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TETIAROA society

• SUSTAINABILITY IN ACTION •

TETIAROA CONSERVATION AND SUSTAINABLE USE PLAN

« CASUP »

Note: This is a discussion draft to facilitate comment and further discussion. This draft will be revised after additional input is received.

TETIAROA CONSERVATION AND SUSTAINABLE USE PLAN

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TETIAROA CONSERVATION AND SUSTAINABLE USE PLAN

1. PREAMBLE

Preamble

Tetiaroa is a natural wonder of astonishing beauty and environmental, historical and cultural importance. It is vital that this treasure be conserved, restored and protected so that its future is as rich as its past.

This Conservation and Sustainable Use Plan ("CASUP") attempts to provide a united vision for the future of Tetiaroa and a plan for managing this natural marvel to facilitate ongoing preservation, protection and responsible use of the atoll, and to make it a model of sustainability.

Objectives of CASUP

The objectives of the CASUP are to articulate a long-term vision - shared by all major stakeholders - for the conservation, protection, and responsible and sustainable use of Tetiaroa; establish both long-term and short-term goals in furtherance of that vision; identify threats to the vision; develop strategies to minimize or eliminate those threats; and set forth recommendations for how the CASUP should be implemented and managed.

Origin of CASUP and Consultative Process

The land of Tetiaroa is owned by SA Frangipani, which is majority owned by the Brando Estate. The only commercial operation on Tetiaroa is The Brando, a luxury eco-resort owned by Pacific Beachcomber S.C. Pacific Beachcomber has leased the motus of Onetahi and Honuea from SA Frangipani under a 99-year lease. There are no other leasehold interests on Tetiaroa. In the interest of protecting and preserving Tetiaroa, SA Frangipani and Pacific Beachcomber (hereinafter, the "Owners") have agreed that there will be no commercial development on any of the motus of Tetiaroa other than Onetahi and Honuea

Tetiaroa Society is a non-profit public benefit company whose purpose is to contribute to the understanding and wise management of tropical island socio-ecosystems through education, conservation, and research related to Tetiaroa. It was founded by the Owners and other interested parties in 2010. In order to encourage and facilitate tax-deductible donations by US taxpayers, it was incorporated in the US and registered under section 501(c)(3) of the US Internal Revenue Code.

The Brando Estate, SA Frangipani and Pacific Beachcomber consider themselves stewards of Tetiaroa, and charged Tetiaroa Society to create a plan for the conservation and sustainable use of the atoll. Subject to their approval and adoption of the CASUP, the Owners intend to commission Tetiaroa Society to implement the CASUP.

In order to engage a broad range of stakeholders in the development of the CASUP, Tetiaroa Society created a Conservation and Sustainable Use Plan Committee, comprised of experts in several fields, to help articulate a common vision for Tetiaroa and to begin the drafting process. The CASUP went through several revisions since work began on it in early 2015, and as of March 2016 is being distributed for comment to the Owners and government officials and regulatory bodies (the atoll is part of the Commune of Arue and

its marine zone is public domain administered by French Polynesia). After receipt of input from the Owners and public authorities, the CASUP will be published on the Tetiaroa Society website and presented for public discussion through various media, including community meetings. Public comments will be incorporated into future versions of the CASUP.

While the land of Tetiaroa is privately owned, the Owners have no statutory or legal authority with respect to the management of the lagoon, the reef or the surrounding waters, which are all in the public domain. The CASUP is thus non-binding with respect to those areas.

The CASUP is envisaged as a living document that will require regular updating. Ongoing revisions will be made and incorporated into revised versions published annually or as appropriate.

Protection of the Lagoon and Reef

Although the governance of the atoll is divided between the Owners and public authorities, Tetiaroa itself is a single integrated ecosystem and it is important that the land, the lagoons and the reef all be managed in a holistic and coordinated fashion. Accordingly, the CASUP sets forth recommendations regarding the use and management not just of the land, but also the lagoons and reef. It is hoped the relevant governmental authorities and policy makers with authority over the lagoons and reef will find these recommendations helpful and valuable and support the recommendations.

Implementation and Management of the CASUP

The CASUP will be successful only to the extent it receives broad stakeholder support and is diligently and faithfully implemented. In their charge to Tetiaroa Society to create the CASUP, the Owners envisaged that Tetiaroa Society will manage its implementation through Tetiaroa Society's (a) Executive Committee, (b) onsite managers, (c) rangers and guides, who will help with protection of the atoll and educating visitors about environmentally sensitive and appropriate conduct on the atoll, and (d) non Tetiaroa Society contractors, scientists, cultural experts, and technical consultants, who Tetiaroa Society will engage to carry out certain programs on the atoll necessary to achieve the CASUP's objectives.

Financing of the CASUP and its Programs

Conservation, protection, education and research all need to be paid for. The ability of Tetiaroa Society to implement the CASUP depends on its receipt of financing to carry out the proposed programs. It is hoped that financial support for the programs outlined in the CASUP can be raised from a variety of sources, including support from guests of The Brando, public donations to Tetiaroa Society, fundraisers and third party grants.

Administrative and Research Authorizations

Several of the projects described in the CASUP depend upon obtaining necessary administrative and research authorizations and support. Accordingly, such projects will be submitted for consideration and approval by the appropriate regulatory authorities before action is taken.

CASUP Committee

The CASUP was developed under the guidance of the following individuals who served as members of CASUP Committee:

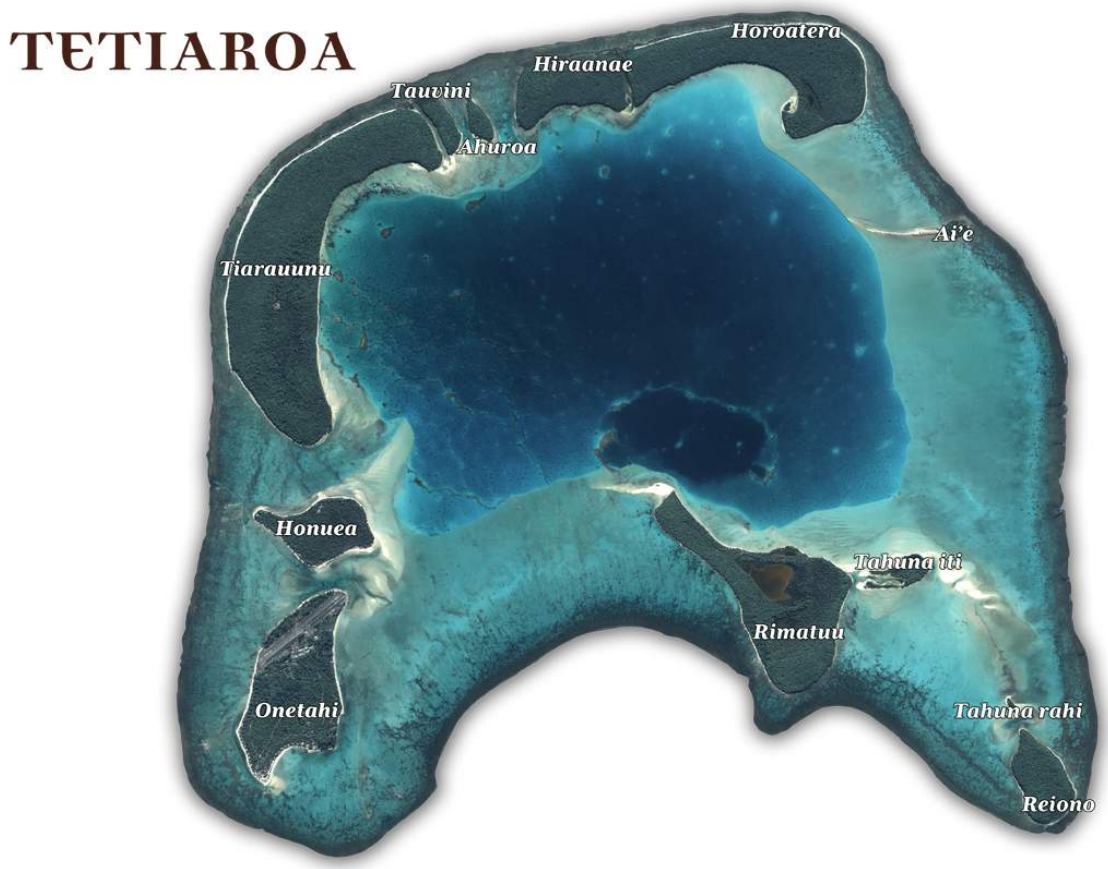
Stan Rowland (Chair)	Chairman, Tetiaroa Society
Richard Bailey	President, Pacific Beachcomber
Hervé Bossin	Medical entomologist with Institut Louis Malardé
Teihotu Brando	Brando family member; long-term resident of Tetiaroa
Costas Christ	Editor and columnist for National Geographic Traveler; expert in sustainable tourism
Neil Davies	Chair, TS Scientific Advisory Board; Director, UC Berkeley Gump South Pacific Research Station, Moorea
Mark Eddowes	Archeologist
Cécile Gaspar	President, Te Mana o te Moana; conservation biologist
Jean-Yves Meyer	Research Mgt Officer, French Polynesia Research Department
Frank Murphy	Associate Director - Scientific Operations, Gump Station
Teurumereariki Hinano Murphy	Chair, TS Cultural Advisory Board; President, Atitia Center; traditional knowledge expert
Serge Planes	Director CNRS-EPHE CRIOBE, Moorea; expert in population genetics of marine fish
Philippe Raust	Président, Société d'Ornithologie de Polynésie
James Russell	Professor of Island Ecology and Biosecurity with the University of Auckland
David Seeley	Counsel to the Brando Estate / CEO, SA Frangipani
Hannah Stewart	Marine biologist

Lead Authors and Contributing Authors

The development of the CASUP relied heavily on the contributions of the individuals identified in each section as either the Lead Author or a Contributing Author. The Lead Authors and Contributing

Authors are identified in acknowledgment and appreciation of the significant time and effort they devoted to preparing their respective sections. While the Lead Authors and Contributing Authors were instrumental in developing their respective sections, the views and recommendations in each section represent a consensus view of the CASUP Committee and do not necessarily reflect the views or recommendations of the Lead Author or any Contributing Author.

Map of Tetiaroa



2. OVERVIEW

Overview

Tetiaroa is a natural wonder of astonishing beauty and significant environmental, historical and cultural importance. It is vital that this treasure be conserved, restored and protected so that its future is as rich as its past.

