

Our journey through the Southern Cook Islands.

Satellite imagery: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

Cook Islands 2026

How living and raised reefs help us understand past sea levels across the Southern Cook Islands.

Initial field report · July 2026

Part of the **HISEAS project** · Funded by the **U.S. National Science Foundation (NSF)**

Prepared for island leaders, schools, communities, project partners, and everyone who made the fieldwork possible.

Islands	5	Numbered sites	25
Rock Samples	123	Surface models	21



Sampling beside the GPS base station at Anaraura, Mauke.

FIELD CAMPAIGN

Reading old reefs for new insights

During May and June 2026, our team travelled to Rarotonga, Atiu, Mangaia, Mauke, and Mitiaro. Local leaders, teachers, students, guides, and residents helped us understand access, place names, coastal conditions, and the questions that matter locally.

We studied living reef flats beside raised reef limestone (makatea), measured fossil corals and reef surfaces, installed temporary tide gauges, collected fossil coral samples, and mapped priority sites by drone. We want to understand why reefs that formed near sea level now occur at different heights and in different forms within and among islands.



Cook Islands field traverse work provides elevation control and geologic context for Last Interglacial sea-level indicators.



Sharing sea-level science with local students and communities.

What remains uncertain

This is an initial report of our efforts, not a final sea-level history. Now we begin the meticulous process of trying to explain the observations in the context of geologic time, sea-level change, and past environmental conditions.

Schools and community events

During the field trip, we visited schools on Rarotonga, Atiu, Mangaia, Mauke, and Mitiaro to explain how corals record environmental change and discuss the project with students and teachers. We also held a community event on Rarotonga.

COOK ISLANDS FIELD TEAM



HISEAS FIELD TEAM ON MANGAIA, COOK ISLANDS.

MEITAKI

Thank you very much

MAATA

to

CLIMATE CHANGE COOK ISLANDS

Our deepest thanks to the office whose extraordinary support made this fieldwork possible.

&

to

The island leaders and community members who supported us along the way.

THE HISEAS PROJECT

HISEAS investigates how much, and why, the Greenland and Antarctic ice sheets melted during the Last Interglacial—the most recent warmer period in Earth's history. This Cook Islands campaign contributes evidence preserved in the raised reefs of the Southern Cook Islands.

Funded by the U.S. National Science Foundation (NSF), EAR 24-20482 (2024–2029).

VISIT HISEAS.ORG ↗

01
Jacky Austermann
ASSOCIATE PROFESSOR
COLUMBIA UNIVERSITY / LAMONT-DOHERTY EARTH OBSERVATORY
jackya@ldeo.columbia.edu

02
Emalee Ott
M.S. STUDENT
UNIVERSITY OF FLORIDA
ott.emalee@ufl.edu

03
William D'Andrea
LAMONT ASSOCIATE RESEARCH PROFESSOR
COLUMBIA UNIVERSITY / LAMONT-DOHERTY EARTH OBSERVATORY
dandrea@ldeo.columbia.edu

04
Blake Dyer
ASSOCIATE PROFESSOR
UNIVERSITY OF VICTORIA
blakedyer@uvic.ca

05
Otillia Steadman
GRADUATE STUDENT
COLUMBIA UNIVERSITY / LAMONT-DOHERTY EARTH OBSERVATORY
oms2128@columbia.edu

06
Oana Dumitru
ASSISTANT PROFESSOR
UNIVERSITY OF FLORIDA
odumitru@ufl.edu

07
Roger Creel
ASSISTANT PROFESSOR
TEXAS A&M UNIVERSITY
Roger.creel@tamu.edu

ANGA'ANGA TAOKOTA'I KIA MATUTU TE KUKI AIRANI KI TE TAUNI'ANGA REVA

Working together to build Cook Islands resilience to climate change.

FIELD METHODS

One evidence chain, from reef to laboratory

01

Map

We recorded reef flats, benches, cliffs, and inland limestone with mapped GPS positions and documented field relationships.

02

Measure

Temporary tide gauges and GPS ties establish working island references for mean sea level. Feature heights are tied to those datums.

03

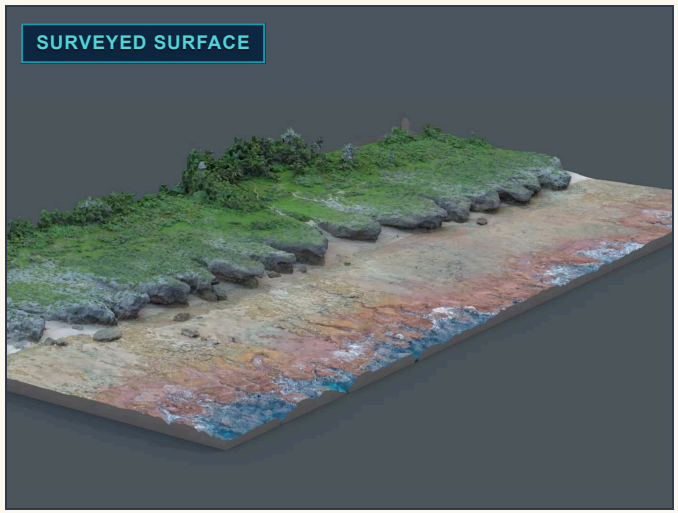
Model

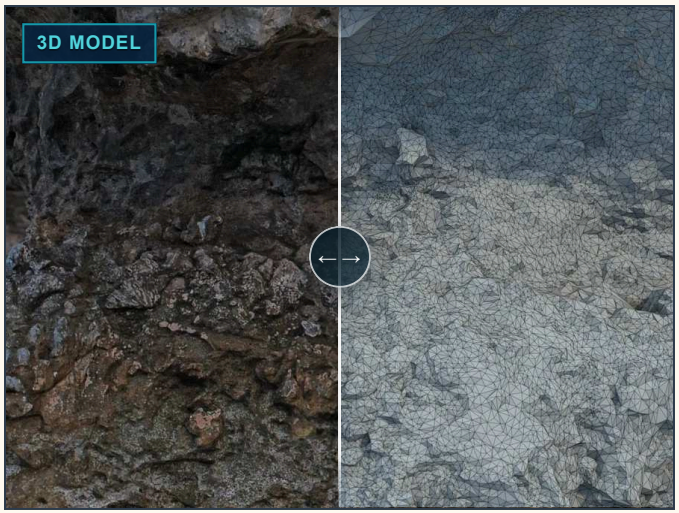
Drone photographs are processed into detailed orthomosaics, elevation models, and 3D assets for 21 of the 25 numbered sites.

04

Collect

We catalogued 123 fossil coral and related samples whose position and height are precisely known, and geochemical preservation will be determined later.





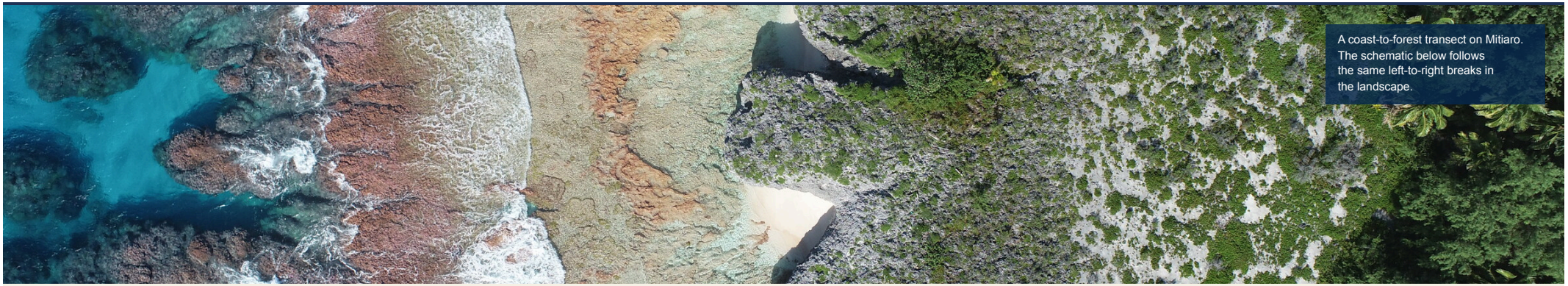
HS123 · Te Rotonui

Overlapping drone photographs produced the site's orthomosaic, elevation model, and textured 3D surface. The overview and exact-frame texture-to-wireframe comparison show how the measured surface becomes a navigable 3D model, allowing us to continue to learn from the rocks at home.

Surveyed surface. An oblique view of the complete photogrammetric surface.

3D model. Texture and wireframe view of the cliff at Te Rotonui. Drag the midline in the web report to compare the photographic texture with the underlying triangular mesh; the print edition shows a left-right comparison.

Explore the complete HS123 survey →



COASTAL TRANSECT

How a reef becomes makatea

A once living reef, preserved above the sea.

Makatea is limestone made by an older reef that grew close to sea level. During the Last Interglacial—a warm interval about 129,000 to 116,000 years ago—sea level was higher than today. Later changes in sea level, together with island uplift, left parts of that reef above the modern shore, where rain, waves, and vegetation reshaped it.

