bruyère et al. 2023d) because the sampling strategy obey to different criteria than atolls.

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Extrinsic factors (such as the wind or wave regimes) and intrinsic factors (such as the degree of aperture) are both strong drivers of ~~the differences in~~ hydrobiogeochemical functioning ~~between~~ in atoll lagoonss (Dufour et al., 2001, Andréfouët al., 2001a). They both need to be taken into account when sampling atoll lagoons for their hydrodynamics, as explained hereafter in generic terms.

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Wind and wave influence the lagoon renewal and its circulation. At archipelago-scale, the swell climate of any given atoll is highly dependent on its position relative to other atolls that can block the incoming swells (Andréfouët et al., 2012b). For instance, the large Tuamotu atolls in the south of the archipelago (Rangiroa, Fakarava, Kaukura, etc.) block all incoming southern swells. It is therefore necessary to measure incoming waves with pressure sensors on, if possible, all the sectors of exposition of the studied atoll. Regional wave models are also useful to assess the conditions during a survey, and Wave Watch III model data have been used at high spatial resolution in some cases (Andréfouët et al., 2012b; Dutheil et al., 2021; Andréfouët et al., 2022; Andréfouët et al., ~~submitted~~2023a). Wind data is generally not monitored during shore-based field campaigns as we relied on either nearby Météo-France weather station if possible (e.g., Takaroa, Gambier Islands, data available through https://publitheque.meteo.fr) or ERA5 reanalysis data (Hersbach et al., 2020). When on board the R/V ALIS, the ship weather station also records wind data.

Although all atolls can be different in terms of lagoon bathymetry (Andréfouët el al., 2020), size, and exposure to wind and waves, all atolls share common geomorphological features that play a role in the lagoon hydrodynamics. Atoll landforms siting on the atoll rims are reef islands (locally named *motu*). They result from the accumulation of carbonate sediments above antecedent (Holocene) conglomerate platforms (Montaggioni et al., 2021). Rims can be vegetated or not (Andréfouët et al., 2001b). Atoll rims can have 0, 1, 2 or 3 (at maximum) deep passages (or pass) and a number of (from a handful to several hundreds) shallow spillways (locally named *hoa*) along the atoll rim that connect the ocean to the lagoon.

In generic terms, water movements from the ocean to the lagoon through the pass and shallow *hoa* are controlled by tide and waves. Note first that the tidal range in this region of the world is low (10 to 50 cm maximum in the ocean from west Tuamotu to Gambier Archipelago) due to the presence of an amphidromic point west of Tuamotu (Dumas et al., 2012; Laurent and Maamaatuaiahutapu, 2019). All the sites treated here are thus in a micro-tidal environment. Incoming waves breaking on the atoll crest directly modulate the flows through the wave-exposed open spillways (Tartinville et al., 1997; Dumas et al., 2012; Aucan et al., 2021; Andréfouët al., 2022b). Number and width of *hoa* are used to define the degree of aperture of an atoll, as a coarse proxy useful to characterize the water exchanges between ocean and lagoon and some biogeochemical variables (Dufour et al., 2001).

The degree of aperture of the atoll also influences the lag between oceanic and lagoonal tides. Even atolls with wide deep passes experience a few hours shift in tidal lagoon signal compared to the ocean. They are also subjected to a lagoon tidal amplitude lower than in the ocean (Dumas et al., 2012; Aucan et al., 2021). These differences are also a factor that complicates the establishment of a common water level baseline between lagoon and ocean (Callaghan et al., 2006). It is a problem specific to atolls with passes (Aucan et al., 2021). Without the availability of appropriate differential sensors (see Sensor section hereafter), the water level baseline is therefore established around the average sea level measured in the lagoon or ocean (Aucan et al., 2021).

In the lagoon, even if current speeds are typically low (Dumas et al., 2012), internal circulation cells occur, that are highly dynamic and predominantly controlled by wind speed and direction, as shown for instance for Ahe (Dumas et al., 2012) or Mururoa Atolls (Tartinville et al., 1997). A large lagoon is potentially much more complex in term of numbers and dynamics of these hydrodynamic cells than the smaller atolls. If there is a pass, its influence can generate locally strong currents; but it is nevertheless spatially limited due to the alternant incoming-outgoing tide-driven currents (Dumas et al., 2012).

Temperature in the lagoon influences oyster development, survival at larval and adult stages, and the final pearl quality, plus other indirect factors such as plankton availability (Thomas et al., 2010; Le Moullac et al., 2016; Latchere et al., 2018; Sangare et al., 2020). Temperature is monitored according to an array of temperature-measuring sensors deployed in the ocean, passes, *hoa* and lagoon. In the lagoon, a systematic spatial coverage is sought as well as a 3D coverage by deploying sensors vertically at sub-surface (approximately 2 m), 10 meters and at last 40 meters depth. This information is also useful to assess lagoon stratification during low wind periods.

~~To summarize, T~~The MANA observational strategy objectives is integrative of all the aforementioned processes. *In situ* instruments were thus deployed to capture:

- Sea level variations, tidal dynamics and surge (ocean, lagoon), using pressure sensors
- Incoming incident waves on the different atoll sectors and wave (wind-induced) in the lagoon, using pressure sensors
- Currents in *hoa* on different atoll sectors, using current meters or current profilers moored in *hoa* facing the pressure sensors that measure the incident waves
- Currents in passes and inside the lagoon using current profilers
- Water temperature variations in ocean and lagoon in different rim and lagoon sectors, using a variety of temperature-recording sensors (temperature-only, pressure or current-meter sensors)

3. Study sites and sampling strategy

This paper presents data collected between 2018 and 2022 in four Tuamotu Archipelago atolls, chronologically Raroia, Takapoto, Apataki and Takaroa Atoll. The following sections (Sect 3.1; 3.2; 3.3 and 3.4) present each atoll and the implemented observational strategy. The length of data acquisition ranged between 3 to 9 months. Raroia and Apataki deployments were organized in legs to achieve long deployment duration while allowing regular instrument maintenance (e.g., battery replacing, bio-fouling, offloaded data, check mooring component). The beginning or end of a leg is thus generally synonymous of short data collection interruption for maintenance. Long deployments were a combination of shore based and research vessel-based work. Atolls were equipped with five different types of instruments namely Acoustic Doppler Current Profilers (ADCPs), current profilers, drag-tilt current meters, temperature and pressure loggers, and temperature sensors ~~ADCPs, Aquadopps, Marotte HS, RBRduet T.D and SBE56 measuring physical process such as current velocity, temperature and pressure~~. Instrument configurations and specificities are presented hereafter in a dedicated Section (Section 4).