The Conservation and Sustainable Use Plan ("CASUP") attempts to provide a united vision for the future of Tetiaroa and a plan for managing this natural marvel to facilitate ongoing preservation and protection and to make it a model of sustainability. It is hoped that through the CASUP the health, diversity, and resources of the Tetiaroa terrestrial and marine ecosystems and the wildlife they support, and the island's rich cultural heritages, will be protected forever.

Readers of this Overview are cautioned that a review of the entire CASUP is essential to understanding it. This Overview is intended merely as an introduction and broad overview of the CASUP.

1) Scientific Research

Human activities are driving the twin crises of climate change and biodiversity loss, making environmental sustainability the defining issue of our time. Addressing this grand challenge requires a far better understanding of complex social-ecological systems and the capacity to predict human and natural change at the scale of management action. Tetiaroa Society should help in meeting this challenge through the use of Tetiaroa's unique resources in scientific research.

Strategies:

- Form a Scientific Advisory Board ("SAB") consisting of local and international scientists (particularly those in the Pacific Region) with expertise in the major scientific disciplines that underpin Tetiaroa Society's mission.
- Leverage the considerable international scientific capacity present in French Polynesia.
- Establish facilities (such as the Tetiaroa Ecostation) and recruit staff to support scientific research on the atoll and communication of its results to key stakeholders.
- Support scientific research on Tetiaroa through work with partner institutions that have the capacity to help Tetiaroa Society achieve its research goals, as guided by its Scientific Advisory Board.

2) Coral Reef Ecosystem

On a global view, coral reefs are often called the rainforests of the sea, both due to the vast amount of species they harbour, and to the high productivity they yield. Aside from the hundreds of species of coral, reefs support extraordinary

biodiversity and are home to a multitude of different types of fish and invertebrates.

Strategies:

- Survey some indicators of the climate change (temperatures and salinity of the coastal environments).
- Observe and interpret the temporal variations of biogeochemical and biological characteristics of the lagoon and the outer reef.
- Check assumptions on the effects of climate change and evolution of the human pressure on these complexes.
- Develop holistic remediation programs.

3) Sea Turtles

Tetiaroa is one the last remaining important nesting site for green sea turtles in the Society Islands. This gives the atoll a high priority in turtle nesting conservation and also in inventory and biological studies. On the IUCN list of threatened species word-wide, green sea turtles are listed as "endangered", and the hawkbill turtle is listed as "critically endangered." Among the threats to sea turtles are poaching, pollution, food resources availability and global warming.

Strategies:

- Update knowledge: Continue surveys and inventories, learn genetic repartition, and obtain a better understanding of life cycles, diet, habitat zone and pollution effects.
- Protect: Maintain pristine coastal habitats and feeding grounds, protect against poaching, help injured sick or weak turtles, set up a conservation plan for nesting sites, measure effects of global warming, and create a territorial hatchling nursery (if permitted).
- Educate: Write an illustrated guide on sea turtles found around Tetiaroa, organize and coordinate education sessions with schoolchildren, students and local population on sea turtles of Tetiaroa (both on the atoll but also as outreach programs on other islands), and create a partnership with day tour charters that offer their guests beach walks on Rimatuu and Tahuna Iti to train them for green turtle nest survey (and become part of our turtle observatory) and how not to disturb the incubation of eggs.

4) Flora and Vegetation

Tetiaroa is one of five atolls in the Society archipelago but the only one of the Windward islands group (which includes the high volcanic islands of Tahiti, Moorea, Maiao and Mehetia). Its native flora is relatively similar to those found in other atolls of the Society and the Tuamotu archipelagos, and has been profoundly

altered by both Polynesians and Europeans on some motus (mainly by coconut plantations).

Strategies:

- Improve and update knowledge on the native and alien flora.
- Educate and build capacity: train the Tetiaroa Society guides, write an illustrated guide of the flora, set up "discovery trails" in the different vegetation types, organize and coordinate "weeding" and native species replanting sessions with school children, students, and other volunteers including the hotel staff and clients.
- Restore and protect: control coconut trees in some motus, control alien weeds, prevent new introductions of alien plants, reintroduce extirpated (locally extinct) native species.

5) Birdlife

Part of the exceptional wealth of Tetiaroa is the diversity and density of its seabird population. The well protected and preserved habitat of Tetiaroa provides favorable nesting conditions, and the richness of the lagoon and the proximity of the open ocean provide seabirds a wide foraging area. The atoll is classified as an IBA (Important Bird and Biodiversity Area) by Birdlife International.

Strategies:

- Improve knowledge on Bird life on Tetiaroa.
- Minimize the impact of threats to birds.
- Enhance habitats for marine and terrestrial birds.
- Restore marine and terrestrial bird species on motus where they have been extirpated.

6) Coconut Crabs

Coconut crabs (*keveu*) are the world's largest terrestrial arthropod, reaching sizes up to 1 meter from outstretched leg to leg, and weighing as much as 5 kilograms. Coconut crabs can live up to 60 years, and reach sexual maturity after approximately 6 years. Tetiaroa should be a protected reserve for coconut crabs.

Strategies:

- Quantify: An atoll-wide monitoring effort should be undertaken with staff and guides of Tetiaroa Society and hotel staff, many of whom are Tahitian and know how to locate and catch coconut crabs.

- Protect: Protection of coconut crabs will come with conservation and protection of the lagoon and motus.
- Educate: Educate visitors via rangers and guides about this unique crab and its threatened status, and restrictions against its harvest on Tetiaroa, and provide information about this rare crab and its threatened status that could be incorporated into education programs for visiting local children via the cultural program.

7) Entomology

A number of introduced species present on Tahiti may not have yet been introduced to Tetiaroa – most notable are mosquitoes, ant species and spiders. Eliminating present alien pest species and preventing the introduction of additional ones should be a priority.

Strategies:

- Eliminate alien insect pest species of medical, veterinary, economic and/or ecological importance
- Prevent the introduction of alien insect (pest) species.
- Leverage the presence of beneficial species to foster innovation.

8) Alien Species Management and Biosecurity

Islands are fragile ecosystems and their biodiversity is more vulnerable than usual to disturbance or "perturbation." One of the strongest drivers of disturbance to island ecosystems is the introduction of alien (non-native) species, some of which can become invasive. These "invasive species" can have dire effects on the ecology and economy of islands, in many cases leading to local species extinctions.

Strategies:

- Eradicate introduced rats, invasive mosquitoes and introduced land birds from Tetiaroa
- Establish terrestrial and lagoon biosecurity on Tetiaroa
- Manage invasive alien plants and ants.

9) Cultural Heritage

In Polynesia, culture and history are tied to the natural world. The spirit of the ancestors lives on in the natural world and

therefore respect for the land and lagoon is respect for the ancestors and their relationship with nature. Tetiaroa should be used in a way that honors the ancestors and the rich Polynesian cultural heritage of the atoll.

Strategies:

- Create a Cultural Advisory Board ("CAB") with members of the local community. This committee should be charged with defining and managing the cultural heritage of Tetiaroa.
- Create a symposium/workshop series to discuss and define the cultural heritage of Tetiaroa. This would allow a larger section of the community to contribute to the history and culture of Tetiaroa and support the efforts of the Cultural Advisory Board.
- Carry out the programs developed by the Cultural Advisory Board.

10) Archeology

Tetiaroa is an important site in Polynesian history and culture. To date a total of over 90 archaeology sites have been identified on Tetiaroa. The amazingly rich cultural and historical heritage of Tetiaroa needs to be understood, protected and shared.

Strategies:

- Conduct more extensive archeological surveys and studies across the atoll and, with appropriate authorizations, excavate archeological sites on Onetahi, Ti'araunu, Hiraana'e, Horoatera, Rimatu'u, and Reiono.
- Create a system of stewardship of sites across the motus that is in the hands of and directed by local Tahitians, so that historic and linguistic knowledge returns to its source, the Tahitians themselves.

11) Educational Program

Education is a key part of any conservation plan. On Tetiaroa there will be a local education program that brings students from local schools to the atoll, and facilities that can be used by these local schools as well as community groups and international schools.

Strategies:

- Create an education program with local schools, construct an education camp, and begin the education program.

12) Fisheries

Tetiaroa is a small atoll - one of the smallest of French Polynesia _ and in light of that we can consider that it will be very sensitive to overfishing, especially if only a few species are targeted.

Strategies:

- Promote a consultation committee involving local fishermen, scientist and other users of the ecosystem.
- Evaluate ecosystem change due to the establishment of the ZPR.
- Enhance fish stocks through a "Post-Larvae Capture and Culture" (PCC) program.
-

13) Tourism

Tourism operations on Tetiaroa should follow Sustainable Tourism guidelines.

Strategies:

- Create a tourism working group among active stakeholders that will set guidelines with advice from experts in many different fields
- Obtain descriptions of all local tourism operations and activities on Tetiaroa and work with active members of this group to review guidelines. These tourism activities will mainly occur on Rimatu'u and Bird Island.
- Meet with all stakeholders to try and create a consensus on guidelines and monitoring of future tourist activities.
- Meet with lagoon committee to coordinate future tourist activities on the public domain. Discuss potential threats from jet skis, sea/float planes, floating homes, fishing, kitesurfing, windsurfing, and drones. Develop comprehensive regulation strategy for tourist activities on the atoll.

14) Built Environnement – The Brando

The built environment on Tetiaroa consists of The Brando – a luxury eco-resort located on the motu of Onetahi that is committed to becoming a new model of sustainability. As part of their commitment to preserve and protect Tetiaroa, the Brando Estate and Pacific Beachcomber have agreed that there will be no commercial development on any of the motus of Tetiaroa other than Onetahi and Honuea, and that the remainder of the atoll will

be maintained as a natural reserve.

Strategies:

- Limit future development on Tetiaroa to the motus of Onetahi and Honuea, with limited exceptions for cultural, educational, scientific programs (such as a children's cultural and educational fare on Rimatu'u) and recreational activities (such as bird watching platforms to minimize stress on the bird population).
- Use the built environment (The Brando) to help support conservation, scientific and educational programs.
- Ensure that all construction blends harmoniously with the environment.
- Avoid all over-water structures including piers, floating platforms, floating hotels and restaurants, houseboats and long-term anchorages.
- Avoid the destruction or impairment of any natural habitat or resource on which plants or animals depend.
- Use mitigation, restoration and enhancement programs in all construction to achieve a net benefit to the natural environment.
- Operate exclusively with renewable, non-fossil energy sources using the sea, sun, coconuts and other renewable resources.
- Determine the carrying capacity of the atoll for different activities and maintain a sustainable level of human activity vis-à-vis the natural environment.