Holocene

the present geologic interval, covering the last 11,700 years

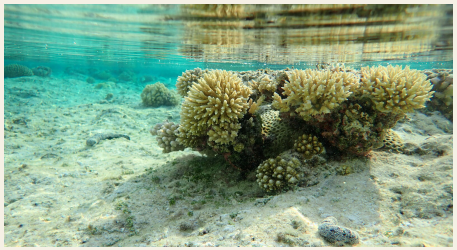
Last Interglacial

a warm interval about 129,000–116,000 years ago



1 Modern reef crest *(ʻĀtinga ngaru / Paringa ngaru)*

Waves wash across the flat at low tide, where calcareous crusts, algae, and other reef life build and bind the surface.



2 Living coral

Living corals build limestone skeletons that contribute to the framework of the modern reef.



3 Beach and back reef *(Pae tai · Akau)*

Shallow back-reef water meets a pocket beach and corals grow outwards into micro-atolls, limited by the water level.



4 Fossil coral in makatea

Coral skeletons preserved in dry limestone show the biological origin of the raised reef.

ISLAND 1 OF 5

Rarotonga

Field records · May 31, 2026

Rarotonga was the expedition's arrival and coordination base and the setting for a school visit and community event, as well as an important comparison with the raised-reef islands. At Ngatangiia we investigated a coastal exposure of fossil coral reef. This site is but a small remnant of the island's former reef, and very distinct when compared to the raised reef (makatea) on the other Southern Cook Islands.

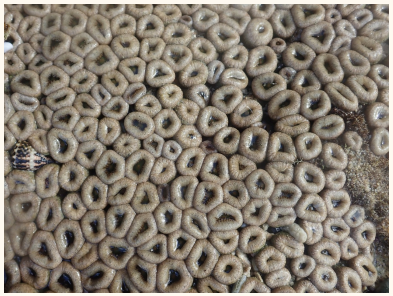
1 comparison locality · 1 sample · no surface model



Roger stands on the exposed reef surface at Ngatangiia, framed by a water-filled channel and weathered coastal rock, with the modern reef flat and breaking-wave edge beyond.



At low tide, weathered coastal rock frames water-filled pools beside the exposed modern reef flat and wave break.



A dense mat of small polyps occupies a shallow pool on the exposed modern reef flat at low tide.



Jacky stands above a coastal ledge with upward-cupping coral colonies in the rock.

What the site showed

- Ngatangiia is a reference locality used in previously published Rarotonga work.
- Low tide exposed the modern reef flat and notch allowing study of the biological zonation of the modern coastline.
- The lower bench contains large encrusting corals and a surface built partly by algae.
- Living encrusting corals, algae, chitons, possible anemones, and worm or vermetid tubes document the modern biological zonation of the exposed reef edge.
- A perched boulder and wave-drainage channels record modern or storm-process overprints that are key parts of the modern reef expression.

ISLAND 2 OF 5

Atiu

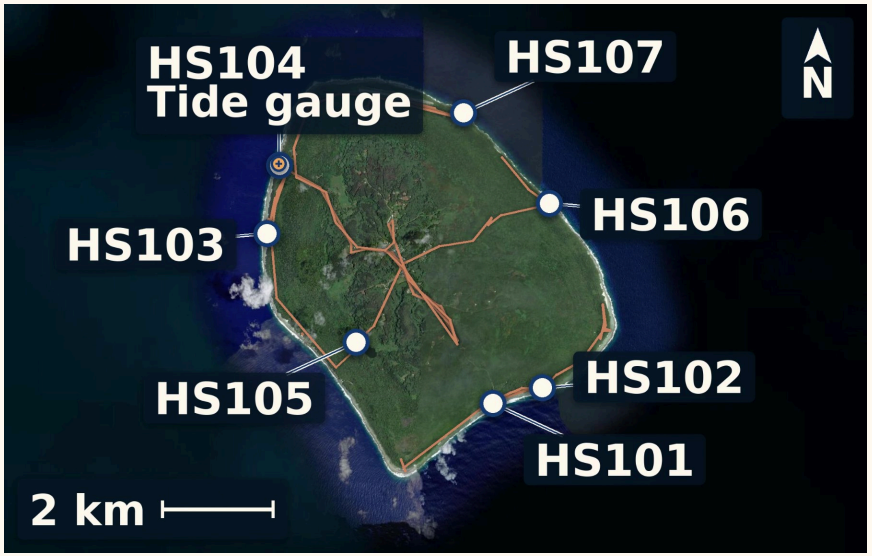
Field records · May 25-29, 2026

7	35	5
numbered sites	samples	surface models

Atiu let us follow exposed reef from the present shoreline into raised jungle-covered limestone. At Matai a lower layer of branching coral framework was distinct from higher coral framework. Rough waves limited work at Takauroa, but the stop documented how exposure controls both access and preservation. Oravaru and Taunganui showed lower reef framework, sand or discontinuous layers, upper rubble or reef units, and fresh harbor-wall textures. Old Canyon and the inland quarry exposed strongly recrystallized limestone, useful for understanding alteration but less useful for dating. At Tarapaku, living Porites-rich reef, microatoll forms, cemented surfaces, and a nearby notch provided a modern guide to possible sea-level indicators. Totiko was the final stop with a higher reef table and clustered coral samples. The temporary tide gauge deployed at Atiu's harbor provides the local height reference needed to test whether these surfaces record one reef-building interval or several different episodes.



At Tarapaku, Oana stands beneath an overhanging, vegetation-covered limestone ledge beside a narrow beach and shallow reef flat, with breaking waves at the reef edge.



Atiu field sites and generalized daily field routes, with the harbor tide gauge distinguished from nearby site markers. Recording gaps remain open; raw positions are retained in the daily logs.

Field route · HS field site · Tide gauge

Satellite imagery: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

HEIGHT REFERENCE

Atiu tidal datum

Four days at the harbour

Working field reference

The harbour record establishes local mean sea level—our zero. Measured features are reported relative to this surface so the reef, notch, and shore can be compared on one scale.

WORKING LOCAL DATUM · 14.23 M

MEAN WATER ABOVE LOGGER

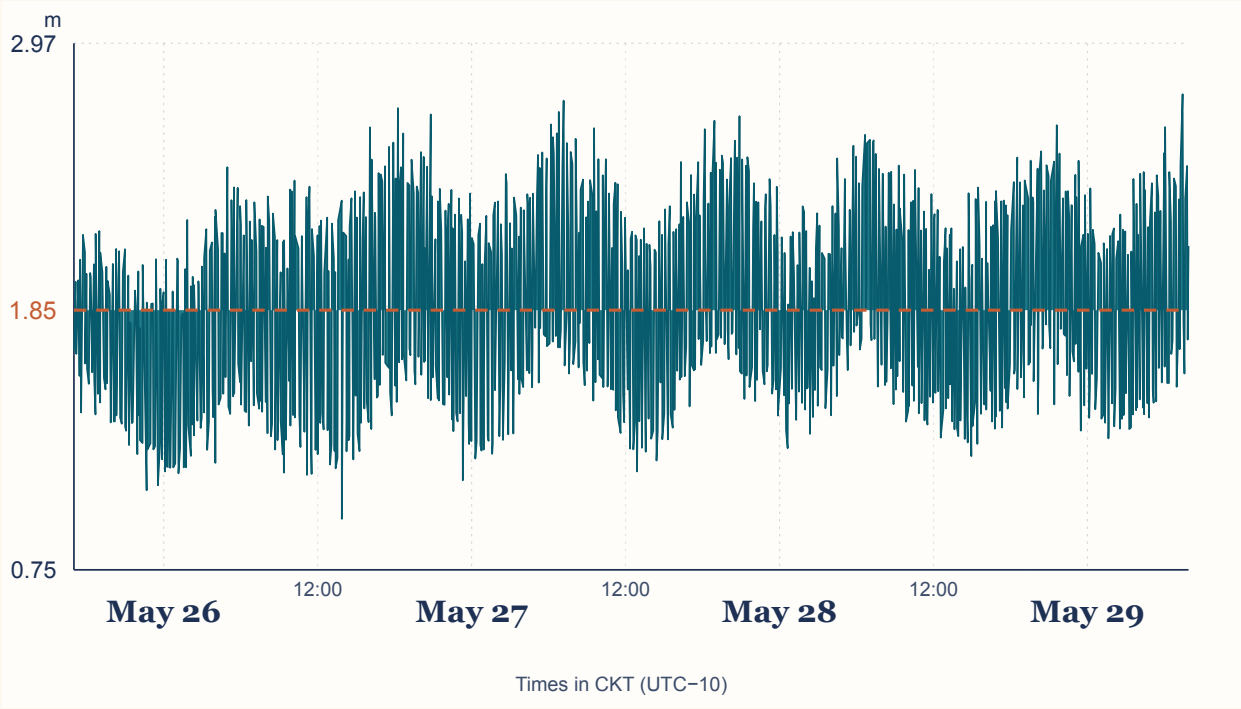
1.85 m

GAUGE TIE

3.32 m

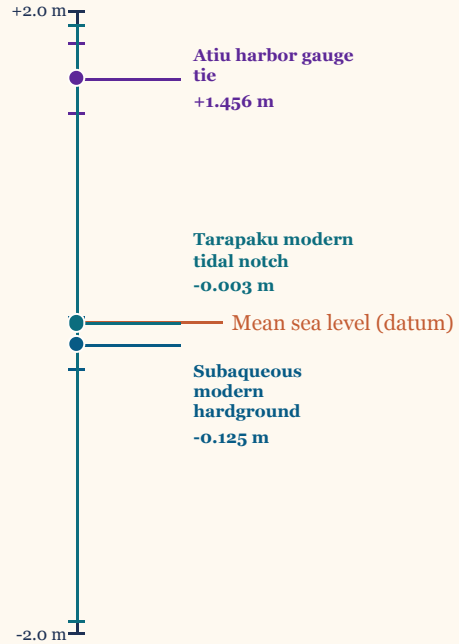
HARBOUR LOGGER (4 DAYS)

Water level above logger (m) · Dashed line is mean sea level (1.848 m above logger).