3.1 Raroia Atoll

Raroia is a large atoll (area 368 km^2) in the central Tuamotu region (Andréfouët et al., 2020). The atoll is oriented along the NE-SW direction (Figure 2) and exposed to the east trade winds. The eastern reef rim is open to the ocean with numerous *hoa* and *motu*. The western side has one deep and wide (500 m) pass (Garue pass) as well as few shallow *hoa*. The southern portion has a wide uninterrupted 5 km-long *hoa*. The northwest and north sides are closed by a vegetated rim.
The lagoon is deep with an average depth of 32 m. It has a typical saucer-shaped geomorphology but with the presence of a very high number of pinnacles (>1600) rising from the floor and distributed homogenously throughout the lagoon (Table 1).
Raroia was the subject of the most complex and intensive deployment. The 9-month physical observations started on middle of May 2019 and ended on late March 2020. The deployments are organized in three legs (respectively between May-August 2018, August to December 2018 and January to March 2019) and one extra "shortleg" conducted during the MALIS2 cruise with a specific setting and deployment (Figure 2). Surveys were in part conducted during the oceanographic campaigns MALIS 1 and MALIS 2 with the R/V ALIS (Andréfouët, 2018; Aucan et al., 2021).
The sampling strategy is summarized in Figure 4. The instruments moored in the lagoon, *hoa*, pass and oceanic sides of the atoll were either moored at the same location during the entire three legs, or their deployment was leg-dependent (see Table A1 in Appendix Section). Three stations were positioned on the external reef slopes on the north-east (O2), south (O3), and north-west (O1) atoll side to measure offshore incident waves with pressure sensors. These oceanic sensors were systematically paired with current meter (profilers or drag-tilt current meters) moored inside *hoa* directly facing the oceanic sensor's location. Water level inside lagoon were recorded at five stations (L4, L5, L6, L7, L8) to deduce surge and tide signal using pressure sensors. Those lagoonal pressure loggers were systematically associated with two temperature sensors moored on the sub-surface and around 20 m depth. These 3-sensor stations were replicated spatially to characterize the within-lagoon spatial heterogeneity. Current profilers were anchored inside three *hoa* (western, eastern and southern) that faced the oceanic pressure sensors. Inside the Garue Pass deep current profilers were moored to evaluate water fluxes lagoonward and oceanward as well as at the edge of the pass lagoonward to study the pass gyre (Pass2). Finally, two additional loggers were positioned in the south lagoon to measure lagoon currents in the spat collection area (L7 and L8). During the short leg, these 2 lagoon profilers were moved to the north lagoon, close to H1 and H2. The Table A1 in Appendix Section refers to the exact period and location of mooring for each sensor.

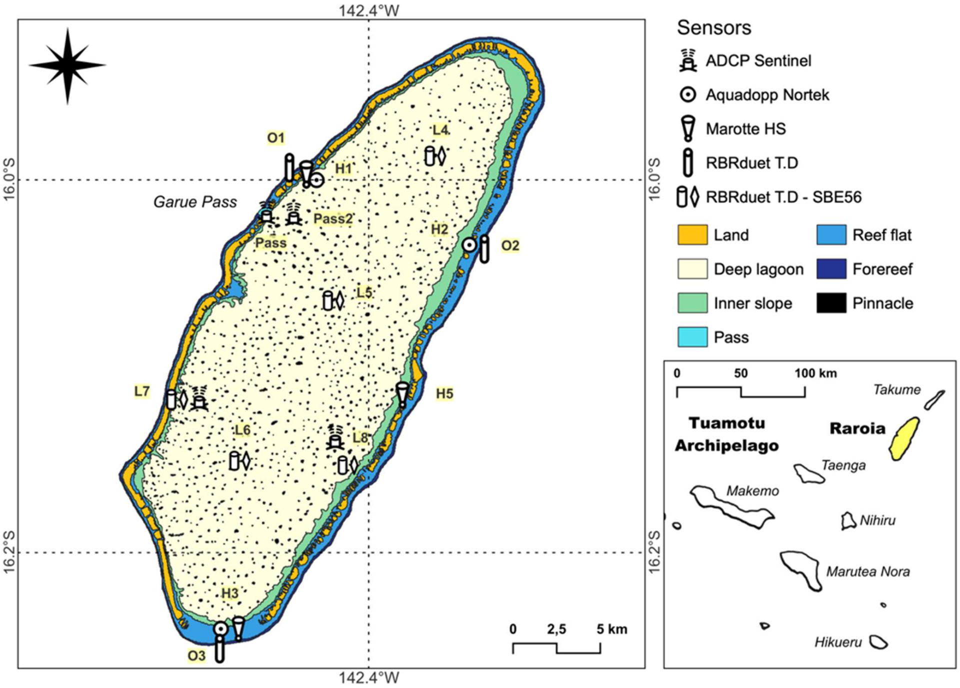

Figure 4: Observational strategy applied during Raroia experiments. ADCP: Acoustic Doppler Current Profiler. Inner slope category is defined approximately between 0-15 m depth. Background map from the Millennium Coral Reef Mapping Project (Andréfouët and Bionaz, 2021). O: oceanic stations. H= *hoa* station. L=Lagoon stations (see TableA1 for details of each station).

3.2 Takapoto Atoll

Takapoto is a medium-size 78 km^2 northwestern Tuamotu atoll. This atoll is distinct from the other studied atolls due to the absence of deep passes connecting the lagoon to the open ocean. It is the most closed of all the study sites with only few several narrow *hoa* present on both the west and east flanks of the atoll (Andréfouët et al., 2022b). The maximal and average lagoon depth are respectively 43 m and 25 m (Table 1). Pinnacles can be found everywhere in the lagoon but their density is higher on the south-west region (Andréfouët et al., 2020).

This atoll was monitored over a 4-month period (November 2021 to March 2022). Measurements focused on the entry of oceanic water via the few active *hoa* present in two regions, namely Teavatika (southest region) and Takaï (northwest region) (Figure 5). Two stations with paired Aquadopp (in the deeper part of *hoa*) and RBRduet T.D (ocean side) were set in Teavatika (station O01 and Aqua2) and Takaï (station O03 and Aqua1) areas in order to measure breaking wave parameters and current velocity related to waves and tides. Inside the lagoon, two additional stations in the middle and south lagoon were instrumented with one RBRduet T.D and two SBE56 (one in sub-surface and one below 30 meters) following the strategy applied for Raroia (see 3.1 Section).