3. VISION, MISSION, GUIDING PRINCIPLES AND GOALS

Vision, Mission, Guiding Principles and Goals

Following are the Vision, Mission, Guiding Principles and Goals of the Tetiaroa Conservation and Sustainable Use Plan.

Vision

That the health, diversity, and resources of the Tetiaroa terrestrial and marine ecosystems and the wildlife they support, and the island's rich cultural heritages, be protected forever.

Mission

Carry out integrated management to achieve strong, long-term protection and perpetuation of Tetiaroa ecosystems in their natural state and preservation and appreciation of its Polynesian cultural heritage and resources.

Guiding Principles

Tetiaroa shall be managed in accordance with the CASUP in a manner that:

- Is consistent with the Vision and Mission;
- Affirms that Tetiaroa and its wildlife are important, unique, and irreplaceable;
- Honors the significance of Tetiaroa for native Polynesians;
- Honors the historic importance of Tetiaroa;
- Incorporates best practices, scientific principles, traditional knowledge, and an adaptive management approach;
- Coordinates with the owner of Tetiaroa, government bodies, native Polynesians, nonprofit organizations, private businesses, and the public; and
- Carries out effective outreach, monitoring, and enforcement of the CASUP to promote compliance.

Goals

Goal 1: Protect, preserve, maintain, and where appropriate restore the natural biological communities and their associated habitats, populations, native species, and ecological processes.

Goal 2: Support, promote and coordinate research and monitoring that increases understanding of Tetiaroa and improves management decision-making.

Goal 3: Manage human activities to maintain ecosystem integrity and prevent or minimize negative impacts.

Goal 4: Enhance public understanding, appreciation, and support for protection of the natural, cultural, and historic resources.

Goal 5: Identify, interpret, and protect historic and cultural resources.

Goal 6: Offer visitors opportunities to learn about and appreciate the wildlife and beauty of Tetiaroa, assist in conservation efforts, and honor its unique human history.

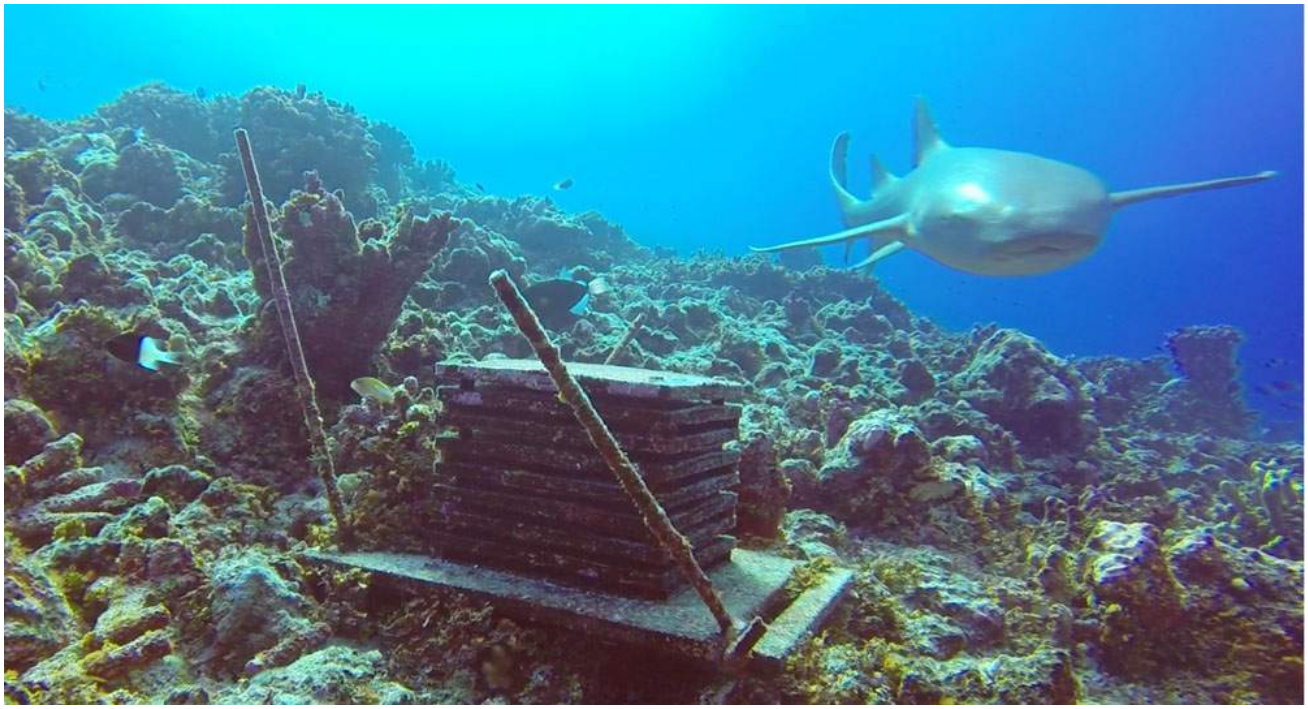
Goal 7: Create a new conservation paradigm that brings together the owner, private businesses, nonprofits, the public, scientists, and the government to conserve, manage, and protect Tetiaroa.

Historical Note: Following are the "Ecological Objectives" set forth in "An Ecological Reconnaissance of Tetiaroa Atoll, Society Islands" by M.H. Sachet and F.R. Fosberg, which was commissioned by Marlon Brando and issued by The Smithsonian Institution in 1983:

1. To maintain the natural diversity of the living component of the Tetiaroa Atoll ecosystem.
2. To maintain the natural beauty of the atoll setting.
3. To avoid the depletion or impairment of any resource of the island on which man or other organisms inhabiting the atoll depend.
4. To avoid the accumulation, over a short term or long, of substances or waste products deleterious to life—human or other forms.
5. To avoid having any species of organism increase seriously in numbers at the expense of other species—in other words, to maintain an ecological equilibrium or balance.
6. To eliminate or reduce to reasonable numbers such exotic species as have been introduced and established in the past and have assumed pest proportions or threaten to do so.
7. To avoid introduction of exotics that may make life more difficult, less pleasant, or may disturb seriously the ecological equilibrium off the atoll, or pose a threat of disease.
8. To determine, and not exceed, the long-term carrying capacity of the atoll for humans in terms of the above stated objectives.

4. PROGRAMS

Scientific Research



Lead Author: Neil Davies

Principal Contributing Authors: Members of the Scientific Advisory Board and Hannah Stewart

Background and Current Situation

Human activities are driving the twin crises of climate change and biodiversity loss making environmental sustainability the defining issue of our time. Addressing this grand challenge requires a far better understanding of complex social-ecological systems and the capacity to predict human and natural change at the scale of management action. Planetary scale science is vital to this endeavor but we must also understand how global drivers interact with local processes. How does global change affect local communities? How can communities use this knowledge to improve their livelihoods, ensuring ecological resilience, economic viability, and social equity?

Natural Laboratories: With a common boundary constraining their physical, ecological, and social networks, islands are unusually tractable model systems in which to address these pressing questions. Their geography sets clear limits on the species to inventory, space holders (ground cover) to measure, organisms to count, physical-chemical contexts to characterize, and natural-human interactions to consider. The neighboring islands of Tetiaroa, Moorea, and Tahiti in French Polynesia provide a particularly powerful model system for sustainability science. They represent increasing scales of complexity from flat, small and

privately owned Tetiaroa to high, large, and urbanized Tahiti. Moorea provides an intermediate step and is already perhaps the best-studied island in the world[1]. Furthermore, their quite affluent populations and relatively intact environments offer useful case studies for other tropical islands that are either still developing or have developed at significant ecological cost.

The **Tetiaroa Conservation & Sustainable Use Plan (CASUP)** aims to strengthen Tetiaroa's resilience to global change, enhance its ecosystem services, preserve its cultural patrimony, and advance basic scientific understanding. It provides the rationale for the Tetiaroa Society's mission programs in Research and Education, which aim to:

- Develop the **Tetiaroa Island Digital Ecosystem Avatar (IDEA),** a place-based data science infrastructure and computational platform for scenario-based planning. As part of the international IDEA network, the Tetiaroa IDEA will be the hub for data management and access to knowledge about the atoll. As a computational platform it will model the complex feedbacks between climate change, management actions, public policy, and ecosystem services across the island's coupled marine-terrestrial landscape. For researchers, it will highlight data needs and help generate hypotheses. For decision makers, it will simulate the outcomes of different management actions under likely scenarios of global change and human activities.

- Build and operate the **Tetiaroa Observatory** that will provide the secure infrastructure and long-term social-ecological datasets needed to assess the effectiveness of management actions, underpin basic scientific research on the atoll, and provide an important reference point for the international global change research community. The observatory will monitor processes underlying sectorial issues prioritized by the UN, including: Water, Energy, Health, Food, Biodiversity and Nutrients.

- Support a suite of **Research Programs** that engage world-class research teams to study the complex processes that shape social-ecological systems across scales of organization from genomes to society. The holistic approach includes *basic* "discovery driven" research as well as *applied* "use inspired" research. As human activities are key to understanding social-ecological systems and achieving sustainability goals, the social sciences and humanities are fully integrated from the outset.

- Encourage community engagement through **Cultural & Educational Programs** that combine traditional knowledge and modern science in a common pedagogic framework. These programs promote the rich cultural heritage of Polynesia, particularly as it relates to living on atolls. Activities will include a Cultural Center on Tetiaroa and cyber-enabled distance learning opportunities (see Education Section).

- Host an annual **P4-IDEA Sustainability Forum** gathering scientists, local community leaders, traditional knowledge experts, philanthropists, and decision makers to improve the health of island social-ecological systems, including their massive marine Exclusive Economic Zones. The forum parallels efforts focused on cities and will explore and develop an innovative "P4 Sustainability" strategy, emulating the revolution in medicine that emphasizes Predictive, Preventive, Personalized, and Participatory (P4) approaches to human health.

[1] Cressey D: Tropical paradise inspires virtual ecology lab. Nature 2015, 517:255–256

Threats

Tetiaroa Society is not a research institution and is unlikely to ever have the scale, competence, or ambition to administer directly the world-class research projects it wishes to see on Tetiaroa. To avoid such over-reach, TS should not hire staff scientists (at PhD level) for scientific research, but work instead with partner institutions that have the capacity to help TS achieve its research goals, guided by a Scientific Advisory Board (SAB).