MEASURED FEATURES RELATIVE TO MEAN SEA LEVEL

m above mean sea level



Whiskers show the field screening range, not a formal confidence interval.

The screened logger record preserves the observed tidal variation.

SITE RECORDS

Brief field views from Atiu

1 Matai MAY 26, 2026

HS101

Matai tests whether lower, large branching framework and higher mixed coral forms represent one variable reef body or a meaningful internal boundary.

OPEN QUESTION

Does the framework transition reflect reef position, exposure, preservation, or a true depositional break?



HS101 on the drone orthomosaic. 7 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.



At HS101 Matai, branching coral framework extends across a broad limestone exposure above the beach. Field observations traced this framework for tens of metres alongshore.

A high-resolution drone orthomosaic and elevation model are available for HS101.

- Lower seaward framework includes in-place upward-branching colonies several metres to tens of metres across.
- Higher landward framework shifts to smaller branchers, brain-like, honeycomb, smooth, and encrusting forms.
- No clear sand layer or hiatus was identified; the transition varies by about one metre in elevation.

Open the complete HS101 survey record

2 Takauroa MAY 26, 2026

HS102

Because rough surf limited imagery, Takauroa's samples were recorded with only mapped, single photos, and observations as context.

OPEN QUESTION

Which HS102 samples will be the best preserved?



At HS102, two researchers record observations above rough surf. These conditions prevented drone and Nikon photography, so samples and mapped GPS ties carry the site record.



HS102 on the best available satellite imagery. 3 sample GPS records are shown.

Sample GPS record

Satellite imagery: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

A high-resolution surface model is not currently available for this site; satellite imagery, the mapped sample positions, and field photographs preserve its documented context.

- Tabular or encrusting coral occurs near a possible framework–infill contact.
- Rough waves prevented drone photography, so mapped sample positions carry much of the comparison.
- Samples A–D span several coral colonies that form part of the site's reef framework.

Open the complete HS102 survey record

3

Oravaru

MAY 27, 2026

HS103

Oravaru preserves reef growth and sedimentation, making it Atiu's clearest exposure for testing the continuity and meaning of its sand-rich interval.

OPEN QUESTION

Do the elevation and ages of measured within-reef contacts align with other Atiu sites?



HS103 on the drone orthomosaic. 2 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.



At HS103 Oravaru, an oblique drone view shows the shallow reef flat, jagged limestone coast, pale pocket beach, and dense forest edge. The team and red tripod give scale to the exposure mapped from above by the drone.

A high-resolution drone orthomosaic and elevation model are available for HS103.

- Coarse angular sand forms pockets and sheets that drape positive reef relief rather than one continuous bed.
- Localized lenses preserve ripples, 10–15 cm tabular cross-beds, coral clasts, and breccia blocks.
- Later corals appear to recolonize the sand surface, possibly after encrusters or cement stabilized it.

Open the complete HS103 survey record

4 Taunganui

MAY 27, 2026

HS104

Taunganui tests whether the lower-coral and upper-rubble pattern seen at Oravaru persists where sand is less obvious.

OPEN QUESTION

Do contacts align in elevation? The contacts are not flat, so must be traced across each outcrop.



Dark, irregular bands cross lighter coral and rubble in the fresh HS104 wall at Taunganui. The field team traced several as encruster horizons, evidence that the upper jumble is locally coherent rather than a loose pile.



HS104 on the drone orthomosaic. 4 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS104.

- Large colonies dominate the lower exposure; cemented rubble, delicate algae, and small corals characterize the upper jumble.
- Several encruster horizons cross the wall rather than forming one simple horizontal layer.
- The fresh cut makes fabrics visible that are harder to distinguish on weathered surfaces.

Open the complete HS104 survey record

5

Old Canyon

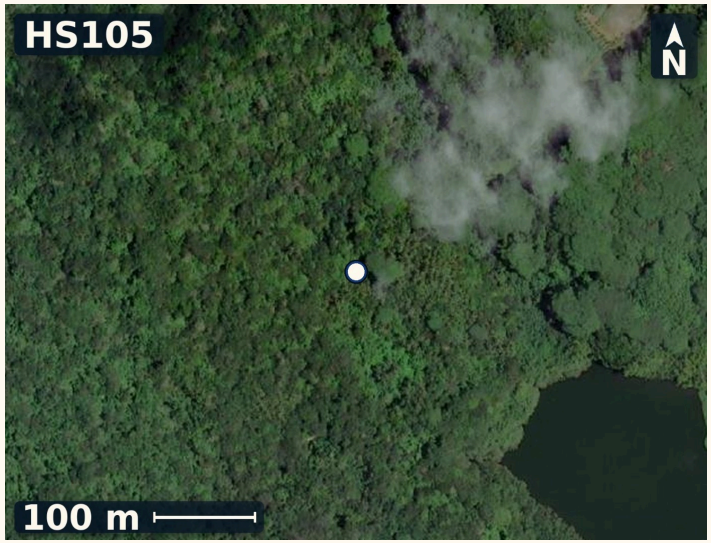
MAY 27, 2026

HS105

This Old Canyon road offers views into inland makatea where strong recrystallization currently makes it contextual rather than secure dating material.

OPEN QUESTION

Does the elevation of this exposure require an earlier interglacial period than the coastal sites?



HS105 on the best available satellite imagery at its mapped site position. Its catalogued sample has no mapped GPS record.

Mapped site

Satellite imagery: Esri, Maxar, Earthstar Geographics, and the GIS User Community.



A dark, weathered limestone face rises through dense forest at Old Canyon. Close field inspection found coral and shell fragments in heavily recrystallized rock; no obvious notch was seen to connect the exposure directly with coastal HS103 or HS104.

A high-resolution surface model is not currently available for this site; satellite imagery, the mapped site position, and field photographs preserve its documented context.

- The inland limestone remains recognizably marine, with coral and shell fragments and visible corallites.
- No obvious notch or front-edge feature links this exposure directly to the lower elevation coastal sites.

Open the complete HS105 survey record

6

Tarapaku

MAY 28, 2026

HS106

Tarapaku pairs a raised-framework section with nearby living reef and notch observations, providing a cautious modern comparison for possible sea-level indicators.

OPEN QUESTION

Does the raised section contain short, horizontal coral forms comparable to modern Tarapaku microatolls?



At HS106 near Tarapaku, fieldworkers stand along a vegetated limestone edge and narrow beach beside the shallow reef flat. Breaking waves cross the foreground; the drone records the same coast from overhead.



HS106 on the drone orthomosaic at its mapped site position. Its 5 catalogued samples have no mapped GPS records.

Mapped site

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS106.

- Large intact metre-scale corals occur low in the exposure; smaller corals, encrusters, and framework dominate higher levels.
- No clear microatoll-style flat was identified within the examined upper jumble.
- The nearby modern notch and coral rich reef flat provide height and morphology checks for reef flat environments.

Open the complete HS106 survey record

7

Totiko

MAY 28, 2026

HS107

Totiko provides a weathered reef table whose exposed fabrics, sample positions, and surface geometry can be compared with Atiu's published reef-unit framework.

OPEN QUESTION

Are Totiko's gullies and ridges primary constructional and wave generated relief, or products of rockfall and later weathering?



HS107 on the drone orthomosaic. 8 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.



At HS107 near Totiko, breaking waves spill across a dark coastal bench beneath a pale undercut limestone cliff and rough ground with low vegetation. The low-oblique view gives the coast-scale setting that the drone records from overhead.

A high-resolution drone orthomosaic and elevation model are available for HS107.

- The rough table contains abundant in-place corals, articulated tridacnid clams, other bivalves, and gastropods.
- Meter-scale coral clumps and ocean-oriented gullies form substantial local relief despite the table's broad flat appearance.
- Multiple coral samples were tied to mapped positions across the reef table.