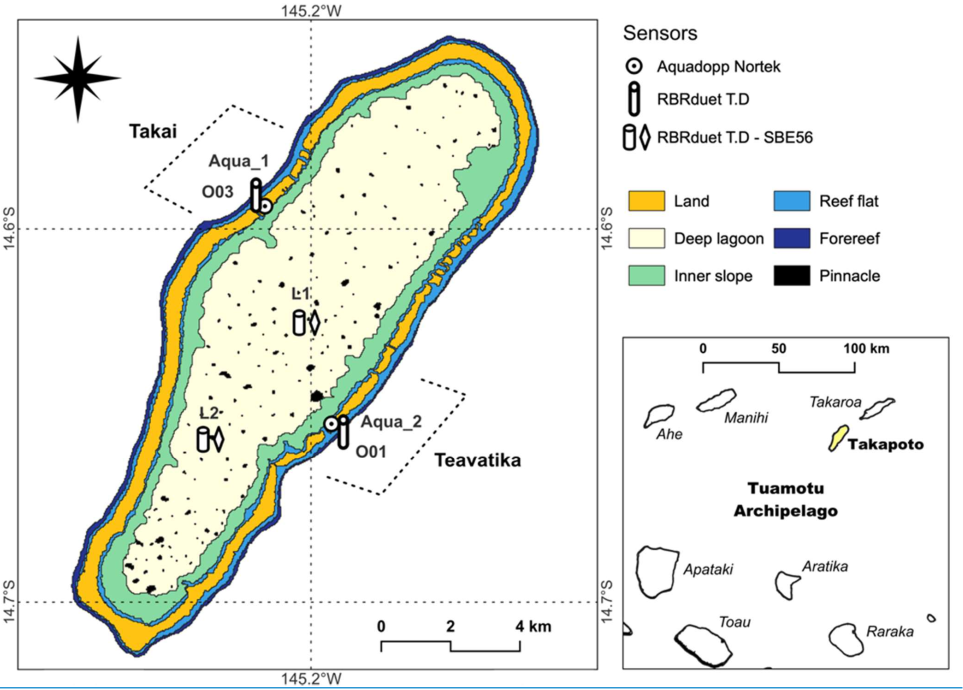

Figure 5: Location of deployed instruments in Takapoto Atoll. Inner slope category is defined approximately between 0-15 m depth. Background map from the Millennium Coral Reef Mapping Project (Andréfouët and Bionaz, 2021). O: oceanic stations. Aqua= *hoa* station. L=Lagoon stations (see TableA1 for details of each station).

3.3 Apataki Atoll

Apataki Atoll is a Western Tuamotu atoll and is the largest instrumented atoll (678 km^2) of the MANA project, representing 8 times the area of Takapoto Atoll (Table 1). The atoll rim is almost completely closed on the east and north sides. The southern region is a 18 km-long, wide open reef flat highly subjected to oceanic entries caused by distant swells (south-south-east are the dominant swell directions). Finally, the western rim is dominated by succession of wide reef flats, narrow *hoa* and *motu*. Two deep passes both located on the west side and respectively named (Pakaka in the south and Tehere in the north) allow to connect oceanic and lagoonal systems. As previously said, complete bathymetric coverage is not yet available for the lagoon and instrumented stations were selected and positioned using satellite imagery. Pinnacles visible on satellite images are few (63, cf. Table 1) and spread over the entire lagoon The resulting data set covers a 4-month period separated into 2 legs: Leg1 (April 2022 to July 2022) and Leg2 (July 2022). Leg2 measurements were managed during the MALIS 3 oceanographic cruise with the R/V ALIS (Andréfouët and Le Gendre, 2022). Lagoonal stations (L1, L2, L3, L6) with one RBRduet T.D and two SBE56 sensors follow the same strategy applied to Raroia and Takapoto (Figure 6). Pressure sensors moored on oceanic forereef were positioned on the south (O1 – O2) and east side (O3) to face *hoa*. The facing southern *hoa* were instrumented with two current profilers (O1 paired with Aqua2 and O2 with Aqua1) in order to record oceanic fluxes crossing the reef. Deep current profilers (P01, P02 and P03) were anchored inside or under the influence of the passes to evaluate current intensity and direction (Figure 6).

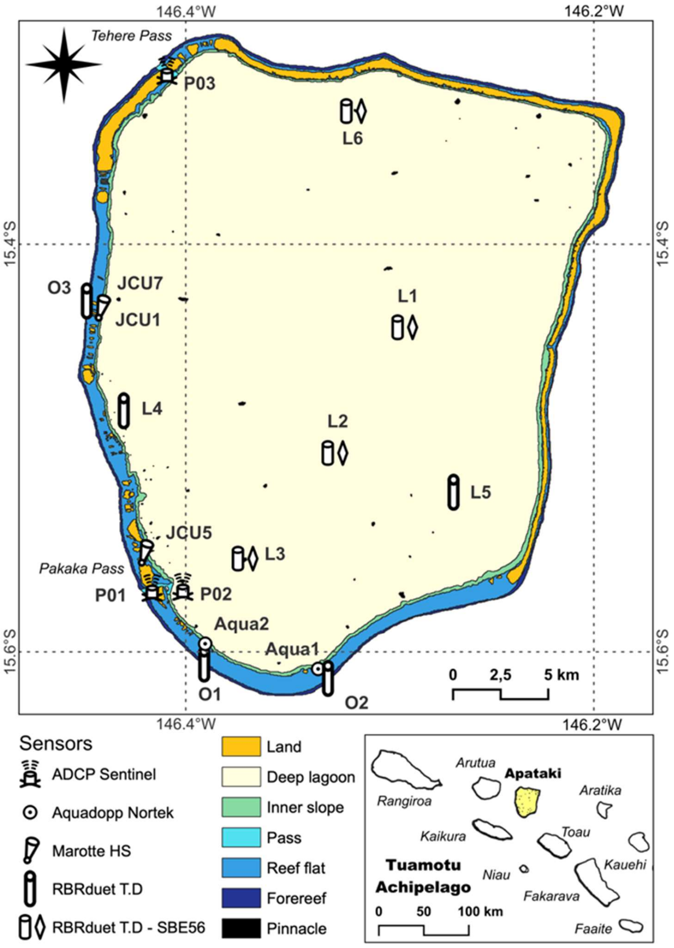

Figure 6: Sampling strategy adopted during Apataki surveys in 2022. ADCP: Acoustic Doppler Current Profiler. Inner slope category is defined approximately between 0-15 m depth. Background map from the Millennium Coral Reef Mapping Project (Andréfouët and Bionaz, 2021). O: oceanic stations. Aqua and JCU= *hoa* station. L=Lagoon stations. P= Pass stations (see TableA1 for details of each station).

3.4 Takaroa Atoll

Takaroa Atoll is located 10 km eastward from Takapoto Atoll (Sect 3.3) in the Northwestern Tuamotu region (14.27°S – 145°W). Its 86 km^2 lagoon is characterized by a semi-closed continuous rim with small *hoa* on the southern region, and by a narrow deep pass (Teaunonae Pass) reaching 170 m long and 20 m depth (Figure 7). The lagoon has a depth average of 26 m and a maximum depth of 47 m (Table 1). Pinnacles are abundant in the central deep lagoon area (Figure 7). This atoll has been previously studied in 2009 (see Le Gendre, 2020b for sampling strategy), but ~~limited~~ the data collected ~~data~~ was limited ~~could be collected~~. During the MALIS 3 cruise in July-August 2022 (Andréfouët and Le Gendre, 2022), the pass was instrumented to get additional measurement (3 months) of currents velocity and direction using one current profiler sensor moored at 18 m depth.