With its key partners providing the scientific personnel and expertise in research administration, TS can focus on providing:

1. CASUP as a key framework to guide research programs
2. SAB to lead scientific strategy
3. Privileged access to Tetiaroa
4. Use of the Tetiaroa Ecostation
5. Essential infrastructure for the Tetiaroa Observatory and Tetiaroa IDEA
6. Logistical support
7. Financial support (through TS fundraising activities)
8. Connection to local community and the atoll's decision makers and managers
9. Communication of Tetiaroa research findings locally and worldwide

Desired Outcomes

Through world-class scientific research that makes best use of the unique opportunities presented by Tetiaroa, we aim to advance global understanding of complex social-ecological systems and to apply this knowledge for local benefit through the Tetiaroa CASUP.

Strategies and Actions

Strategy 1: Form a Scientific Advisory Board (SAB) consisting of local and international scientists (particularly those in the Pacific Region) with expertise in the major scientific disciplines that underpin Tetiaroa Society's mission.

Activity 1.1 Appoint founding members of SAB (completed in 2014):

- Neil Davies – UC Berkeley Moorea (Chair)
- Hervé Bossin – Institut Louis Malardé
- Robert Carpenter – California State University Northridge
- Sylvia Earle – Sylvia Earle Alliance/Mission Blue
- Cécile Gaspar – Te Mana o te Moana
- Ruth Gates – Hawaii Institute of Marine Biology
- Daniel Kammen – University of California Berkeley
- Patrick Kirch – University of California Berkeley
- Chris Meyer – Smithsonian Institution
- Jean-Yves Meyer – French Polynesia Research Department
- Serge Planes – CNRS-EPHE CRIOBE
- James Russell – University of Auckland

- Billie Swalla – University of Washington

Activity 1.2 Engage the government authorities responsible for overseeing scientific research in French Polynesia and invite them to participate as *ex officio* observers invited to the annual SAB meeting and any other SAB activities that interest them.

- Head of Research Department, Government of French Polynesia
- Regional Director of Research & Technology, French High Commission

Activity 1.3 Put in place procedures for international scientists from any institution to propose research projects on Tetiaroa. All research projects should (a) be reviewed by the SAB and approved by TS Executive Committee, (b) utilize the Tetiaroa IDEA platform – as and when it is operational – to manage data and communicate results, and (c) integrate studies closely with the Tetiaroa Observatory.

Activity 1.4 Develop a strategic plan for scientific research on Tetiaroa (essentially this Chapter and Exhibit 1), identifying key areas where Tetiaroa can have maximum impact on global scientific understanding as well as to support the local goals of CASUP on Tetiaroa. It is expected that SAB members would play a key role in leading projects in these priority areas, recruiting colleagues with relevant expertise from around the world to join them.

Activity 1.5 Establish the Tetiaroa Observatory, identify the needs in terms of staffing, logistics (including on-site housing), and instrumentation to achieve those goals.

Activity 1.6 Establish the Tetiaroa IDEA as the data management infrastructure. Work with partners in the IDEA Consortium to establish the near-term goals for the Tetiaroa IDEA and being its implementation.

Strategy 2: Leverage the considerable international scientific capacity present in French Polynesia

Activity 2.1 Establish a partnership with the Moorea Ecostation (CNRS-EPHE CRIOBE and UC Berkeley Gump Station), which has a long experience of hosting international scientists to study Polynesia's remarkable natural and cultural heritage. Among a broad range of programs, CRIOBE coordinates France's center of excellence for coral reef research (LABEX-CORAIL) and Gump Station houses the U.S. National Science Foundation's Moorea Coral Reef Long Term Ecological Research (LTER) site - the only coral reef in the 25-site NSF LTER network. The two stations also house the Moorea Biocode Project, an unprecedented $5.2M effort to collect specimens, photographs, and DNA sequences of every species of plant, animal and many of the fungi on the island.

Activity 2.2 Collaborate with scientific institutions on Tahiti (e.g., ILM, IRD, UPF, IFREMER) as well as science-based conservation NGOs (e.g., Te Mana o Te Moana, SOP MANU/Birdlife) and government agencies (e.g., DIREN, Del. Rech., Marine Resources).

Activity 2.3 Integrate Tetiaroa Ecostation with the emerging Polynesian Research & Education Network (PolyREN) cyberinfrastructure, linking the research community of French Polynesia to global Research & Education Networks via high speed internet.

Strategy 3: Establish facilities (Tetiaroa Ecostation) and recruit staff to support scientific research on the atoll and communication of its results to key stakeholders.

Activity 3.1 Pacific Beachcomber constructed a facility (completed in 2014) for TS (at a cost of approximately $1,000,000) including land and two buildings with labs and dormitory-style residences for up to 15 visiting scientists. Significantly, the marine laboratory has a flow-through seawater system with access to deep ocean water via the hotel's "seawater air-conditioning" system (SWAC). The facility is accessible to scientists, engineers, writers, artists, and students from around the world.

Activity 3.2 Pacific Beachcomber and The Brando provided a space in the heart of the hotel for the Tetiaroa Society's "Visitor Center" (completed in 2015). Part of the Ecostation, the Visitor's Center enables TS to communicate its programs to hotel guests and is the primary office for TS's resident Chief Scientist and TS personnel on-site.

Activity 3.3 Recruit an Ecostation Manager to oversee TS on-site staff and facilities (completed in 2015). Explore how this position should evolve and/or be supplemented as usage levels increase.

Activity 3.4 Recruit through an academic partner(s) a resident Chief Scientist, preferably as part of a multi-year, long-term arrangement, with as funds permit, other scientists/technicians as necessary to:

- Design, initiate and then operate the Tetiaroa Observatory, a long-term ecological research program that investigates the impact of global change on atolls and how local actions can increase ecosystem resilience.
- Help develop and maintain the Tetiaroa IDEA, a data science infrastructure for the Observatory and all programs on the atoll, making all past and current research available.
- Help manage and coordinate the scientific research programs at Tetiaroa Society's Ecostation on the atoll (note: this task is closely aligned with Tetiaroa IDEA).
- Provide assistance to Tetiaroa Society's Scientific Advisory Board.
- Explore potential for programs involving university-level training (undergraduate, graduate, postdoctoral, and professional).
- Provide technical advice and assistance to the Tetiaroa Conservation and Sustainable Use Plan.
- Support Tetiaroa Society's educational program (note: digital resources and online interfaces to different user groups are to be coordinated through Tetiaroa IDEA).
- Seek additional support (grant writing, fundraising) to grow and expand scientific programs on Tetiaroa, as well as related programs in conservation and education.

APPENDIX

Attached in Exhibit 1 is an Appendix to this section on the Scientific Research Program. Part of the draft Strategic Plan for Scientific Research on Tetiaroa, it provides additional information on proposed goals and objectives and specific activities related to the Tetiaroa IDEA, Observatory, Major Science Themes, Educational Programs and the P4-IDEA Island Sustainability Forum.

Coral Reef Ecosystem

Lead Author: Serge Planes
Principal Contributing Authors: David Lechini, Yannick Chancerelle, Gilles Siu

Background and Current Situation

On a global view, coral reefs are often called the rainforests of the sea, both due to the vast amount of species they harbour, and to the high productivity they yield. Aside from the hundreds of species of coral, reefs support extraordinary biodiversity and are home to a multitude of different types of fish and invertebrates. Covering less than one percent of the ocean floor, **reefs support an estimated 25% of all marine life while they cover 0.02% of ocean surfaces**. But the majority of coral reefs are facing significant loss or damage world-wide with more than 25% definitively gone and an estimated 50% facing major stress. This loss is not deliberate and coral reefs are being mostly degraded by an accumulation of stressors arising from human activities and natural impacts. In simple terms, stressors can be grouped by the actions of people extracting material from, and placing materials upon, coral reefs. Over-fishing, pollution and coastal development are at the top of the list of chronic stressors. In many situations chronic stressors are overwhelming the resilience, (or the capacity for self-repair), of reef communities. In addition climate change are viewed as responsible for coral bleaching as well and enhancing ocean acidification for which effect on coral reefs is not fully understand. Cyclone, coral diseases and outbreaks of crown of thorn starfish have increase significantly in the last 10 years and are also threatening coral reefs significantly.

In that context long term studies, based on the survey of a limited number of periodically measured variables are required in order to distinguish the effects of climate changes from those induced by human action. It is important to study these compartments at various temporal scales, because of the diversity of environmental forcing and of the life-traits characteristics of the biological communities. Short term studies will make it possible to learn about consequences of the intense but transient meteorological events, seasonal studies to take into account the existing weather periodicity and inter-annual studies to see the effects of large scale climatic phenomena like the ENSO.

Tetiaroa atoll is a small atoll very similar to classic atoll system without a lagoon pass. It is surrounded by coral reefs that were surveyed by the CRIOBE over the last 15 years. Overall the outer reef is showing high leave coral cover. Over the last 5 years, coral reefs of Tetiaroa have been subject to crown of thorn outbreaks that significantly damaged coral. Coral are now slowly recovering.

Threats

Tetiaroa atoll is not really aside from this general frame since several of these threats are potentially impacting coral reef. Among the major threats we mention here mostly natural threats since there is a separate section on fisheries which addresses human threats:

- Coral bleaching has been observed on Tetiaroa coral reefs similarly to most coral reefs of the Society archipelago and usually coinciding with El nino years. ENSO disturbances are leading to calm weather situation and are increasing water temperatures stressing coral symbiosis and driving bleaching;

- Crown of thorn outbreaks are well known in volcanic high islands of the Society archipelago, but usually don't occur in atolls. However for the first time Tetiaroa has experienced a crown of thorn outbreak over the last 4 years destroying a significant part of corals;

- Cyclones are rare in French Polynesia and even more rare in the Society archipelago, but they are observed on average every 10 years and they lead to dramatic destruction of coral within the first 20 metres.

These are the major threats that have already affected coral reefs of Tetiaroa, but there are also some potential threats that have not been yet identified in Tetiaroa but could arise such as some coral diseases.

Desired Outcomes

Assuming direct human impact will be limited and controlled in the future, the objective will be:

- to deploy an observatory to monitor the evolution of coral reefs and to control for climate change impact;

- to evaluate and develop some projects to remediate coral reef damage induced due to climate change and natural loss of coral reefs.