Open the complete HS107 survey record

ISLAND 3 OF 5

Mangaia

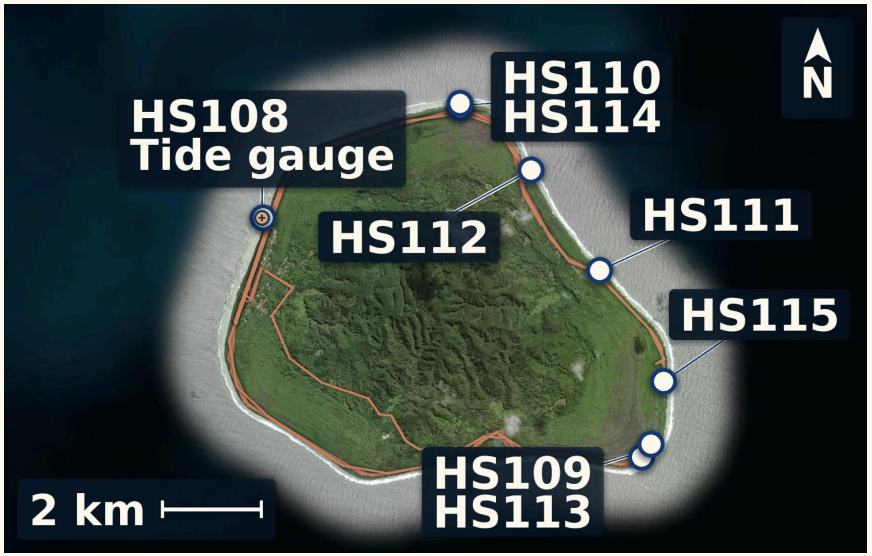
Field records · June 1-4, 2026

8	41	7
numbered sites	samples	surface models

Mangaia presented the clearest multi-level reef problem of the trip. The Avarua harbor reef flat and tide gauge established the modern starting point. Saragossa I exposed dense fossil coral framework, channelized textures, recrystallized grainstone, and coral-bearing rock near the next inland cliff. At Araoa, notch-like forms, infill, and adjacent reef framework offered several competing histories. Ivirua and Karanganui provided strong growth-position framework comparisons beside modern low-tide surfaces. Higher on the island, Saragossa II contained intermediate coral-rich highs that may be patch reefs rather than a single continuous terrace. The modern Araoa survey measured water depth across a living reef flat, while Saragossa III extended the work toward higher mounds, cliff-attached reef, and possible fallen or collapsed blocks. Together these sites show that Mangaia cannot be explained as one simple sea level highstand. Dating, high-resolution surface models, and the working local tidal datum will be used to learn which features formed together and which record local relief, channels, erosion, or collapse.



Two field team members stand in shallow water on the Araoa reef flat during the HS114 survey, with breaking waves and the open ocean beyond.



Mangaia field sites and generalized daily field routes, with the harbor tide gauge distinguished from nearby site markers. Recording gaps remain open; raw positions are retained in the daily logs.

Field route · HS field site · Tide gauge

Satellite imagery: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

HEIGHT REFERENCE

Mangaia tidal datum

Four days at the harbour

Working field reference

The harbour record establishes local mean sea level—our zero. Measured features are reported relative to this surface so the reef and shore can be compared on one scale.

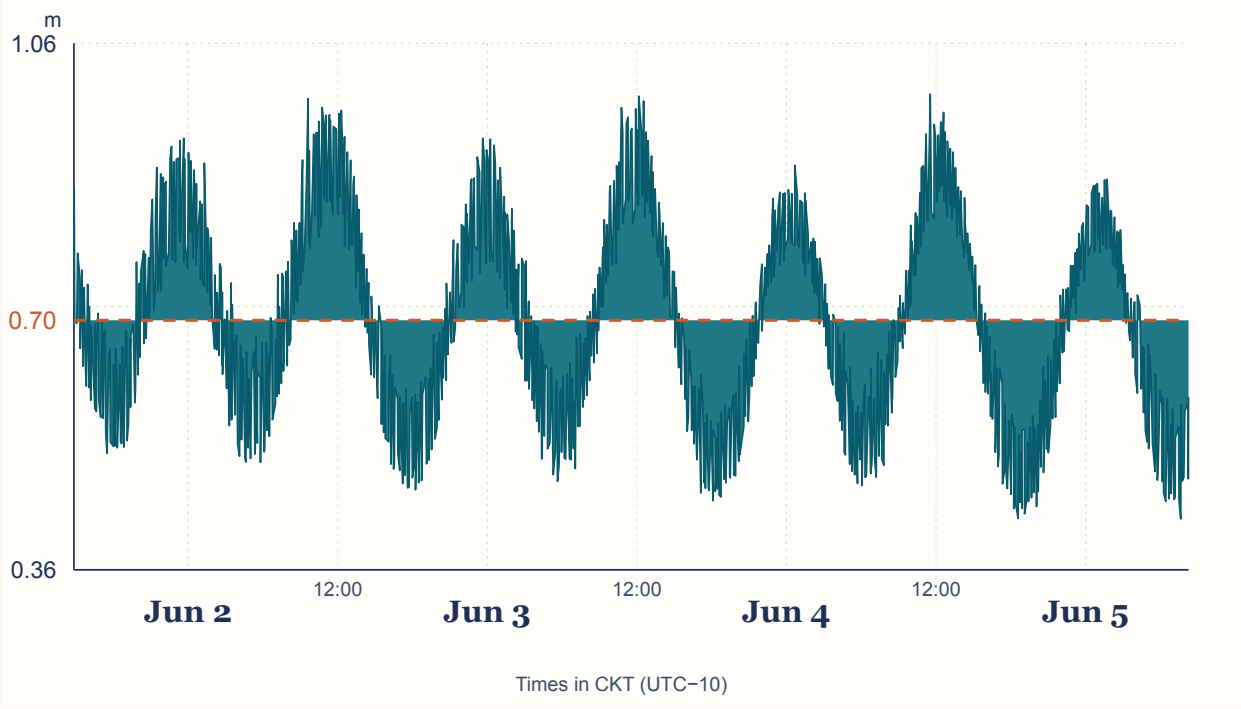
WORKING LOCAL DATUM · 12.47 M

MEAN WATER ABOVE LOGGER

0.70 m

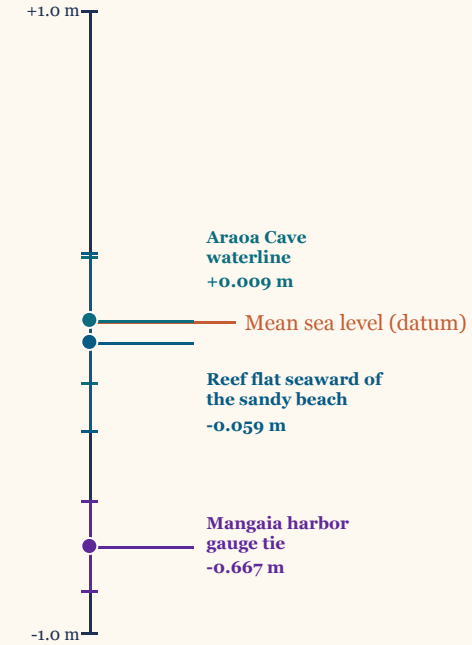
HARBOUR LOGGER (4 DAYS)

Water level above logger (m) · Dashed line is mean sea level (0.695 m above logger).



MEASURED FEATURES RELATIVE TO MEAN SEA LEVEL

m above mean sea level



Whiskers show the field screening range, not a formal confidence interval.

A pressure offset was corrected using the stable post-retrieval record; tidal variation is preserved.

SITE RECORDS

Brief field views from Mangaia

1 Avarua JUNE 1, 2026

HS108

Avarua provides Mangaia's local height anchor, linking the temporary tide gauge and repeated ties to the low coastal surfaces compared across the island.

OPEN QUESTION

Are harbor adjacent units from the last interglacial period or the early holocene?



HS108 on the best available satellite imagery at its mapped site position. No sample is catalogued for this comparison site.

Mapped site

Satellite imagery: Esri, Maxar, Earthstar Geographics, and the GIS User Community.



Looking south along the HS108 coastal traverse, a broad, low reef-flat surface with shallow pools and pale sand patches extends between dense vegetation and the water.

A high-resolution surface model is not currently available for this site; satellite imagery, the mapped site position, and field photographs preserve its documented context.

- A lower intertidal branching coral colony was recorded on the harbor reef flat.
- Repeat tide-gauge points provide the principal local control for later height corrections.

Open the complete HS108 survey record

2 Saragossa I

JUNE 1, 2026

HS109

Saragossa I connects a fossil-reef sampling transect from coastline all the way to a second inland cliff within one mapped section.

OPEN QUESTION

Do fractures and cracks align with broader patterns seen from above?



At HS109, Billy and Roger stand on the next cliff landward of the coastal exposure, giving scale to the rugged and sharp terrain.



HS109 on the drone orthomosaic. 7 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS109.

- The road-adjacent upper unit is heavily recrystallized grainstone, unlike the fresher coral framework.
- Coral samples A–G and a Tridacna were documented across the main exposure.
- The inland cliff base exposes sharp makatea and a coral head beyond the road-adjacent unit.

Open the complete HS109 survey record

3

Araoa

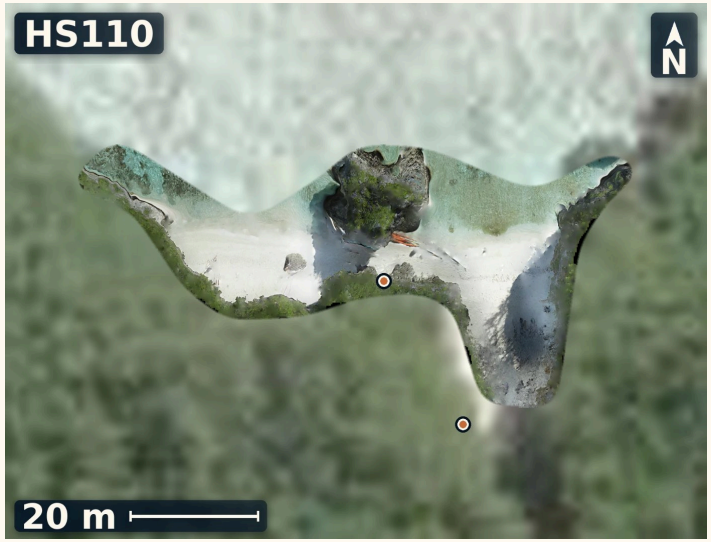
JUNE 2, 2026

HS110

Araoa poses a difficult puzzle on how reef construction, erosion, and later filling or recolonization. Without geochonology, several emplacement histories remain plausible.