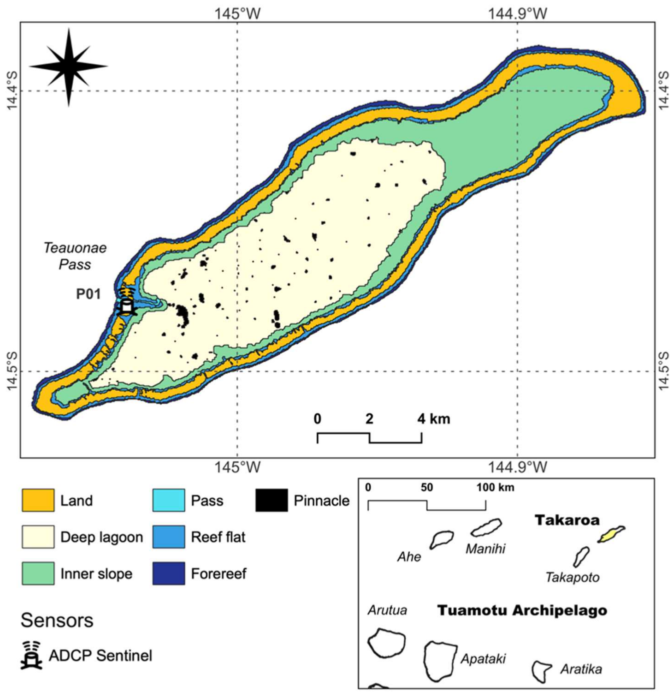

Figure 7: Position of the single station P01 in Takaroa Atoll during MALIS 3 cruise. ADCP: Acoustic Doppler Current Profiler. Inner slope category is defined approximately between 0-15m depth. Background map from the Millennium Coral Reef Mapping Project (Andréfouët and Bionaz, 2021). P= Pass station (see TableA1 for details).

4. Oceanographic instruments

Each sensor deployed in various atolls wasere autonomous and moored on the seabed by SCUBA with a suitable structure adapted to the station substrate (sand-rubble, rock-coralline, coral, pavement, etc.) to avoid displacements and ensure durability across the planned sampling period.
Figure 8 illustrates the main types of instruments and their installations. A detailed summary (location, measured parameters, frequency, station depth, etc.) of all deployed instruments is available in Appendix section (Table A1).

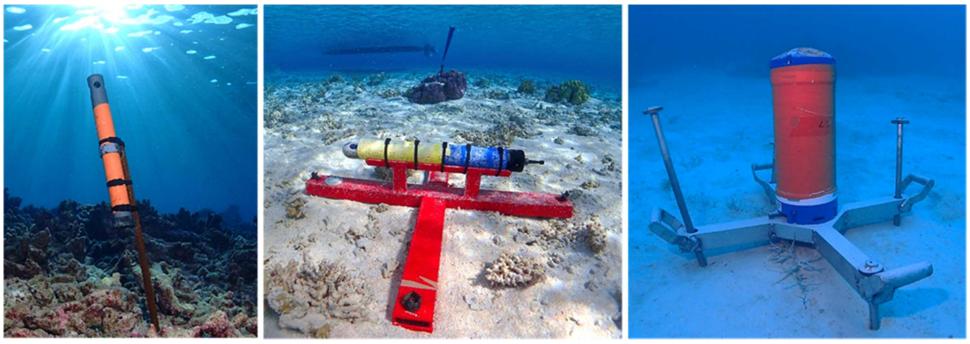

Figure 8: Images of moored structures and deployed instruments in Raroia atoll. Left: PVC tube for RBRduet T.D or SBE56 sensors fixed on hard coralline bottom. Middle: Aquadopp Nortek (on the forefront) and Marotte HS (at the back) moored on same station on pavement or coral head. Right: ADCP Sentinel instrument moored at the bottom of a deep lagoon (photos: Serge Andréfouët).

4.1 Compact Temperature and Pressure sensors

Two types of compact loggers have been used to monitor respectively temperature/pressure or temperature data. First, RBRduet T.D is a data logger constructed by RBR Ltd (https://rbr-global.com/products/compact-loggers/rbrduet-td/, last access: 07 April 2023) recording temperature and pressure at high sampling frequency (continuous sampling were set at 1 Hz interval). Those precise sensors were anchored between 8 to 12 m deep on external reef slopes into differently exposed atoll sectors to provide sea-state parameters during post processing steps (waves and sea level). RBRduet T.D loggers have also been deployed inside lagoons (6.7 m to 13.5 m deep) in order to measure tide and surge variations.

High precision temperature data were recorded with SBE56 sensors from SEABIRD Electronics Inc (https://www.seabird.com/sbe-56-temperature-sensor/product?id=54627897760, last access: 07 April

2023). Depending on atolls deployments, loggers were set up with a sampled frequency of 10 seconds (Raroia) or 1 min (Takapoto and Apataki).
To evaluate the temperature stratification in the water column, two SBE56 were systematically moored on the same station at two different depths (one sensr mostly around 2 m and one sensor up to ~~ntil~~ 40 m), plus the setting also included one of the aforementioned RBRduet T.D moored at 6-13 m between the SBE56.

4.2 Current profilers

Two kinds of current profilers were deployed in the passes or *hoa* to measure current velocity and estimate the water fluxes between ocean and lagoon. ~~ADCPs (~~Acoustic Doppler Current Profilers (ADCPs) were always bottom-mounted (upward-looking mode) to measure the water column ~~until~~ up to the sub surface. The number of cells were specific to each instrument and depth of mooring. ADCPs were set to sample in burst mode.

- ADCPs from Teledyne RD Instruments Inc. (TRD-I) (i.e; Sentinel profilers) measured current intensity and direction across the water column according to a pre-defined number of cells, as well as pressure and temperature related to the presence of a sensor in its transducer head (Figure 8, right image). The cell size was set to 50 cm, 1 m or 2 m depending on the instrument configuration, and the number of cells was dependent of the station depth. This instrument model was deployed inside the passes (Raroia, Apataki, Takaroa), in the lagoon close to the pass to characterize lagoon areas under the pass influence (Raroia, Apataki), or inside the lagoon away from the pass to characterize the lagoonal wind-induced circulation (Raroia). For each deployment, instruments were set up with a 10-minute burst frequency except for two stations in Raroia (L7 and L8) where the sampling rate was 30 minutes. For Raroia, two Sentinel V20 model and two Sentinel V50 of respectively 1000 KHz and 500 KHz working frequency (http://www.teledynemarine.com/workhorse-sentinel-adcp?ProductLineID=12, last access: 07 April 2023) were moored during the Leg2 and "shortleg". For Apataki, two Sentinel V50 where deployed inside passes and one V20 in the lagoon upstream the southern pass. Finally, for Takaroa, only one V20 was installed inside the pass.

- ADCPs from Nortek (i.e., Aquadopp profilers) ~~Aquadopp Profilers from Nortek~~ are suitable instruments for shallow current measurements (Figure 8, middle image). As such, they were predominantly moored inside various *hoa* (station depth < 3 m). This sensor measures pressure and 3D velocities which allow to deduce water elevation and vertical currents speed and direction. In Raroia, two Aquadopp 2 MHz (https://www.nortekgroup.com/fr/products/aquadopp-profiler-2-mhz, last access: 06 April 2023) were moored inside two different *hoa* with a 5-minute sampling rate with a cell size equal to 20 cm and 3 pings per ensemble. Beam coordinate systems for Raroia deployments were set in Cartesian coordinates (XYZ). Two stations in Takapoto and Apataki Atoll were also equipped with Aquadopps. Cell size was also set to 20 cm but settings were adjusted with 18 pings at each 10-minute frequency burst and beam coordinates were configurated to measure in Earth normal coordinates (ENU).