Strategies and Actions

Based on a scientific study at intermediate and long terms of the variability and change of the physicochemical processes and biological communities which develop, an overall strategy that consist in setting up a long term observatory program. Beyond this overall strategy, we propose some actions:

Action 1 - To survey some indicators of the climate change (temperatures and salinity of the coastal environments).

Action 2 - To observe and interpret the temporal variations of biogeochemical and biological characteristics of the lagoon and the outer reef.

Action 3 - To check assumptions on the effects of climate change and evolution of the human pressure on these complexes.

Action 4 -To develop some holistic remediation programs.

Sea Turtles

Lead Author: Cécile Gaspar, Te mana o te moana/CRIOBE
Principal Contributing Author: Matthieu Petit

Background and Current Situation

Tetiaroa is one the last remaining important nesting site for green sea turtles in the Society Islands. This gives the atoll a high priority in turtle nesting conservation but also in inventory and biological studies. Tetiaroa is also important because it is the only long-term monitoring site in.

French Polynesia (with eight years of data) that can provide information on population trends and serve as a point of comparison with other sites across the Pacific.

Out of seven species of sea turtle worldwide, five are present in French Polynesian waters but two are the most commonly seen: green sea turtles (*Chelonia mydas*) and hawkbill turtles (*Eretmochelys imbricata*). On IUCN list of threatened species wordwide *Chelonia mydas* is under the category

"endangered", and *Eretmochelys imbricata* is under the category "critically endangered." Tetiaroa provides green turtles a nursery and nesting habitat, with potentially a strong contribution of West Pacific populations (Fiji islands). Tetiaroa also provides the hawksbill turtles a nursery and foraging area.

Sea turtles play important ecological roles in the marine ecosystems. They are known to maintain healthy seagrass beds and coral reefs. They also help balance marine food webs and facilitate nutrient cycling from water to land.

Sea turtles are also important ecologically and culturally for the peoples of Polynesia. So much so that they are an emblem of this region, figuring prominently in sculpture, tattoos, ceremonies and legend. However, this important creature's greatest threat comes from activities of humans both locally and abroad. Climate change, ocean acidification, shoreline development, oceanic plastic pollution and poaching are taking a toll of the turtle populations of French Polynesia and the world. For example, research from Scilly and Mopelia atolls have shown a strong decrease in nesting females stocks over the past 30 years (Balazs 1995), and his pattern of decline is representative of worldwide trends.

The lack of integrated data regarding French Polynesian turtle populations is in contrast to many results from South Pacific countries that have, over the past decade, dedicated considerable effort to better understand their turtle stocks and their population dynamics. The huge geographic area of French Polynesia presents logistical, coordination and funding challenges.

Tetiaroa 's green sea turtle nesting and adult migration to the West of the South Pacific have been studied since 2007 by te mana o te moana team, however trends need to be confirmed with more in-depth long term research. In addition in-water inventories around the reef outer-slope have shown seasonality and variability in both green and hawkbill population around the atoll that also need to be confirmed.

Threats

If we consider the two main turtle species found in French Polynesia, common threats are: poaching, pollution, food resources availability, and global warming.

Because green sea turtles mate and nest in French Polynesia, they face additional dangers: loss of nesting habitats, light and noise pollution, beach erosion, beach increased temperature, unbalance male/female adult ratio, nests flooded by high tides, nest natural poaching and predation, hatchling predation before reaching the ocean (rats, crabs, birds, cats, ants, then carnivorous fish, moray eels…).

In addition to these first categories, green sea turtles are subject in French Polynesia to poaching for their meat (not the Hawkbills that are considered toxic, even if many are injured or killed by spear gun and received at te mana o te moana sea turtle clinic in Moorea)

Desired Outcomes

Maintain, preserve and protect the two main species of sea turtles (green and hawksbill) around Tetiaroa and preserve crucial green sea turtle nesting sites on Tetiaroa and help improve survival rate of hatchling produced.

Strategies and Actions

(*Upon Administrative and Research Authorizations*)

A. For Hawkbill Turtles

Strategy 1: Update knowledge

A.1.1 Set up trimester in water inventory with manta tow technique

A.1.2 Learn genetic repartition of hawksbill in French Polynesia

A.1.3 Have a better understanding of their life cycle and tag turtles

A.1.4 Learn about their diet and habitat zone

A.1.5 Understand pollution effects

Strategy 2: Protect

A.2.1 Maintain pristine coastal habitats and feeding grounds around the atoll

A.2.2 Help injured sick or weak hawkbill turtles if found around the atoll

B. For Green Turtles

Strategy 1: Update knowledge

B.1.1 Set up trimester in water inventory with manta tow technique

B.1.2 Learn genetic repartition of green turtle in South Pacific Region and the specificity of green turtles found on Tetiaroa

B.1.3 Have a better understanding of their life cycle (age at maturity and nesting cycles) as well as their migration through satellite tagging

B.1.4 Learn about their diet and habitat zones for subadults and adults

B.1.5 Improve understanding of nesting parameters and survival rate of hatchlings

B.1.6 Measure impact of global warming on hatchling success and sex ratio

Strategy 2: Protect

B.2.1 Maintain pristine and clean lagoon and ocean environment

B.2.2 Try to help decreasing poaching for green turtles around the atoll

B 2.3 Set up a conservation plan for nesting sites on Onetahi motu in link with the Brando resort (night light management, no equipment on beaches, protection of nest)

B 2.4 Protect all nesting sites if necessary and relocate them if flooding risk linked to high tides

B.2.5 Help green sea turtle recovery by helping deformed, sick or hatchling blocked into nests

B.2.6 Great a territorial hatchling nursery and raise babies up to one year before release for increasing green turtle population (one action as part of the Territorial conservation plan, if accepted and justified)

C. For Both Hawkbill And Green Sea Turtles: Educate

Action 3.1. Write an illustrated guide on sea turtles found around Tetiaroa, and a detailed report of green sea turtle nesting characteristics to share with the Brando staff, kids and visitors as well as residents and school teachers.

Action 3.2. Set up "discovery scuba dive" with guests and children around sea turtles in link with the "sea turtle observatory".

Action 3.3. Set up discovery tours during nesting season for observing female nesting and babies hatchling, train volunteers for on field data collections.

Action 3.4 Organize and coordinate education sessions with schoolchildren, students and local population on sea turtles of Tetiaroa, both on the atoll but also as outreach programs on other islands (schools or public displays).

Action 3.5 Create a partnership with day tour charters that offer their guests beach walks on Rimatuu and Tahuna iti in order to train them for green turtle nest survey (and become part of our turtle observatory) and how not to disturb the incubation of the eggs.

Flora & Vegetation

Lead Author: Jean-Yves Meyer, Délégation à la Recherche de la Polynésie française, Tahiti, and Tetiaroa Society Scientific Advisory Board

Contributing Authors: Ravahere Taputuarai, nature protection group Te Rau Ati Ati a Tau a Hiti Noa Tu, Tahiti

Background and Current Situation

Tetiaroa is one of the five atolls of the Society archipelago (with Tupai, Scilly/Manuae, Bellinhausen/Motu One and Mopelia/Maupihaa) and the only one of the Windward islands group (which include the high volcanic islands of Tahiti, Moorea, Maiao and Mehetia). Its native flora and vegetation ("coastal strand vegetation" *sensu* Mueller-Dombois & Fosberg, 1998) are relatively similar to those found in other atolls of the Society or the Tuamotu. Some of these species are also commonly found on sandy and calcareous islets ("motus") of the high volcanic islands (e.g. Moorea, Bora Bora Raiatea). About 40 native (indigenous) vascular (flowering plants and ferns) plant species have been recorded on the 13 islets of Tetiaroa atoll (Sachet & Fosberg 1983; Florence et al. 2007; Butaud, 2006; Meyer, pers. obs. 2014 and 2015). The relatively low number of non-native (alien) plants, with about 50 recorded species, compared to other atolls in French Polynesia (Meyer, 2014) might be related to the few number of inhabitants living on Tetiaroa. Alien plants were restricted in the past and for a long period of time to the two inhabited islets of Onetahi and Rimatuu (Raynal, 1973). The proximity to Tahiti (at ca. 50 km), the presence of an airstrip, the specific land ownership, and the presence of a research station ("Tetiaroa Society Ecostation"), provide unique opportunities to conduct efficient research, resource management, species conservation and habitat restoration projects.

Threats

The native flora of Tetiaroa has been profoundly altered by both Polynesians and Europeans (Sachet & Fosberg, 1983). Large coconut plantations set up in most of the islets since the early 20th century (Sachet & Fosberg 1983) and until the 1950's (Papy 1951-54) for copra production, have replaced most of the native vegetation. Human activities (housing development, cultivation, alien plant introductions) are still the main threats to terrestrial biodiversity, and thus have to be carefully managed to ensure long-term ecological sustainability. The impacts of climate change (e.g. sea-level rise, air temperature increase, potentially more frequent and intense cyclones) may also alter species composition, structure and dynamics of the terrestrial vegetation in the future.

Desired Outcomes

In order to maintain and preserve the different native vegetation types found on the atoll (e.g. the *Pisonia-Pandanus-Guettarda-Hernandia-Cordia* forests, the *Suriana-Pemphis-Scaevola-Heliotropium* shrublands, the *Ipomea-Lepturus-Triumfetta-Vigna-Boerhavia* creeping vines and herbs and the wetlands dominated by sedges *Cladium-Mariscus-Eleocharis*-Fimbristylis), and to enhance terrestrial ecosystem resilience to climate change, we propose:

(1) the complete protection of some of the most preserve/pristine small islets (e.g. Aie, Tahuna Iti, Tahuna Rahi, Reiono), with restricted access and limited management;

(2) the restoration of native forest in some selected larger islets covered by abandoned coconut plantations, by removing coconuts and promoting native species natural recruitment and/or reintroducing native species;

(3) the reintroduction in protected areas of some rare endemic plants such as *Sesbania coccinea* subsp. *atollensis* var. *parkinsonii*, last noted on the atoll in 1973 (Raynal, 1973) and extirpated since (currently known in the wild only from the atoll of Tupai). Other native plants which have not been recorded since the 1980's (Sachet & Fosberg, 1983) such as *Achyranthes aspera* var. *velutina, Hedyotis romanzoffiensis, Heliotropium anomalum*, and *Pipturus argenteus* var. *tuamotensis* (Butaud, 2006) might be reintroduced in the atoll, if not retrieve after extensive surveys.