OPEN QUESTION

Was the drilled Porites growing in place, or reworked into younger cemented fill?



HS110 on the drone orthomosaic. 2 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.



Inside the Araoa coastal cave, a pale, layered exposure and loose sand sit against a deeply weathered limestone wall.

A high-resolution drone orthomosaic and elevation model are available for HS110.

- The drilled Porites may be in place, fallen from the cave wall, or incorporated into cemented infill.
- Samples were collected from the front face, a possible younger patch, higher cave material, and the previously drilled Porites.
- The upper sample area remains less well constrained by mapped than the outer wall and lower cave.

Open the complete HS110 survey record

4 Ivirua

JUNE 2, 2026

HS111

Ivirua offers tests of whether Mangaia's outer makatea has paleo-surfaces that preserve constructional reef fabric rather than erosion.

OPEN QUESTION

Does Ivirua's second notch-like horizon reflect a former sea level or another process?



A branching coral preserved in place at HS111, photographed with a ruler for scale near the cliff top.



HS111 on the drone orthomosaic. 3 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS111.

- Large corals were recorded in growth position within the framework.
- Platy or crusting coral forms appear oriented seaward.
- Sample C may be rubble rather than secure bedrock.

Open the complete HS111 survey record

5 Karanganui

JUNE 2, 2026

HS112

Karanganui extends the Mangaia work with a fossil-framework reef locality with its own sample set, extending preservation and age tests.

OPEN QUESTION

Do Karanganui's dated corals match Ivirua's reef-building interval despite being a separate exposure?



HS112 on the drone orthomosaic. 4 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.



At HS112, rough coastal limestone overlooks a narrow cove and the broad reef flat exposed at low tide. The view supplies the setting for the framework comparison.

A high-resolution drone orthomosaic and elevation model are available for HS112.

- Samples A–D and Z were recorded across the framework exposure.

Open the complete HS112 survey record

6 Saragossa II

JUNE 3, 2026

HS113

Saragossa II shows how local constructional relief can complicate Mangaia's stepped-terrace geometry.

OPEN QUESTION

Are the intermediate highs separate patch reefs, or remnants of one surface later cut by channels?



At HS113 Saragossa II, a fieldworker records GPS in a vegetation-lined low beneath rising jagged limestone.



HS113 on the drone orthomosaic. 10 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS113.

- Diamond-shaped intermediate highs are separated by lower corridors.
- Delicate upward-branching Acropora-like coral dominates the high patches until the traverse enters lower channels.
- Sample I was recorded in growth position and appears better preserved internally than at its exterior.

Open the complete HS113 survey record

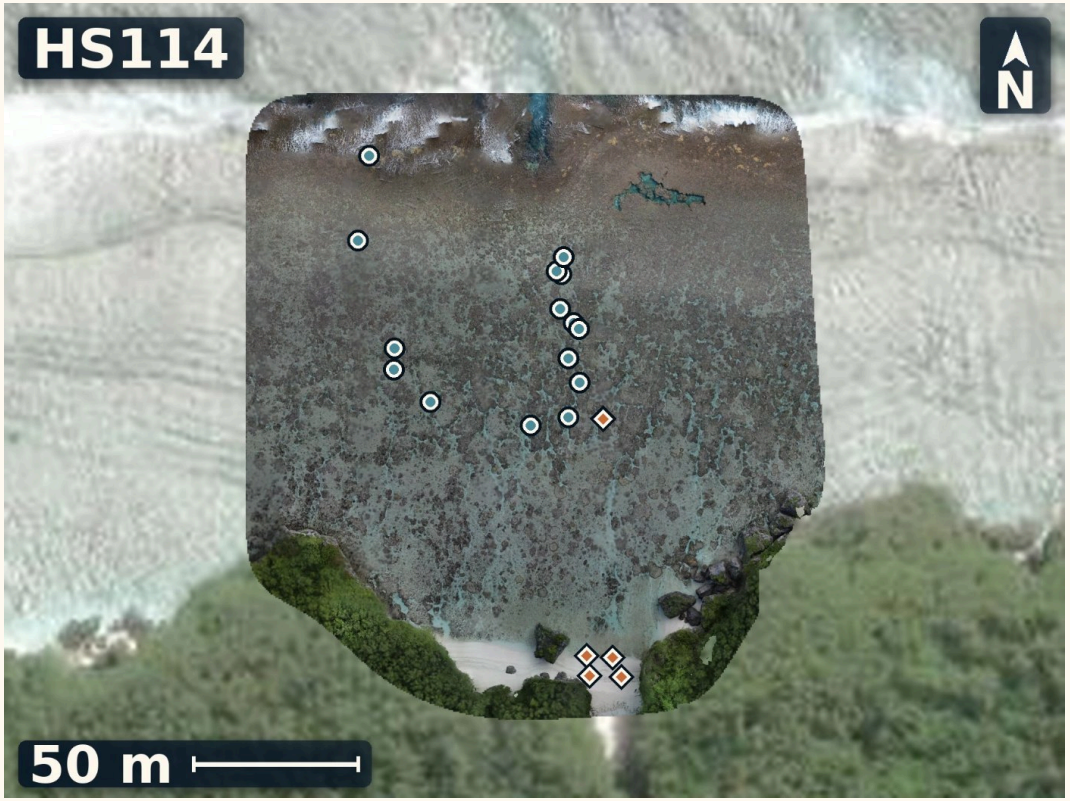
7 Araoa (modern reef) JUNE 4, 2026

HS114

Araoa's modern reef flat survey supplies a living height-and-water-depth reference needed to interpret fossil reef-flat candidates elsewhere on Mangaia.

OPEN QUESTION

How do tide-corrected HS114 depths and elevations compare with Mangaia's candidate fossil reef-flat surfaces?



HS114 on the drone orthomosaic. 15 water-depth GPS records and 6 ground-control GPS records (including one repeat control occupation) show survey coverage across the modern reef flat; its 2 catalogued samples have no mapped GPS records.

Water-depth GPS record **Ground-control GPS record**

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS114.

- Water depth and reef-flat elevation were recorded along a dense transect.
- Mapped reference points span the modern reef flat alongside the drone survey.

Open the complete HS114 survey record

8 Saragossa III

JUNE 4, 2026

HS115

Saragossa III extends the Mangaia transect north eastward, testing whether intermediate mounds sitting on the first major flat record primary reef growth or later collapse.

OPEN QUESTION

Do HS115's landward mounds record attached reef growth? If so, from when?



A low oblique drone view places HS115's cleared shoreward transect between the shallow reef flat and the vegetated inland rise. The exposed limestone, access track, and low coastal cliff are visible.



HS115 on the drone orthomosaic. 5 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS115.

- Preserved framework with Porites-like groups and encrusters occurs near the seaward start of the transect.
- Cleared flats retain pits, sand, moved boulders, and large corals that appear in place.
- Mottled, recrystallized, and blue-black surfaces prompted competing vegetation, primary-fabric, fallen-block, and sea-cave-collapse interpretations.

Open the complete HS115 survey record

ISLAND 4 OF 5

Mauke

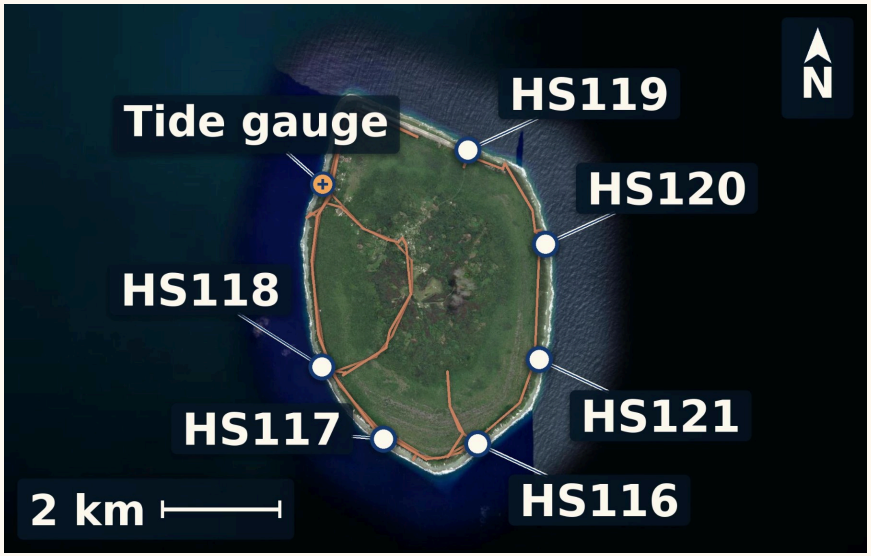
Field records · June 5-8, 2026

6	23	5
numbered sites	samples	surface models

Mauke work focused on modern reef-flat observations, coastal sections, inland exposures, and published profile locations. After installing the harbor tide gauge, we began at Anaraura, where low coastal reef relations and samples required careful separation of in-place framework from rubble. The south-southwest section and Tukume added layered reef, Tridacna and coral samples, and higher limestone exposures. At Uriaata, raised spur-and-groove fabric, large Porites, modern reef-flat microatolls, and possible stranded boulders could be compared within one coastal setting. Arapaea revealed a notch-like feature, while Aanga supplied another comparison site. These sites span very different elevations, but height alone cannot show whether they formed at different sea levels. The working Mauke datum, growth-position checks, surface models, and coral ages will help separate original reef relief from later erosion, wave transport, clearing, and alteration in the raised reef limestone. Additionally, study of the modern reef and wave regimes will offer insight into the processes that shaped the raised reef and its preservation.