4.3 Drag-tilt current meters

Marotte HS are low-cost drag-tilt current meters manufactured by the Marine Geophysics Laboratory of James Cook University, Australia (https://www.marinegeophysics.com.au/current-meter, last access: 03 April 2023). They measure temperature and velocities components (*u,v*) at the instrument level (Figure 8, middle image). Speed and direction parameters are deduced from the sensor accelerometer and magnetometer without considering the device orientation. Sampling frequency was set to 10 seconds (Apataki) or 1 minute (Raroia). Marotte HS were always moored in shallow locations (< 2 m depth). During the Raroia legs, Marotte HS were paired with Aquadopp instruments (as showed in Figure 8) in order to compare the measured velocity between sensors. In Apataki, two Marotte sensors were moored on *hoa* along the western side during Leg 1 and 2. A number of these instruments were lost or failed in the course of the MANA deployments shown in Figure 3.

5 Data Processing and quality control

The processing and protocols applied to the data sets presented herein are similar with Bruyère et al. (2022) for the study of New Caledonia lagoons. For each data logger types, after retrieving the data from the instruments with the manufacturer's software, data were post-processed using Python 3.7 routines. Data were systematically converted in NetCDF format. Each NetCDF file contains variables and related metadata information including global attributes. Global attributes describe the data ensuring their reusability by giving geospatial position, temporal coverage, sampling frequency, depth, instrument serial number, investigator's name and any additional other useful comments for data users. Depending on instruments, specific processing steps were performed (or not), namely:

- For RBRduet T.D, pressure data were corrected from a constant atmospheric pressure (101 325 bar) in order to avoid influence of weather conditions changes. No~~ne~~ vertical referencing by Differential Global Positioning System ~~DGPS~~ (DGPS ~~Differential Global Positioning System~~) were achieved due to the vicinity of breaking waves in the case of forereef stations. To deduce wave parameters (Significant wave height, Peak frequency and Mean wave period), data were filtered using the Fourier transform to acquire a pressure spectrum (in a range between 3-25 sec). Then, the methods referenced in Aucan et al.~~,~~ (2017) were applied using the linear wave theory with a homogenous cut-off frequency (set to 0.33) to filter high frequency spectrum. To calculate water level, depth measurements were subtracted from the mean sea level (long-term depth-averaged of the temporal series). As a result, two output files were created, one at one hour resolution containing waves parameters and another file at one minute frequency with temperature and water level.

- Current meter profilers (~~ADCPs~~ Sentinel and Aquadopps) do not provide reliable current measurements near the sea surface due to contamination of the Doppler velocity related to acoustic sidelobe reflections from the boundary. To avoid contaminated cells, sea surface currents data were always removed from the processed files. Vertical and temporal resolutions remain dependent on deployment settings. No barometric correction was applied on depth but the mean depth of the entire time series were subtracted to data to obtain water elevation. For Raroia, Aquadopp's coordinate system was set to Cartesian coordinates, to be consistent with other measures, directions were recalculated in ENU coordinates using the heading orientation.

- Marotte HS data were averaged at 1 minute frequency to smooth the high frequency fluctuations. The by-default direction convention (initially ClockWise (CW) from east) was changed to be congruent with other instruments and with the oceanographic current convention (CW from north).

- Finally, for SBE56 instruments no specific treatments were applied on temperature records, and final NetCDF files keep the raw frequency settings.

For all sensors, a visual check was performed with Ferret software (http://ferret.pmel.noaa.gov/Ferret/, last access: 20 October 2023) to exclude all out-of-water data in order to set the correct start and end of time series. The screening step also helps to detect any remaining anomalous values (out of range values) from the processed files. If any remaining anomaly is observed a specific comment in the NetCDF Global attributes is included.

6 Example of results

Examples of collected data sets on the different atolls are provided hereafter for each category of sensors and deployment. They are by no means exhaustive (see Table A1 in Appendix Section). No lagoon processes that require taking into account multiple data sets are interpreted here as this makes the object of dedicated publications (e.g., Andréfouët et al. 2023a~~submitted; Le Gendre et al. in prep~~), but some basic descriptive interpretations are provided here.

6.1 Water Temperature records

The Figure 9a illustrates water temperature time series for stations O1 and L5 stations in Raroia Atoll ~~. Figure 9B shows the temperature differences between Raroia lagoon and the ocean, for stations O1 and L5~~ (Figure 4). The 9-month deployment in Raroia includes almost the entire 2018 winter season and the 2018-2019 summer season. This example shows the passage from the cold to the warm season (approximately 26 °C in August-September to 30 °C in April).~~The example shows the passage from cool to warm season with August September lows to the highest April values (approximately +4 degrees differences).~~ The sampling period shows that the variations are not continuously linear. ~~, with d~~Different rates of changes occur ~~(~~between Leg 2 and Leg 3 for instance~~,)~~ and there are ~~with~~ episodes of trend inversion (such as a period of cooling in mid-November 2018) (Figure 9A).

Noteworthy are the differences between ocean and lagoon, with a lagoon cooler than the ocean during winter season, and the opposite in October, when lagoon became warmer than the ocean. The ocean-lagoon differences are less than 1 degree (-0.83 °C to +0.42 °C).

Inside the lagoon, Figure 9B shows the surface – bottom water temperature differences for L4, L5, and L6 stations at Raroia Atoll (Figure 4). ~~(Figure 9B), t~~The surface-bottom delta for three stations shows that fluctuations are spatially synchronous, but can be of different amplitude. High amplitudes reveal water column stratification more intense during Leg2 and Leg3. Surface temperatures are generally higher than bottom temperature. In some rare instances, the delta is negative as in three events in June 2018, September 2018 and February 2019 during which bottom temperature was +0.3 °C warmer than the surface. Interpretation of all these patterns require using wind data (not shown).