Strategies and Actions

Strategy 1: Improve and update knowledge

Action 1.1:. Conduct extensive surveys in each islets/motu to update the list of native and non-native (alien) species and compare it with previous surveys, in collaboration with the local guides of Tetiaroa Society.

Action 1.2:. Map all vegetation types (using satellite and/or aerial images) and locate (GPS) rare native species.

Action 1.3: Collect seeds of common and rare native plants for cultivation and propagation in a plant nursery on the atoll of Tetiaroa to both understand their bio-ecology, and use them for gardens in the hotel and restoration in the wild (see below).

Action 1.4: Monitor the abundance (number of populations and individuals) and phenology (flowers and fruits) of some rare native taxa.

Strategy 2: Educate and train

Action 2.1: Build local capacity by organizing training sessions for the guides of the Tetiaroa Society (in the fields of botany, plant ecology, conservation, biological invasion, restoration).

Action 2.2: Write an illustrated guide of all the native and alien flora (Polynesian and European introduced plants) of the atoll for the general public (accessible on-line on the Tetiaroa Society website) with their Tahitian names and traditional uses if known.

Action 2.3: Set up "discovery trails" in the different vegetation types.

Action 2.4: Organize and coordinate with the local guides "weeding" and native species replanting sessions with schoolchildren, students, and other volunteers (including the hotel staff and clients).

Strategy 3: Restore and protect

Action 3.1: Control coconut trees (tree cutting, uprooting) in some islets to rehabilitate or restore native habitats, with long-term monitoring of the natural recruitment of native species, and/or with some replanting of native species.

Action 3.2: Control alien weeds (by hand removal, tree cutting, without chemical treatments) and eradicate selected/priority invasive plants if feasible (e.g. if small and localized populations, short longevity of the seed bank).

Action 3.3: Prevent new introductions of alien plants by elaborating a biosecurity action plan with clear procedures (e.g. "no new alien" strategy, cleaning shoes and clothes, inspecting building material, etc.), especially in the most pristine islets.

Action 3.4: Reintroduce extirpated native species such as Sesbania coccinea (a legally protected species in French Polynesia, requiring a special permit from the Direction de l'Environnement) or Pipturus argenteus (a food source for frugivorous fruit doves if they are reintroduced).

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Seabirds

Lead Author: Philippe Raust

Principal Contributing Authors: James Russell, Lucie Faulquier, Jean-Claude Thibaut

Background and Current Situation

Part of the exceptional wealth of Tetiaroa is the diversity and density of its seabird population. The well protected and preserved habitat of Tetiaroa provides favorable nesting conditions, and the richness of the lagoon and the proximity of the open ocean provide seabirds a wide foraging area. Tetiaroa hosts several thousand seabirds belonging to nine breeding species, which makes it one of the most important breeding sites for seabirds in all of French Polynesia. The atoll is classifed as an IBA (Important Bird and Biodiversity Area) by Birdlife International.

The Brown Noddy (*Anous stolidus*) is the most abundant species on the atoll, with five to ten thousand pairs nesting on the ground or in trees and bushes throughout the atoll. The Sternidae family is best represented with four species breeding on the atoll: the Greater Crested Tern (*Thalasseus bergii*), the Sooty Tern (*Sterna fuscata*) and the Grey-backed Tern (*Sterna lunata*) all nesting on the ground, and the Common White Tern (*Gygis alba*), which is remarkable for its immaculate all-white plumage and its nesting pattern. This species does not build a nest – it lays and incubates its single egg on a bare branch, usually

within a slight depression. Tetiaroa and especially motu Tahuna rahi is the sole breeding site of the Greater Crested Tern in the Windward Islands.

Tetiaroa is also the most important breeding site in the Society Islands for the Red-footed Booby (*Sula sula*) that nest in trees, and the Brown Booby (*Sula leucogaster*) that nest on the ground. Both species catch prey by impressive plunge diving from several meters high.

The Great Frigatebird (*Fregata minor*) and the Lesser Frigatebird (*Fregata ariel*) nest in the bushes of the motu located in the north of the atoll. They are the only seabird family that displays obvious, significant differences in plumage between the sexes, as the males are wholly glossy black and have a collapsed throat sac inflatable into a huge scarlet balloon in display. Many other seabird species also occasionally visit the atoll.

In addition to being a haven for seabirds, Tetiaroa hosts a large breeding population of Pacific Reef Egret (*Egretta sacra*), a native terrestrial species with white, dark grey and intermediate morphs. The atoll is also a wintering site for migratory species such as the Pacific Golden Plover (*Pluvialis fulva*) and the Wandering Tattler (*Tringa incana*) which breed in North America, and the Long-tailed Cuckoo (*Eudynamys taitensis*) from New Zealand.

Threats

Birds of Tetiaroa have to face some threats, especially seabirds that use the land to breed and the ocean to feed:

- Several charter companies organize tours on motu Manu (aka Bird Island), located southeast of the atoll, which hosts the highest density and diversity of seabirds. This increase in eco-tourism may cause a significant disturbance of birds if it is not properly regulated and controlled.
- Invasive rats exert high levels of predation on eggs and chicks, resulting in a reduction of the population and the loss of some species. The absence of ground-nesting seabirds on some motu of the atoll is probably due to the presence of rats.
- The Common Myna (*Acridotheres tristis*) and the Red-vented Bulbul (*Picnonotus cafer*) have been reported present on the atoll. They are introduced species classified as harmful to the Polynesian biodiversity by the local government and may compete with or predate on other birds. Invasive ants can also damage dramatically the bird colonies.
- Finally, global warming can also affect seabirds both on land and at sea: the rise of sea level can result in a loss of habitat, and the water temperature rise can reduce the availability of food supplies.

Desired Outcomes

The desired outcomes from the proposed program include the following:

- Tetiaroa, which is an important bird and biodiversity area (IBA), should be kept as a natural bird sanctuary for future generations.
- Our vision is to restore most of the motu to their best natural state to make it a sanctuary for seabirds and endangered terrestrial birds.
- The presence of man on Tetiaroa should be a chance for nature and birds to showcase their beauty and uniqueness.

Strategies and Actions

Strategy 1: Improve knowledge on Bird life on Tetiaroa

Action 1.1: Monitor seabird and migratory species on a regular basis (every 6 months)

Action 1.2: Monitor regularly breeding colonies for qualitative and quantitative data.

Action 1.3: Check regularly the presence (or absence) of alien invasive species (AIS) such as rats and introduced birds on the different motu.

Action 1.4: Monitor and evaluate of the impact of human activities (tourism, fishing, collect of eggs eventually).

Strategy 2: Minimize the impact of threats to birds

Action 2.1: Establish an education program to mitigate stress due to human contact.

Action 2.2: Establish observation platforms at the most important sites.

Action 2.3: Establish biosecurity measures to avoid introduction or control present AIS

Strategy 3: Enhance habitats for marine and terrestrial birds.

Action 3.1: Establish Tetiaroa as a protected area with special status for selected sites as a result of the monitoring actions

Action 3.2: Eradicate when feasible nonnative species on all motus where they have a negative impact on the survivorship or reproductive performance of native birds.

Action 3.3: Restore components of the native vegetation communities that are important to seabird nesting.

Strategy 4: Restore marine and terrestrial bird species on motus where they have been extirpated.

Action 4.1: Use social attraction techniques to encourage recolonization by seabirds (including Petrels and Shearwater) of selected motu.

Action 4.2.: Introduce or reintroduce selected atoll endemic bird species such as :

- *Gallicolumba erythroptera* (Society Ground-dove) - CR
- *Prosobonia parvirostris* (Tuamotu Sandpiper) - EN
- *Vini peruviana* (Blue Lorikeet) - VU

- Optional : *Acrocephalus atyphus* (Tuamotu Reed Warbler), *Ptilinopus coralensis* (Atoll Fruit-dove) and *Ducula aurorae* (Polynesian Imperial-pigeon)

Action 4.3: Maintain biosecurity protocols to prevent the introduction of alien species that may prove hazardous to native birds.

Crabes de Cocotier

Lead Author: Hannah Stewart

Background and Current Situation

Coconut crabs (Birgus latro) or "Kaveu" are the world's largest terrestrial arthropod, reaching sizes up to 1 meter from outstretched leg to leg, and weighing as much as 5 kilograms. Coconut crabs can live up to 60 years, and reach sexual maturity after approximately 6 years. Related to hermit crabs, juveniles using a gastropod shell to protect their soft abdomens, but in adult crabs the exoskeleton of the abdomen hardens and they stop carrying a shell. Coconut crabs live in rock crevices and underground burrows that they dig in loose soil or sand. Coconut crabs molt between May and August, and remain in their burrows during this vulnerable time. They rely on moist habitats to breathe and are primarily nocturnal foragers. Coconut crabs eat coconuts and fruit of the pandanus tree, but also other fruits, seeds, and will scavenge carrion and other organic matter, including turtle hatchlings and other crabs.

The life cycle of the coconut crab begins with eggs released into seawater, and larvae are planktonic for 25-33 days. Post-larval crabs settle to the bottom, migrate to the shore, and find and wear a suitable shell. Once leaving the ocean, they become terrestrial, lose their ability to swim and can drown in the sea. Once sexually mature (~5-6 years) mating occurs on dry land and eggs are carried and protected by the female until she migrates into seawater to release her eggs.

Coconut crabs require vegetated areas adjacent to ocean access for completion of their lifecycle.

Its meat is considered a delicacy and an aphrodisiac and coconut crabs have been extirpated on many islands with human populations.

The coconut crab is a native species in French Polynesia and throughout much of the Pacific. In 1981 the coconut crab was listed on the IUCN Red List of Vulnerable Species, but subsequent lack of data resulted in its classification to be amended in 1996 to data deficient, but it is considered a threatened species in French Polynesia.

Observations by guides and archeology researchers indicated there are coconut crabs on Tetiaroa on motus other than Onetahi, particularly in the creviced trunks of the native pu'atea trees on motu Reiono but their abundance has not been quantified.

Current conservation management in Polynesia includes:

Harvesting restrictions: restriction against harvesting of gravid females, restrictions on harvesting recently molted crabs that hide in their holes, and a minimum size for capture (4cm thorax length).

Habitat conservation: Encouraging areas of dense natural vegetation adjacent to the shore that are not restricted by coastal development and alteration of the shoreline via seawalls, roads, etc.

Threats

Harvesting by humans, habitat destruction, coastal development, predation by rats, (pigs and dogs - not an issue on Tetiaroa).