On Mauke's western coast, a weathered limestone spur rises above a shallow pool beside the exposed reef flat, with breaking waves at the ocean edge. The undercut face establishes how modern erosion imprints on older fossilized environments.



Mauke field sites and generalized daily field routes, with the harbor tide gauge distinguished from nearby site markers. Recording gaps remain open; raw positions are retained in the daily logs.

Field route · HS field site · Tide gauge

Satellite imagery: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

HEIGHT REFERENCE

Mauke tidal datum

Three days at the harbour

Working field reference

The harbour record establishes local mean sea level—our zero. Measured features are reported relative to this surface so the reef and shore can be compared on one scale.

WORKING LOCAL DATUM · 12.53 M

MEAN WATER ABOVE LOGGER

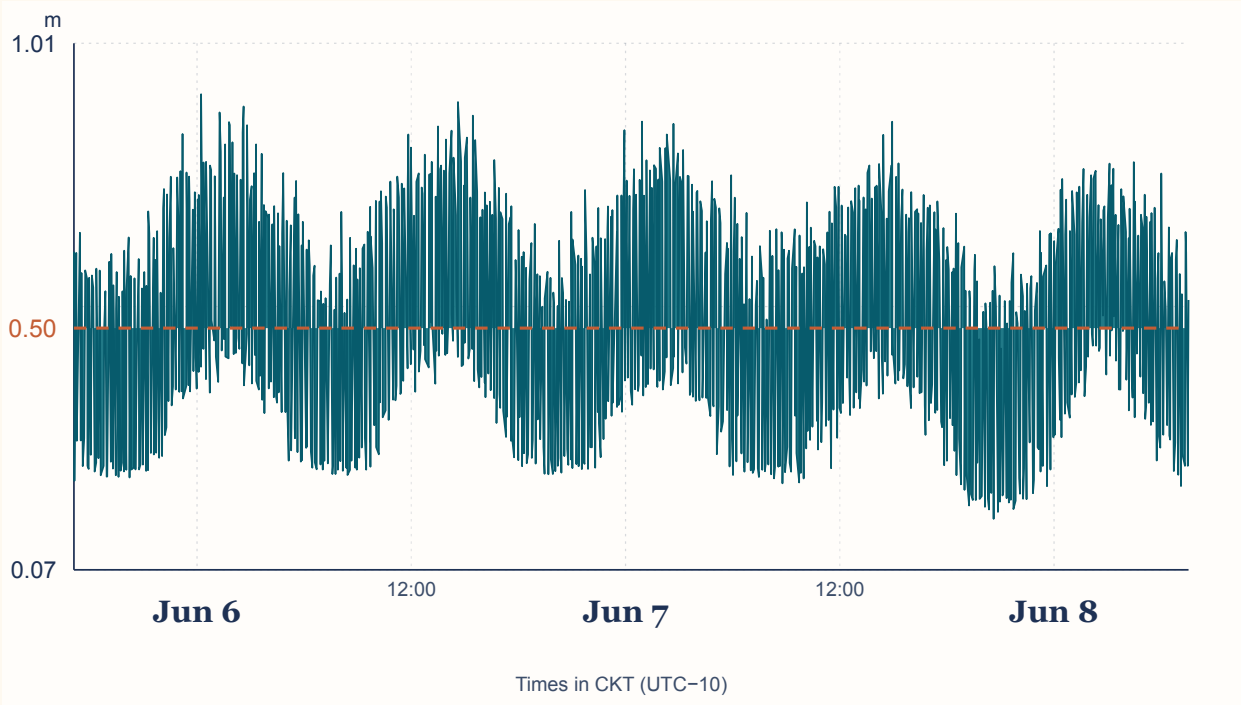
0.50 m

GAUGE TIE

2.70 m

HARBOUR LOGGER (3 DAYS)

Water level above logger (m) · Dashed line is mean sea level (0.503 m above logger).

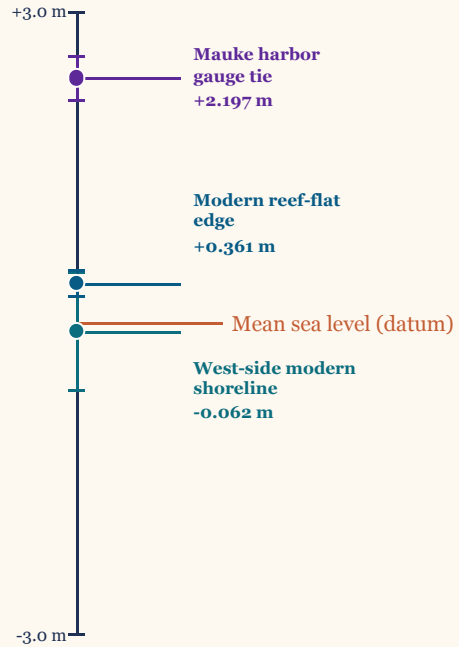


Water level above logger

Times in CKT (UTC−10)

MEASURED FEATURES RELATIVE TO MEAN SEA LEVEL

m above mean sea level



Whiskers show the field screening range, not a formal confidence interval.

The short, shallow deployment required island-specific screening.

SITE RECORDS

Brief field views from Mauke

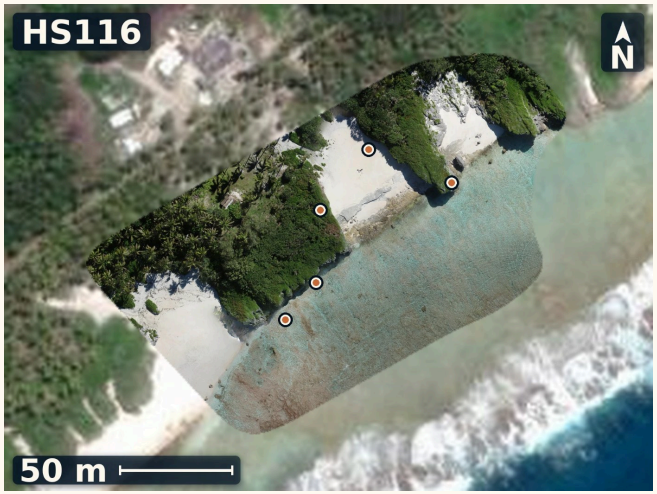
1 Anaraura JUNE 6, 2026

HS116

Anaraura combines a candidate two-unit exposure with dense photographic, sample, and mapped control, making growth position and height reconstruction testable.

OPEN QUESTION

Does the irregular contact persist across spurs, and are its corals in growth position rather than groove rubble?



HS116 on the drone orthomosaic. 5 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.



At Anaraura, an undercut limestone face meets shallow reef-edge water. Dark, irregular bands and contrasting rougher rock are visible near its base, but the photograph does not show whether they mark separate reef units, older notch fill, or later weathering.

A high-resolution drone orthomosaic and elevation model are available for HS116.

- Large coral spurs rise above grooves where accumulated rubble may obscure whether corals grew in place.
- A large Tridacna was observed on top of one coral spur.
- Small Porites-like colonies occur in the lower unit in front of the main spur.

Open the complete HS116 survey record

2 South Southwest

JUNE 6, 2026

HS117

South Southwest provides Mauke's clearest comparison to HS116, testing whether coral growth created distinct reef units separated by an island-spanning surface.

OPEN QUESTION

Are HS117 corals securely in growth position above and below the irregular contact?



At HS117, a pale, irregular band crosses a coral-rich limestone wall, with large coral forms visible above and below it. Field observations treat the band as a contact, but the photograph alone does not establish growth position or distinct reef units.



HS117 on the drone orthomosaic. 4 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS117.

- Thinner vegetation makes the two-layer relation easier to see here than at HS116.
- A Tridacna and additional coral samples were documented at the site.
- The lower material may include both in-place colonies and rubble trapped against the wall.

Open the complete HS117 survey record



FIELD NOTE · 13:30

Corals on the contact

The 13:30 field record describes corals growing directly on HS117's irregular contact surface. The photograph preserves that relationship; whether colonies on either side are securely in growth position remains unresolved.

1 **Recorded contact surface**

2 **Corals noted directly on it**

Photographed 13:29, 6 June 2026 · **Open the daily field note**

3

Tukume

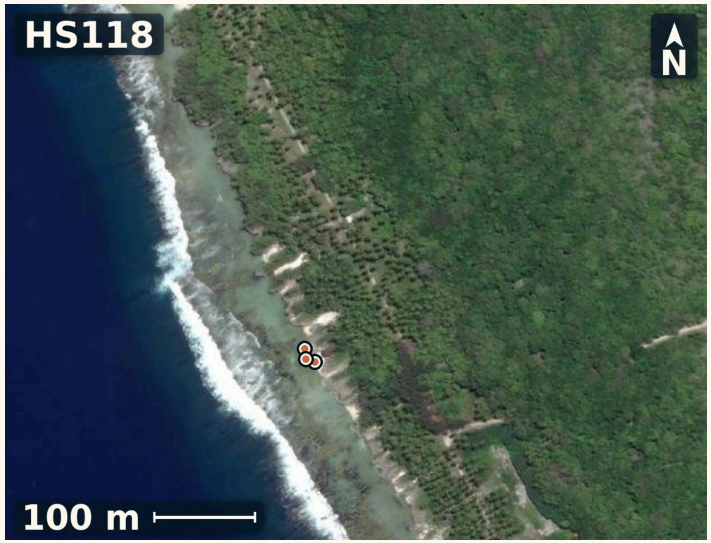
JUNE 6, 2026

HS118

Tukume extends the transect to the southwest, supplying another independent test of whether the layered relation continues along the coast.