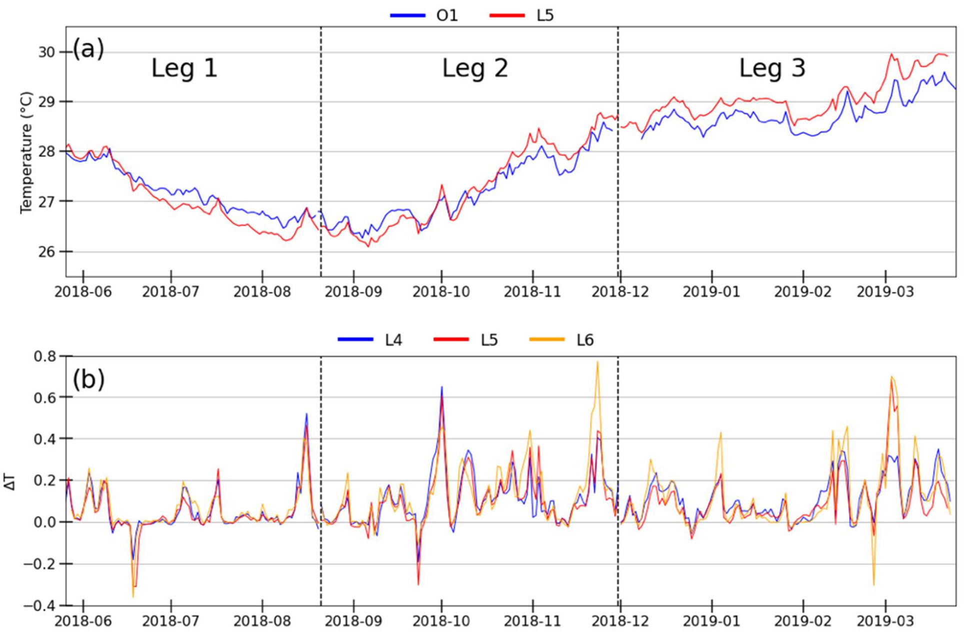

Figure 9: For Raroia atoll, (a~~A~~) ~~dD~~aily temperature time series of oceanic station O1 (9 m depth) and lagoon station L5 (2 m depth) at daily scale over the entire deployment period. (b~~B~~) Surface – bottom temperature differences at daily scale for L4, L5 and L6 lagoon stations.

6.2 Current records

Figure 10 shows current intensities (m.s^{-1}) and directions (~~degrees~~°N) distributed over the water column in the Takaroa pass (Figure 7). The ADCP was moored at~~by~~ 17 m depth (Table A1). Current directions (Figure 10, middle window) inside the pass are vertically homogenous and follow the semi-diurnal tide cycles (ebb and flow) with a westward (red) orientation during ebb and eastward (blue) during flow which correspond to the channel orientation (see Figure 7). Changes in current direction are very abrupt when the tide changes, in a matter of minutes. Current intensities (Figure 10, first window) are also homogenous according to depth. The weakest currents occur during slack water corresponding to high or low tide maximum. Figure 10 (bottom panel) shows how current speed is related to spring tide with stronger outgoing current at that time. During "normal" conditions (no meteorological or wave events), water exchanges between ocean and lagoon through the pass are mostly driven by tide but meteorological events can alter the rhythm if the lagoon fills up due to incoming swells for instance.

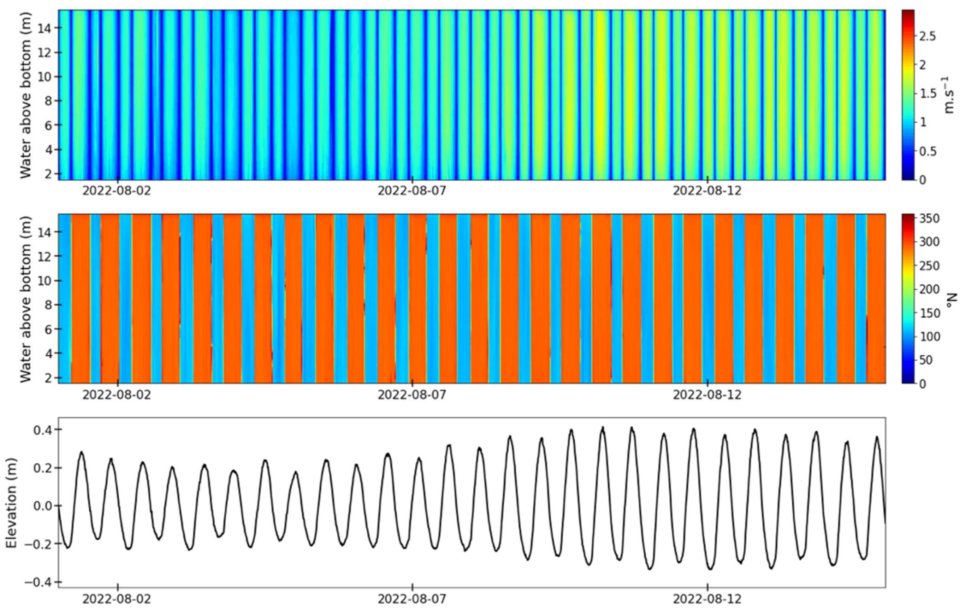

Figure 10: Fifteen days zoom of current speeds (upper), directions (middle) over water column and water elevation time series (bottom window) measured with an ADCP Sentinel V20 moored into Teaunonae Pass station (P01) in Takaroa Atoll. For direction interpretations, the oceanographic convention is employed (direction in which the current is propagated).

6.3 Sea state parameters

Wave parameters post-processed from pressure data measured by RBRduet T.D sensors deployed in Apataki Atoll are shown Figure 11. The contrast between wave exposure in the different sides of an atoll is demonstrated by station O~~0~~1 where incident wave heights ranged between 0.8 m and 2 m, and up to 4m during the mega swell episode hitting French Polynesia (mid-July 2022) (Andréfouët et al. 2023a). Conversely, the incident waves measured on the eastern station O~~0~~3 never reach above 1m high (Figure 11a~~A~~). Water elevation measured inside the lagoon (station L02~~5~~) shows the entry of oceanic waters especially during the mid-July 2022 mega-swell and the corresponding positive +50 cm surge (Figure 11c), as well as a strong distortion of the tide signal (~~Figure 11B and)~~ Figure 11b~~C~~).

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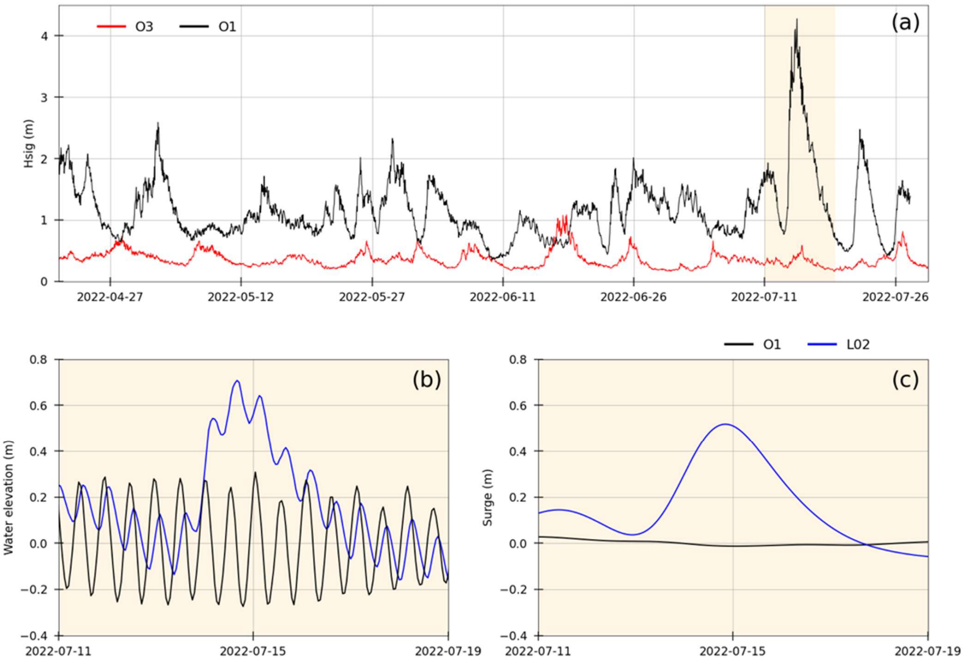

Figure 11: (a~~A~~): Significant wave height observed in station O~~0~~1 (south side) and O03 (east coast) over the entire period of measure in Apataki Atoll. (b~~B~~): Surge elevation in oceanic station (O~~0~~1) and inside lagoon (L05) during the wave event. (c~~C~~): Zoom of tidal signal recorded in oceanic station (O~~0~~1) and inside lagoon (L02) during the period of mega-swell.