Desired outcomes

Have a sustainable population of coconut crabs on Tetiaora.

Strategies and Actions

Strategy 1: Quantify

Action 1.1: An atoll-wide monitoring effort could be undertaken with staff and guides of Tetiaroa Society and hotel staff, many of whom are Tahitian and know how to locate and catch kaveu. Involving hotel staff in the conservation effort would help to include them in the stewardship of the island, and discourage any poaching that might otherwise occur. Initial effort could be concentrated on Reiono, then expanded to other motus as resources permit. Ideally, a baseline survey to quantify abundance and distribution across all motus would be conducted.

Strategy 2: Protect - Protection of kaveu will come with conservation and protection of the lagoon and motus.

Action 2.1: Restricting access to the motus will eliminate hunting.

Action 2.2: On motus where visitors are allowed, ensure that all visitors understand that collection of coconut crabs is forbidden. Restrictions against harvesting of kaveu should be explicitly written in to the contracts currently under review with catamaran/sailboat day charters, particularly if their clients will be walking through the motu on paths.

Action 2.3: Eradication of rats from Tetiaroa will help conserve coconut crabs as young crabs are eaten by rats.

Strategy 3: Educate

Action 3.1: Education of visitors via rangers and guides about this unique crab and its threatened status, and restrictions against its harvest on Tetiaroa.

Action 3.2: Information about this rare crab and its threatened status could be incorporated into education programs for visiting local children via the cultural program.

Action 3.3: Tetiaroa Society could develop a presentation about the coconut crabs on Tetiaroa for guests and staff/inhabitants of Tetiaroa.

Entomology

Lead Author: Hervé Bossin

Background and Current Situation

Atolls are generally considered to have naturally impoverished biotas, due to their extreme isolation, low elevation, relatively uniform physical conditions and lack of soil development (Mueller-Dumbois & Fosberg 1993). None of the motus of Tetiaroa atoll exceed 3m in elevation and while there is some variation between coastal and interior habitats on the motus, the vegetation is generally quite uniform. The motus were modified for copra cultivation in the early twentieth century and much of the vegetation in the interior of the larger motus are abandoned coconut plantations; some abandoned taro plantations are also present which may pre-date the copra plantations (Sachet & Fosberg 1983). Given the natural impoverishment of the atoll's biota combined with human alterations, the terrestrial arthropod fauna is composed primarily of widespread species, both native and introduced. There is recorded evidence of recent insect pest species introduction including the mosquito disease vector *Ae. aegypti*, (Bossin, 2014) and the glassy-winged sharpshooter *Homalodica vitripennis* (Claridge, 2007) to the island. A number of introduced species present on Tahiti may not have yet been introduced to Tetiaroa, most notable are mosquitoes, ant species and spiders. Eliminating present pest species and preventing the introduction of additional ones should be a priority because they are both undesirable for the natural ecosystem and a nuisance to hotel guests and staff.

Threats … and opportunities

Existing threats are essentially due to the presence of arthropods of medical, veterinary, ecological and/or economic importance, on the atoll:

- Mosquitoes (*Culicidae*): Four of the 14 species recorded in French Polynesia are present in Tetiaroa: namely *Aedes polynesiensis, Aedes aegypti, Culex quinquefasciatus and Culex annulirostris* (Bossin, et

al. 2007, 2014). The (day-biting) *Aedes* species have played a key role in active disease transmission on motu Onetahi during the recent Chikungunya outbreak. The two *Culex* species are a significant source of nuisance at night. A pilot study using an integrated and environmentally safe approach is underway to eliminate both *Aedes* species from Onetahi.

- Biting midges ("nonos", *Ceratopogonidae*): Abundant on motu Rimatuu where it breeds in the edges of brackish water ponds, *Culicoides belkini* inflicts painful bites, which can lead to infected wounds particularly in children and tourists. Although there are no breeding sites that can sustain its establishment on motu Onetahi, *Culicoides belkini* can be transported occasionally from nearby Rimatuu by wind causing seasonal nuisance. A pilot study should be considered to test the efficacy and sustainability of innovative control approaches.

- Filth flies: House flies (*Muscidae*), blow flies (*Calliphoridae*) and flesh flies (*Sarcophagidae*) are significant nuisance pests on Tetiaroa and favor the spread of bacteria and other disease–causing organisms. Filth flies often feed and lay eggs on garbage, manure and carrion (dead rats or birds), sewage and rotting plant material before contaminating human foods and food preparation surfaces when landing, feeding and defecating on them. The key to managing all filth flies resides in the implementation of an integrated fly management program primarily sanitation and inspection as well as exclusion (keeping fly entry points closed or screened), and mechanical (trapping) and biological (parasitoids) control. A native species of note is the signal fly (*Scholastes lonchifer*), which occurs at remarkable densities on Tetiaroa, mostly likely due to the abundance of rotting coconut material on the motus. These flies may cause a nuisance to hotel guests and staff.

Potential threats correspond to the risk of introduction of invasive pest species primarily from Tahiti and Moorea. Most notable species include mosquitoes such as *Aedes vexans* and *Wyeomyia mitchellii* (Bromeliad mosquito), ant species like *Anoplolepis gracilipes (*Yellow crazy ant), *Pheidole megacephala* (Big headed ant), *Solenopsis geminata* (Tropical fire ant) and *Wasmannia auropunctata* (Little fire ant) which can cause painful bites, and spiders such as *Latrodectus geomtericus* (Brown Widow). The risk of plant insect pests (fruit flies, coccoidea) introduction is also extremely high warranting the observance of strict phyto-sanitary measures to protect the atoll.

***Opportunities*:**

- Honey Bees (*Apis mellifera*): Honeybees were introduced to Tetiaroa to produce honey, which is sold primarily at The Brando for use in the restaurants and for sale to the guests. Bees were brought in directly from the Marquesas where there are no known diseases such as the American foulbrood *(Paenibacillus larvae)*, which affects Tubuai in the Austral. All bee keeping equipment used on Tetiaroa was new and never used on any other bees before coming to Tetiaroa. There are now bee hives on Onetahi, Reiono and Hiraanae. The introduction of honey bees to Tetiaroa is of great interest for other islands and atolls where bees are absent. A protocol for bee introduction into such environments was recently proposed (Fert & Pajuelo, 2013).

- Bioconversion of organic wastes: Although introduced, *Hermetia illucens* (Black soldier fly) is usually not a pest (they are not attracted to human habitation) and its presence on Tetiaroa may be seen as an opportunity. Larvae of the black soldier fly are commonly used to compost and sanitize organic wastes, for house fly control, for waste bioconversion and may also be used as animal feed (e.g. fish food). The bioconversion of organic wastes, like copra by-products into protein-rich animal feed would (a) prevent

houseflies and blowflies from laying eggs in the material inhabited by black soldier fly larvae and (b) provide an value-added solution to the management of organic wastes on site.

Desired Outcomes

Tetiaroa should be a natural, pest free sanctuary through carefully planned, sustainable pest elimination and biosecurity programs

Strategies and Actions

Strategy 1: Eliminate insect pest species of medical, veterinary, ecological and/or economic importance

Action 1.1: Investigate life histories and breeding places of insect species that have multiplied to pest proportions (e.g., mosquitoes, flies and biting midges ("nonos")).

Action 1.2: Conduct an ant survey in all motus, and prevent Anoplolepis gracilipes (yellow crazy ant) and other agressive alien ants from reaching non-invaded motus (through biosecurity protocols & measures)

Action 1.3: Control or eliminate mosquitoes and other alien pest species on motus where they exert a medical, veterinary, ecological or economic burden.

Action 1.4: Conduct a detailed survey of insects and other terrestrial arthropods to find out what species are present, what are their habitats, and what are their roles in the ecosystem.

Indicators of success: no more biting nuisance, no more risk of disease transmission to humans and birds

Strategy 2: Prevent the introduction of insect (pest) species

Action 2.1: Establish an education and (low-maintenance) monitoring program to rapidly detect and contain mosquitos and any arthropod (pest) species introduction.

Action 2.3: Strictly enforce biosecurity protocols to prevent the introduction of alien arthropod (pest) species.

Indicator of success: no alien species introduced

Strategy 3: Leverage the presence of beneficial species to foster innovation

Action 3.1: Test the efficacy and sustainability of using *Hermetia illucens* (Black soldier fly) for on-site bioconversion of organic wastes and control of filth flies.

Indicator of success: management of organic wastes improved. Fly nuisance reduced.

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Alien Species Management and Biosecurity

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Pricincipal Contributin Authours: Jean-Yves Meyer and Hervé Bossin

Background and Current Situation

Islands are fragile ecosystems and their terrestrial and marine biodiversity is more vulnerable than usual to perturbation. One of the strongest drivers of disturbance to island ecosystems is the introduction of alien (non-native) species. Some of these species are introduced intentionally for recreational or aesthetic purposes, whereas others arrive unintentionally hitch-hiking with humans. Introductions can lead to some of these species becoming overly abundant and causing negative impacts. These 'invasive species' can go on to have dire effects on the ecology and economy of islands, in some cases leading to species extinctions.

A balance must be struck in accommodating alien species. Although some cultivated plant species add value to Tetiaroa, every presence or future introduction of a non-native species should be considered within a risk framework. Currently, problematic invasive species (the subset of alien species causing negative impacts) include rats (two species), mosquitos (three species), land birds (two species under management),

ants (multiple species) and plants (multiple species). Introduced rats and mosquitoes are currently the highest priority for control or potentially eradication, due to their disproportionate level of negative impact on the island inhabitants, hotel guests and native species. Some research has already been undertaken on these species. Some, but not all, invasive ants of French Polynesia have been recorded on islets (called "motus") of Tetiaroa but their extent of invasion is not fully documented, and future invasions are likely. Invasive or potentially invasive alien plants are primarily restricted to the currently inhabited motu of Onetahi and the earlier inhabited motu of Rimatuu. Myna and red-vented bulbul have been controlled to low densities but are always at risk of reinvasion.