OPEN QUESTION

Do corrected sample heights place Tukume's possible horizons within the elevation range of other sites?



HS118 on the best available satellite imagery. 3 sample GPS records are shown.

Sample GPS record

Satellite imagery: Esri, Maxar, Earthstar Geographics, and the GIS User Community.



Coral framework is exposed at HS118; the two-layer relation recorded farther along the Mauke coast is less obvious here.

A high-resolution surface model is not currently available for this site; satellite imagery, the mapped sample positions, and field photographs preserve its documented context.

- Framework reef is present, but no contact matches the clarity of HS117.
- Two sampled corals were sighted roughly 1.3 m above nearby mapped reference points.

Open the complete HS118 survey record

4 Uriaata JUNE 7, 2026

HS119

Uriaata connects a modern reef-flat, and a coastal elevated reef with some of the highest elevations on the island.

OPEN QUESTION

Is the coastal cliff and flat sequence temporally equivalent to the elevated inland coral up the road?



At Uriaata, an undercut reef-limestone wall meets the exposed modern reef flat. No clear two-layer boundary was recognized here; linking this face to the higher inland framework requires surveyed heights.



HS119 on the drone orthomosaic. 5 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS119.

- The coastal spur is about 8 m high; higher outcrops upslope contain large corals described as in place.
- Modern microatolls occupy the lowest tidal pools beside the raised exposure.
- Reef-framework fabric continues inland beneath large trees, but becomes less obvious and may rise gradually.

Open the complete HS119 survey record

5

Arapaea

JUNE 7, 2026

HS120

Arapaea suggests the layered pattern is regional and not island-spanning. The site also hosts a broad notch-like feature that may be from the early holocene.

OPEN QUESTION

Does the broad recess follow one sloping surface or define a separate horizon once tied to the surface model?



HS120 on the drone orthomosaic. 1 sample GPS record is shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.



At Arapaea, a deeply undercut limestone spur meets shallow reef-edge water, with the reef flat and breaking waves beyond.

A high-resolution drone orthomosaic and elevation model are available for HS120.

- A broad recess descends gradually into the waterline rather than holding one clear level.
- Framework coral and a large Tridacna occur without an obvious second layer.
- Rubble beside a groove may record local channel fill rather than a regional boundary.

Open the complete HS120 survey record

6 Aanga JUNE 7, 2026

HS121

Aanga establishes mapped control at a previously published location, creating a measured target for comparing to the published section.

OPEN QUESTION

Do the HS121 reference points and exposure geometry align with the previously published Aanga profile?



At Aanga, a marked survey target sits on rough coastal limestone above a narrow beach, shallow reef flat, and wave-cut edge. The photograph places mapped control in its coastal setting.



HS121 on the drone orthomosaic. 2 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS121.

- Five mapped reference points were recorded at the stop.
- The exact profile match remains unverified against the published map and field coordinates.

Open the complete HS121 survey record

ISLAND 5 OF 5

Mitiaro

Field records · June 9-12, 2026

4	23	4
numbered sites	samples	surface models

Mitiaro focused attention on the difficult boundary between younger coastal deposits and older reef limestone. A temporary harbor tide gauge provided a working island height reference before reconnaissance of weathered limestone and south-coast reddish outcrop. At Teunu, HS122 documented coral-bearing boulders, low ledges, reef-flat surfaces, vegetated pools, and seven samples whose transport and growth position still need checking. Te Rotonui, HS123, exposed coral-rich rock beneath an angular sand layer that may be perched-beach or storm-deposited material, together with possible younger tidal notch and coral fill closer to water level. Te Rua O Te Pui, HS124, recorded wind and wave setup across a modern reef flat and larger corals on spur tops. Okore, HS125, added broad backreef relief, lower spurs, a near-sea-level clast horizon, and mobile sand on the high-energy west coast. The datum, surface models, and future ages will test which features are young, which belong to older reefs, and how waves and preservation created the differences seen around the island.



At Te Rotonui, a low-oblique drone view reveals similarities between the wave-washed reef flat and fossilized limestone spurs. Towards the vegetated interior, an access track, and one of Mitiaro's inland lakes can be seen. The island setting is distinct from the other Southern Cook Islands in that the entire island is quite low lying.



Mitiaro field sites and generalized daily field routes, with the harbor tide gauge distinguished from nearby site markers. Recording gaps remain open; raw positions are retained in the daily logs.

Field route **HS field site** **Tide gauge**

Satellite imagery: Esri, Maxar, Earthstar Geographics, and the GIS User Community.

HEIGHT REFERENCE

Mitiaro tidal datum

Three days at the harbour

Working field reference

The harbour record establishes local mean sea level—our zero. Measured features are reported relative to this surface so the reef and shore can be compared on one scale.

WORKING LOCAL DATUM · 13.51 M

MEAN WATER ABOVE LOGGER

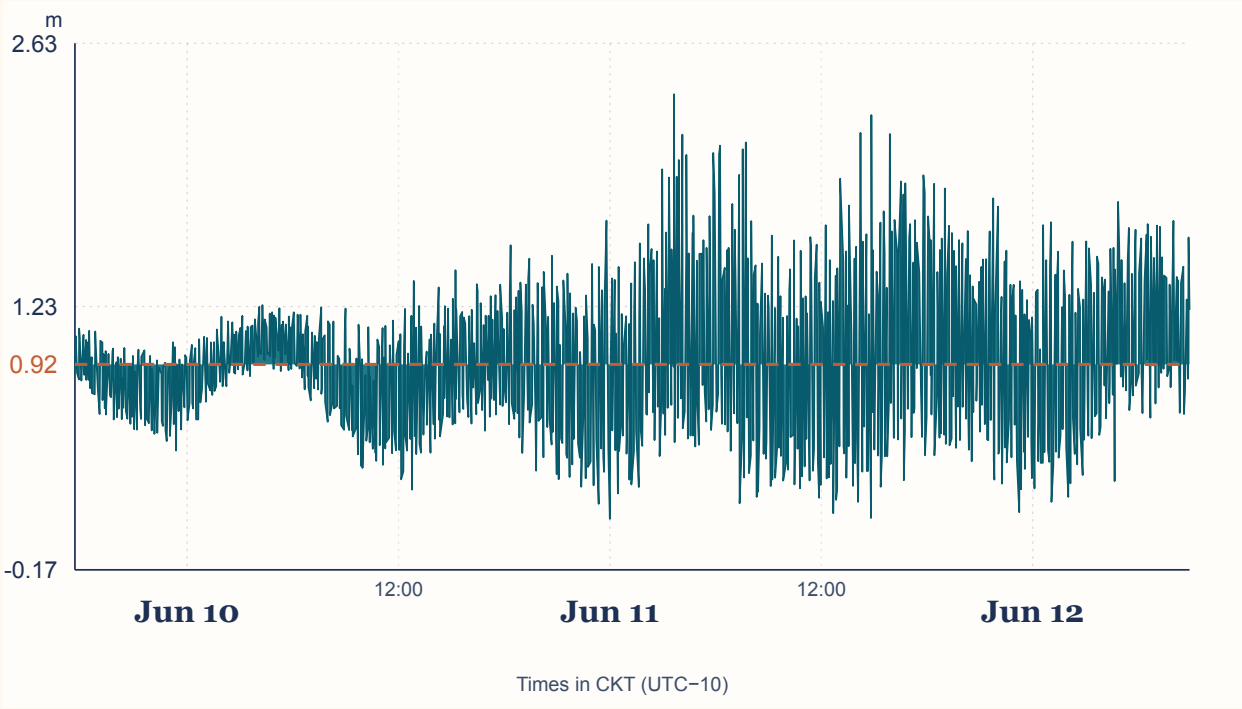
0.92 m

GAUGE TIE

1.91 m

HARBOUR LOGGER (3 DAYS)

Water level above logger (m) · Dashed line is mean sea level (0.920 m above logger).

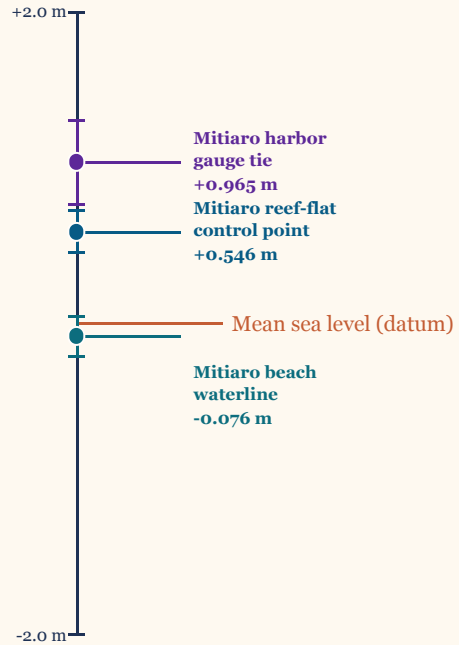


Water level above logger

Times in CKT (UTC−10)

MEASURED FEATURES RELATIVE TO MEAN SEA LEVEL

m above mean sea level



Whiskers show the field screening range, not a formal confidence interval.