7 Data availability

The data sets presented here are publicly available on SEANOE (SEA ScieNtific Open data Edition) open data publisher (https://www.seanoe.org/, Seanoe, 2023). Data are in open source and are identified per atoll and provided in NetCDF format with missing values set to -999. Permanent DOI's for each individual repositories are presented in Table 2. Those data sets have already been used for field investigations (Andréfouët et al., ~~submitted~~2023a; Aucan et al., 2021), and hydrodynamics models ~~cal/val~~calibration and validation (e.g., Le Gendre et al., in prep).

Mis en forme : Justifié

Table 2: DOI's and references associated to the four data sets presented in this paper.

Atoll	SEANOE	
	DOI	Reference
Raroia	https://doi.org/10.17882/94147	Andréfouët et al. (2023b)
Takapoto	https://doi.org/10.17882/94032	Bruyère et al. (2023b)
Apataki	https://doi.org/10.17882/94031	Bruyère et al. (2023a)
Takaroa	https://doi.org/10.17882/94146	Bruyère et al. (2023c)

8 Conclusions

The data sets presented in this paper come from five years of investigations conducted in four specific pearl farming atolls in the Tuamotu Archipelago (French Polynesia). ~~Another pearl farming site (Gambier) was not presented here as it was a lagoon with several high islands and the sampling strategy was different.~~ Combined, the four study sites represent one of the largest volume of oceanographic data collected for any atoll archipelago worldwide. Those data inform on the inter-atoll and intra-lagoon differences due to the replication of field sites in most lagoons. Intra lagoon and ocean-lagoon temperature, sea levels and hydrodynamics variables can be better understood with this existing data set. More investigations can nevertheless be required in different configurations to continue representing the diversity of Tuamotu and Gambier pearl farming sites. Besides pearl farming, the data provided here can also be useful for a variety of ecological, geomorphological, sedimentological and management applications.

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8 Appendix

Table A1: List of stations and instruments features (station position and depth, instrument type, raw and processed parameters, deployment date, sampling frequency and legs occurrence).

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Station	Instrument	Raw parameters	Longitude (W)	Latitude (S)	Date Start	Date End	Freq	Depth (m)	Processed parameters	Legs
RAROIA										
H1	ADCP Aquadopp Nortek	Current - pressure	142.433389	15.997081	30/11/2018	25/03/2019	5 min	2	Current speed & direction – water level	3
H1	Marotte HS	Current – temperature	142.433389	15.997081	25/05/2018	25/03/2019	1 min	1	Temperature – current speed & direction	1,2,3
H1	ADCP Sentinel V50	Current – temperature – pressure	142.43138	16.00012	01/12/2018	10/12/2018	10 min	28.7	Temperature – current speed & direction – water level	shortleg
H2	ADCP Sentinel V50	Current – temperature – pressure	142.36775	16.02864	01/12/2018	10/12/2018	10 min	29.8	Temperature – current speed & direction – water level	shortleg
H2	ADCP Aquadopp Nortek~~Workhorse~~	Current - pressure	142.345943	16.034883	02/05/2018	22/03/2019	5 min	1.2	Current speed & direction – water level	1,2,3
H3	Marotte HS	Current – temperature	142.479320	16.240945	27/05/2018	23/03/2019	1 min	2	Temperature – current speed & direction	1,2,3
H3	ADCP Aquadopp Nortek~~Workhorse~~	Current - pressure	142.479320	16.240945	27/05/2018	29/11/2018	5 min	1.9	Current speed & direction – water level	1,2
H5	Marotte HS	Current – temperature	142.38182	16.11527	31/05/2018	23/03/2019	1 min	2	Temperature – current speed & direction	1,2,3
L4	RBRduet T.D	Temperature – pressure	142.364141	15.987224	25/05/2018	23/03/2019	1 Hz	8.5	Temperature – wave height & period – water level	1,2,3
L4	SBE56	Temperature	142.364223	15.987153	25/05/2018	23/03/2019	10s	2	Temperature	1,2,3
L4	SBE56	Temperature	142.364048	15.987401	25/05/2018	23/03/2019	10s	20	Temperature	1,2,3
L5	RBRduet T.D	Temperature – pressure	142.418776	16.064754	25/05/2018	22/03/2019	1 Hz	8.4	Temperature – wave height & period – water level	1,2,3
L5	SBE56	Temperature	142.418871	16.064706	25/05/2018	22/03/2019	10s	3	Temperature	1,2,3
L5	SBE56	Temperature	142.418481	16.064874	25/05/2018	22/03/2019	10s	18	Temperature	1,2,3
L6	RBRduet T.D	Temperature – pressure	142.469034	16.150707	27/05/2018	23/03/2019	1 Hz	8.4	Temperature – wave height & period – water level	1,2,3
L6	SBE56	Temperature	142.468992	16.150752	28/05/2018	23/03/2019	10s	2	Temperature	1,2,3
L6	SBE56	Temperature	142.469120	16.150592	28/05/2018	23/03/2019	10s	19	Temperature	1,2,3
L7	RBRduet T.D	Temperature – pressure	142.502743	16.117741	27/05/2018	23/03/2019	1 Hz	6.7	Temperature – wave height & period – water level	1,2,3
L7	SBE56	Temperature	142.502806	16.17779	28/05/2018	23/03/2019	10s	2	Temperature	1,2,3
L7	SBE56	Temperature	142.502613	16.117493	28/05/2018	23/03/2019	10s	19	Temperature	1,2,3