Deployment and recovery measurements were screened together before calculating the working datum.

SITE RECORDS

Brief field views from Mitiaro

1 Teunu JUNE 9, 2026

HS122

Teunu reveals how storm transport, reef-flat relief, and older limestone meet on Mitiaro’s exposed coast.

OPEN QUESTION

Is the highest mound weathering primary reef, or part of storm-reworked material?



HS122 on the drone orthomosaic. 7 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.



At HS122 Teunu, a low-oblique drone view follows jagged coastal spurs from the wave-washed reef flat toward a vegetated surface and forest-lined road.

A high-resolution drone orthomosaic and elevation model are available for HS122.

- A near-constant ledge rims a vegetated low; pool erosion, inherited relief, and overwash ponding remain alternatives.
- Ledge photos show blocky microcrystalline carbonate with lighter platy or elongate fabric.
- A recently overturned storm block exposed fresh white rock where the team sampled the outcrop.

Open the complete HS122 survey record

2 Te Rotonui

JUNE 10, 2026

HS123

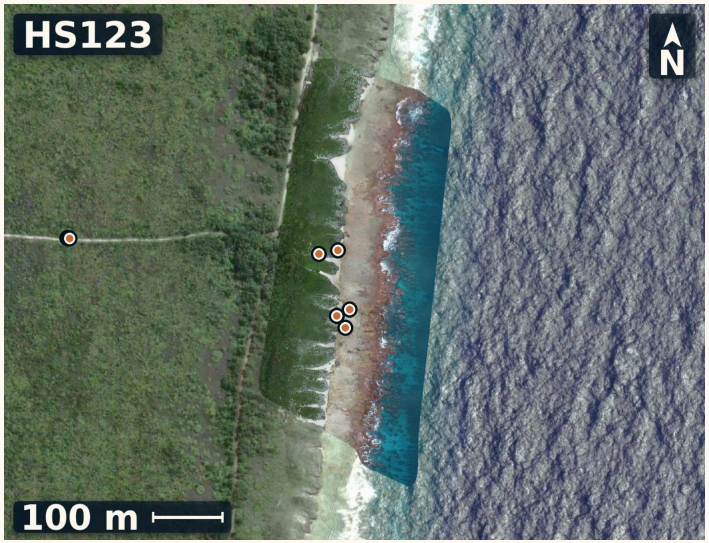
Te Rotonui exposes possible younger notch fill against older reef rock, and has abundant cross-cutting cracks that can mimic geologic surfaces.

OPEN QUESTION

Which fabric, mineralogy, and elevation criteria can distinguish younger notch fill from older wall rock at HS123?



At HS123 Te Rotonui, a notch-like recess is visible in the coral-rich coastal limestone beside the exposed reef-flat path.



HS123 on the drone orthomosaic. 7 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS123.

- Corals within and near the notch may be younger fill, but separation from older wall rock remains unresolved.
- Horizontal cracks cut through large coral colonies, so they cannot automatically be treated as exposure surfaces.
- Rocky highs beside the road may be local patch-reef relief rather than a continuous surface.

Open the complete HS123 survey record

3 Te Rua O Te Pui

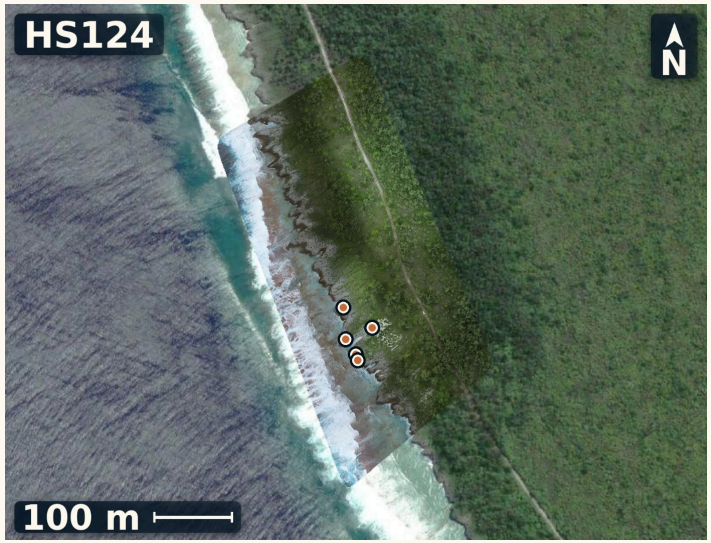
JUNE 10, 2026

HS124

Te Rua O Te Pui offers clear exposure of a southwest facing reef with spurs and grooves that appear primary.

OPEN QUESTION

Does the spacing and relief of Te Rua O Te Pui's spurs and grooves tell us anything about the paleo-environment?



HS124 on the drone orthomosaic. 5 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.



At HS124 Te Rua O Te Pui, a researcher works beside the red survey tripod above a narrow, water-filled channel of jagged reef rock.

A high-resolution drone orthomosaic and elevation model are available for HS124.

- Larger coral colonies occupied spur tops, distinct from the morning stop.
- Rock surfaces were sharper and more micro-rough than at earlier Mitiaro stops.
- Two mapped reference points were recorded near the end of the day.

Open the complete HS124 survey record

4 Okore

JUNE 11, 2026

HS125

Okore has a near-sea-level clast horizon whose weathering differs from overlying rock, offering a focused test of storm emplacement versus older reef fabric versus early holocene highstand.

OPEN QUESTION

Is the groove's clast horizon storm-emplaced material, in-place reef, or weathered older limestone?



Low-oblique drone overview of HS125 on Mitiaro's west coast, showing the wave-washed reef flat, broad pale landward surface, and forest edge.



HS125 on the drone orthomosaic. 4 sample GPS records are shown.

Sample GPS record

Cook Islands 2026 drone orthomosaic; Esri World Imagery context.

A high-resolution drone orthomosaic and elevation model are available for HS125.

- The clast horizon occurs within a groove close to modern sea level.
- Its weathering differs from the material above it.
- Four mapped reference points document the stop.

Open the complete HS125 survey record



FIELD NOTE · 14:51

A clast-rich band in the groove

Photographed is a distinct clast-rich band beside Jacky, close to modern sea level, where the rock weathers differently from material above. Whether it is storm-emplaced material, in-place reef, or weathered older limestone remains unresolved.

1 **Clast-rich band**

2 **Differently weathered rock above**

Photographed 14:50, 11 June 2026 · **Open the daily field note**

NEXT RESEARCH

Three planned research papers for the next phase

PAPER 1

Reef morphology, elevation, waves, and sea level

Compare site elevation and morphology within and among islands using digital elevation models (DEMs), orthomosaics, tidal datums, field fabric, and modern analogues. Test which combinations of wave exposure, reef setting, relative sea level, erosion, transport, and preservation can explain each site.

PAPER 2

Why relative sea level differs between islands

Use dated reef indicators and corrected heights to test contributions from volcanic loading, lithospheric flexure, volcanic swells, and glacial isostatic adjustment while separating these signals from reef ecology, preservation, age, and measurement uncertainty.

PAPER 3

Geochronology, coral preservation, and makatea formation

Date the sites, document how coral preservation changes with time and environment, and constrain when the raised reef units formed. Last Interglacial ages and elevations can improve constraints on polar ice in a warmer world and, through appropriate models, inform future local sea-level projections.

IMMEDIATE WORK

- Screen coral mineralogy and preservation before selecting material for geochronology.
- Use high-resolution elevation models and orthomosaics to test surface continuity, relief, and wave exposure.
- Compare HS locations with published profiles and dated localities.

SOURCES THAT FRAME THE INTERPRETATION

Stoddart et al. (1990)	Describes makatea morphology, elevations, reef units, and storm-boulder cautions on Atiu, Mauke, and Mitiaro.
Woodroffe et al. (1991)	Provides dated Southern Cook Islands reef evidence and shows why growth position, preservation, age, and height must be interpreted together.
Huppert et al. (2015)	Supplies a Hawaiian volcanic-loading and flexure mechanism analogue, not a Cook Islands calibration.
Du et al. (2026)	Constrains the ages and geometry of Tama and Rarotonga volcanism while leaving the longer hotspot history unresolved.

FIELD GLOSSARY

A short field glossary

Raised reef limestone (makatea)

Old coral reef and reef sediment that now stand above the living shore.

Microatoll

A coral colony whose upper surface stops growing where repeated low-water exposure limits growth while its outer edge continues outward.

Orthomosaic

A map-like image assembled from many overlapping drone photographs.

U-Th dating

A laboratory method that estimates coral age from uranium and thorium isotopes.

Reef flat

A shallow, wave-washed surface where corals, algae, shells, and sediment occur near sea level.

Coral framework

Reef rock that preserves corals and other builders where they grew, rather than as loose transported rubble.

Digital elevation model

A high-resolution map of the height and shape of the ground or reef surface.

Tidal datum

A local sea-level reference used to compare elevations measured on different days and islands.