L7	ADCP SentinelV50	Current – temperature – pressure	142.50232	16.11715	21/08/2018	29/09/2018	30 min	27.2	Temperature – current speed & direction – water level	2
L8	RBRduet T.D	Temperature – pressure	142.411028	16.153079	27/05/2018	23/03/2019	1 Hz	8.2	Temperature – wave height & period – water level	1,2,3
L8	SBE56	Temperature	142.410957	16.153191	28/05/2018	23/03/2019	10s	2	Temperature	1,2,3
L8	SBE56	Temperature	142.411200	16.152837	28/05/2018	23/03/2019	10s	19	Temperature	1,2,3
L8	ADCP Sentinel V50	Current – temperature – pressure	142.41797	16.14340	21/08/2018	29/09/2018	30 min	30.7	Temperature – current speed & direction – water level	2
O1	RBRduet T.D	Temperature – pressure	142.436940	15.993521	26/05/2018	25/03/2019	1 Hz	8.8	Temperature – wave height & period – water level	1,2, shortleg, 3
O2	RBRduet T.D	Temperature – pressure	142.341032	16.036994	26/05/2018	22/03/2019	1 Hz	11.7	Temperature – wave height & period – water level	1,2,3
O3	RBRduet T.D	Temperature – pressure	142.479930	16.248699	26/05/2018	22/03/2019	1 Hz	10.3	Temperature – wave height & period – water level	1,2,3
Pass	ADCP Sentinel V20	Current – temperature – pressure	142.45482	16.01760	22/08/2018	11/12/2018	10 min	17.3	Temperature – current speed & direction – water level	2
Pass2	ADCP Sentinel V20	Current – temperature – pressure	142.44022	16.01851	23/08/2018	11/12/2018	10 min	20.2	Temperature – current speed & direction – water level	2
TAKAPOTO										
Aqua1	ADCP Aquadopp Nortek	Current - pressure	145.21235	14.593897	12/11/2021	02/03/2022	10 min	1.4	Current speed & direction – water level	1
Aqua2	ADCP Aquadopp Nortek	Current - pressure	145.19452	14.652203	12/11/2021	02/03/2022	10 min	1.6	Current speed & direction – water level	1
O01	RBRduet T.D	Temperature – pressure	145.19135	14.654374	13/11/2021	03/03/2022	1 Hz	12.3	Temperature – wave height & period – water level	1
O03	RBRduet T.D	Temperature – pressure	145.21473	14.590963	13/11/2021	03/03/2022	1 Hz	10.9	Temperature – wave height & period – water level	1
L1	SBE56	Temperature	145.20117	14.625101	18/11/2021	02/03/2022	1 min	37	Temperature	1
L1	RBRduet T.D	Temperature – pressure	145.2008	14.624614	18/11/2021	21/02/2022	1 Hz	10.6	Temperature – wave height & period – water level	1
L1	SBE56	Temperature	145.20077	14.624549	18/11/2021	02/03/2022	1 min	5	Temperature	1
L2	SBE56	Temperature	145.22712	14.656898	18/11/2021	02/03/2022	1 min	31	Temperature	1
L2	RBRduet T.D	Temperature – pressure	145.22689	14.656434	18/11/2021	02/03/2022	1 Hz	9.5	Temperature – wave height &	1

									period – water level	
L2	SBE56	Temperature	145.22691	14.656352	18/11/2021	02/03/2022	1 min	2	Temperature	1
APATAKI										
O1	RBRduet T.D	Temperature – pressure	146.39095	15.605983	21/04/2022	27/07/2022	1 Hz	11	Temperature – wave height & period – water level	1,2
O2	RBRduet T.D	Temperature – pressure	146.330261	15.613003	21/04/2022	27/07/2022	1 Hz	12.1	Temperature – wave height & period – water level	1,2
O3	RBRduet T.D	Temperature – pressure	146.448461	15.427796	21/04/2022	29/07/2022	1 Hz	7.8	Temperature – wave height & period – water level	1,2
JCU1	Marotte HS	Current – temperature	146.441272	15.431240	22/04/2022	28/07/2022	1 min	2	Temperature – current speed & direction	1,2
JCU5	Marotte HS	Current - temperature	146.420131	15.551322	22/04/2022	31/05/2022	1 min	1	Temperature – current speed & direction	1,2
JCU7	Marotte HS	Current – temperature	146.441272	15.431240	22/04/2022	28/07/2022	1 min	2	Temperature – current speed & direction	1,2
L1	RBRduet T.D	Temperature – pressure	146.292631	15.440699	22/04/2022	28/07/2022	1 Hz	12.1	Temperature – wave height & period – water level	1,2
L1	SBE56	Temperature	146.292631	15.440699	22/04/2022	28/07/2022	1 min	2	Temperature	1,2
L1	SBE56	Temperature	146.292631	15.440699	22/04/2022	28/07/2022	1 min	37	Temperature	1,2
L2	SBE56	Temperature	146.326862	15.501658	22/04/2022	28/07/2022	1 min	32	Temperature	1,2
L2	RBRduet T.D	Temperature – pressure	146.326799	15.502053	22/04/2022	28/07/2022	1 Hz	13.5	Temperature – wave height & period – water level	1,2
L2	SBE56	Temperature	146.326839	15.502305	22/04/2022	28/07/2022	1 min	3	Temperature	1,2
L5	RBRduet T.D	Temperature – pressure	146.268736	15.521516	22/04/2022	28/07/2022	1 Hz	10.7	Temperature – wave height & period – water level	1,2
L3	SBE56	Temperature	146.369834	15.553718	23/04/2022	27/07/2022	1 min	27	Temperature	1,2
L3	RBRduet T.D	Temperature – pressure	146.37076	15.553979	23/04/2022	27/07/2022	1 Hz	10.7	Temperature – wave height & period – water level	1,2
L3	SBE56	Temperature	146.370889	15.554061	23/04/2022	27/07/2022	1 min	3	Temperature	1,2
L4	RBRduet T.D	Temperature – pressure	146.430374	15.481611	23/04/2022	28/07/2022	1 Hz	9.1	Temperature – wave height & period – water level	1,2
L6	RBRduet T.D	Temperature – pressure	146,31786	15,33485	04/07/2022	05/07/2022	1 Hz	11.1	Temperature – wave height & period – water level	2

L6	SBE56	Temperature	146,31887	15,33591	04/07/2022	05/07/2022	1 min	30	Temperature	2
L6	SBE56	Temperature	146,31774	15,33471	04/07/2022	05/07/2022	1 min	4	Temperature	2
Aqua1	ADCP Aquadopp Nortek	Current - pressure	146.335086	15.608373	21/04/2022	27/07/2022	10 min	2.4	Current speed & direction – water level	1,2
Aqua2	ADCP Aquadopp Nortek	Current - pressure	146.390457	15.596022	23/04/2022	27/07/2022	10 min	3.3	Current speed & direction – water level	1,2
P01	ADCP Sentinel V50	Current – temperature – pressure	146,416472	15,568417	02/07/2022	02/07/2022	10 min	27.6	Temperature – current speed & direction – water level	2
P02	ADCP Sentinel V20	Current – temperature – pressure	146,401393	15,567935	02/07/2022	02/07/2022	10 min	21.3	Temperature – current speed & direction – water level	2
P03	ADCP Sentinel V50	Current – temperature – pressure	146,40919	15,31504	05/07/2022	05/07/2022	10 min	30.5	Temperature – current speed & direction – water level	2
TAKAROA										
P01	ADCP Sentinel V20	Current – temperature – pressure	-145.03939	-14.47516	20/07/2022	18/10/2022	10 min	17.6	Temperature – current speed & direction – water level	1

Author contributions

SA is the PI of the MANA project. SA, RLG, JA and VL raised funds. SA, RLG, VL, JA designed and conducted the experiments. SA, RLG, BB, DV, JB, TT, YF, JA; VL had repetitive implications in the field experiments. OB, MC, RLG, JA, SA, TT, YF, VL organized, processed, checked, and archived the data sets. OB and SA prepared the paper and designed the figures, with contributions from all co-authors.

Competing interests

The authors declare that they have no conflict of interest.

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