Terrestrial and marine biosecurity on Tetiaroa for ALL exotic species not currently present requires consideration within a risk management framework (i.e. indicating pathways and vectors of invasions) inclusive of (i) The Brando hotel guests and staff associated with hotel operations (ii) "Bird Island" tourism operations and (iii) Fisherman encampments. French Polynesia maintains a plant quarantine system headquartered at Papeete (Motu Uta docks) but the level of compliance by visitors to Tetiaroa is unknown. Although some biosecurity activities currently exist on Tetiaroa in association with hotel operations they require independent auditing to maintain standards. Control or eradication of introduced rats, land birds and mosquitos and some invasive plants and weeds from Tetiaroa would have substantial benefits for tourism and conservation, and is considered a viable end-point. However, any such eradications must be associated with a concomitant increase in biosecurity to prevent reinvasion by these, or similar, species (e.g. mice never recorded on Tetiaroa but travel easily in stores). A biosecurity program consisting of quarantine, regular surveillance for pests, and contingency response to new invasions, is currently absent. There is an urgent need for regular and independent audits of biosecurity processes in island management.

Threats

Threats to the Tetiaroa ecosystem and biodiversity from the introduction of non-native species include the following:

- Ongoing decline in seabird fauna from introduced rats
- Negative economic and tourism consequences from introduced rats, ants and mosquitos
- Negative impacts of introduced land birds including introduced plant dispersal and precluding native land bird reintroductions
- Invasion of *Anoplolepis gracilipes* (Yellow crazy ant), *Solenopsis geminata* (Tropical fire ant) and *Wasmannia auropunctata* (Little fire ant) from Tahiti and Moorea
- Spread of invasive plants and ants from motu upon which they already occur
- New invasions and a lack of rigorous audited biosecurity processes to prevent them
- Hotel guest or staff pets transported to Tetiaroa (e.g. cats or dogs)
- Lack of data on distribution and impact of introduced ants and plants on Tetiaroa
- Monoculture of coconut forest
- Marine invasions of the lagoon
- Biosecurity risks outside the control of The Brando hotel, e.g. fisherman encampments and natural dispersals (e.g. land birds)

Desired Outcomes

The desired outcomes from exotic species management and biosecurity programs include the following:

- No new invasive or potentially invasive alien species establishments on Tetiaroa
- A robust biosecurity process of quarantine, surveillance and contingency response for all pathways and vectors of pest introduction which is considered an international benchmark for island resort operations and coral atoll conservation.
- Eradication of non-native vertebrates (rats and land birds) from Tetiaroa atoll within a decade, and at priority motu, within five years.
- Eradication of invasive mosquitos from Tetiaroa.
- Monitoring and where appropriate control of invasive ants and plants on Tetiaroa atoll.
- Prevention of the spread of invasive species already on Tetiaroa between motus
- A culture of biodiversity and biosecurity in all visitors to the island which respects the need for preventing unwanted introductions and values the benefits accrued to biodiversity and the overall experience of visitors to Tetiaroa. At the same time the value of non-native species to the island (e.g. Polynesian introductions and hotel operations associated introductions) are respected but managed in a risk framework.
- Tetiaroa atoll, The Brando hotel, and Tetiaroa Society are recognized as world-leaders in terrestrial and marine management, conservation and restoration activities on the atoll.

Strategies and Actions

Strategy 1: Eradicate introduced rats from Tetiaroa

Action 1.1: Control rats on Onetahi and Honuea in association with hotel operations

Action 1.2: Obtain a feasibility plan for rodent management and eradication on Tetiaroa.

Action 1.3: Ground-based eradications of rats from priority motu of Rimatuu and Reiono

Action 1.4: Implementation of a rodent biosecurity program to prevent rat and mouse spread to the atoll or motu within the atoll from which they are absent

Action 1.5: Aerial eradication of rats from Tetiaroa atoll

Strategy 2: Eradicate invasive mosquitoes from Tetiaroa

Action 2.1: Control mosquitoes on Onetahi and Honuea in association with hotel operations

Action 2.2: Obtain a feasibility plan for mosquito management and eradication on Tetiaroa

Action 2.3: Eradication of mosquitoes from priority motu of Rimatuu and Reiono

Action 2.4: Implementation of mosquito biosecurity program to prevent mosquito spread to the atoll or motu within the atoll from which they are absent

Action 2.5: Aerial or ground eradication of mosquitoes from Tetiaroa atoll.

Strategy 3: Eradicate introduced land birds from Tetiaroa

Action 3.1: Remove myna and red-vented bulbul from Tetiaroa

Action 3.2: Monitor for land bird reinvasion to respond rapidly with ongoing removal.

Strategy 4: Establish terrestrial biosecurity on Tetiaroa

Action 4 The main outcome should be the development of a Cultural Committee that will be charged with defining and managing the Cultural Heritage of Tetiaroa..1: Identify pathways and vectors of introduction of new species to Tetiaroa

Action 4.2: Establish a biosecurity screening procedure for all staff and guests arriving at The Brando

Action 4.3: Establish a biosecurity monitoring programme on motu across Tetiaroa for key threat species, with particular focus on sites of regular human visitation (e.g. Bird Island and fisherman encampments)

Action 4.4: Erect signage educating all visitors to Tetiaroa about the risk of new species introductions and the responsibility of everyone to prevent them.

Action 4.5: Establish a biosecurity plan for screening, quarantine, surveillance and contingency response, which is externally audited every 5 years.

Strategy 5: Manage invasive plants and ants

Action 5.1: Prevent establishment of *Anoplolepis gracilipes* (yellow crazy ant), *Solenopsis geminata* (Tropical fire ant) and *Wasmannia auropunctata* (Little fire ant) by biosecurity associated with The Brando hotel operations

Action 5.2: Thoroughly document the distribution of invasive alien plants and ants on Tetiaroa

Action 5.3: Where appropriate control or eradicate invasive alien plants and ants from motu of Tetiaroa

Strategy 6: Establish lagoon biosecurity on Tetiaroa

Action 6.1: Implement a voluntary marine best practice biosecurity standard for visiting vessels e.g. bio-fouling

Cultural Heritage

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Background and Current Situation

It is easy to describe the natural heritage of Tetiaroa but not so easy to describe the cultural heritage. Firstly the cultural heritage is connected intimately to the land. Parks Canada defines a cultural landscape as: "*An Aboriginal cultural landscape is a place valued by an Aboriginal group because of their long and complex relationship with that land. It expresses their unity with the natural and spiritual environment. It embodies their traditional knowledge of spirits places, land uses, and ecology.*"[1]

In Polynesia culture and history are tied to the natural world. The spirit of the ancestors lives on in the natural world and therefore respect for the land and lagoon is respect for the ancestors and their relationship with nature. Specific sites are connected to legends and myths (history), which have been passed down through oral traditions.

The relationship of Polynesians to the land is fundamental to their identity – Polynesians are *taata tumu* or *taata fenua* – people of the land. For Tetiaroa, even though the island is own by the Brando Trust, it still remains a part of Polynesians life. Their relationship to it has evolved over centuries, and this includes

customs to protect and care for the environment. One such custom is *rāhui* – restricting access to, or limiting fishing and other resource use from particular areas. *Taata fenua* have a proven track record of protecting the natural environment. They have a *ti'a'au* or stewardship role concerning natural resources based on the spiritual and cultural relationship they have always had with the environment.

The Cultural Heritage of Tetiaroa includes both the material culture of the island – built cultural sites and artifacts – and the intangible culture in the form of legends, myths, place names, genealogy, and historic connections to other islands.

The UNESCO World Heritage Centre recognized this, "*a key element in the new vision of protected areas promoted by IUCN is an appreciation of the important cultural and non-tangible values that are associated with many places around the world that were previously valued only for their natural qualities.*"[2]

The present owners (the Brando estate) are caretakers of the material cultural heritage and the conservation of this is dealt with in the Archaeology Section. The stewards of the intangible culture are a large number of scholars, elders, and cultural experts in French Polynesia and elsewhere. The Cultural Heritage plan should cover both the tangible and intangible culture of Tetiaroa.

The stakeholders in the Cultural Heritage of Tetiaroa are all groups associated with the island – the Brando estate, The Brando, and Tetiaroa Society, the community, and outside tourism interests.

Threats

Neglect is always a serious threat to cultural heritage, and this has been the case with Tetiaroa. The physical sites on the island are only now being surveyed completely, and connected with place names and genealogies. Partly because the local community has been largely disconnected from the island, and partly because or more general issues of modernization, the oral traditions of the island have been ignored.

As with the Education component of the CASUP, the effort put into developing and conserving the Cultural Heritage of Tetiaroa will directly affect the conservation of the natural heritage of the island. Engaging the community in the cultural heritage of Tetiaroa will foster respect for both the island and for the efforts of the Brando estate, the Brando, and Tetiaroa Society to conserve it. This was recognized by the UNESCO World Heritage Center, "*There is a growing respect for the cultural traditions and political rights of indigenous peoples generally, and an increasing awareness of the importance of local people in determining the success or failure of conservation efforts.*" 2

Desired Outcomes

Because Tetiaroa has been somewhat protected for a long time, and because of this plan to conserve the island, it can become a natural museum. If the Cultural Heritage is gathered and handled properly this should be a major component of this museum. The main outcome should be the development of a Cultural Committee that will be charged with defining and managing the Cultural Heritage of Tetiaroa.

Strategies and Actions

Strategy 1. Create a Cultural Committee with members of the local community. This committee should be charged with defining and managing the Cultural Heritage of Tetiaroa

Strategy 2. Create a symposium/workshop series to discuss and define the cultural heritage of Tetiaroa. This would allow a larger section of the community to contribute to the history and culture of Tetiaroa and support the efforts of the Cultural Committee.

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[2] – 2002. Adrian Phillips. *Cultural Landscapes: IUCNs Changing Visioin of Protected Areas.* World Heritage Papers, Cultural Landscapes: The Challenges of Conservation, UNESCO World Heritage Centre Workshop, Ferraro, Italy

Archeology

Lead Author: Mark Eddowes

Background and Current Situation

Although we lack archaeological information to date the initial human settlement on Tetiaora, it is likely that it was discovered by the same Polynesian navigators who first landed on the high islands of Tahiti and Moorea around the 11th century A.D. At this time the atoll could have been visited temporarily by groups established on the neighboring islands that would come over to acquire specific resources like bird's feathers or turtles.

During the following centuries the atoll became a place of long-term extended occupation. Some communities settled on the different motu, as evidenced by the number of features and structures on all motu. From the high islands, people brought basalt adzes (a tool similar to an axe but with the head mounted perpendicular to the handle) that they used for cutting trees, carving house posts or building

canoes. These tools have been found throughout the atoll. Remains of fishbones and shells associated with firepits were also recovered in old deposits during excavations. On the motu of Onetahi and Rimatu'u, many taro-cultivating ditches and pits were found near dwelling sites.

Among the most impressive constructions on the atoll are the marae which were built both inland and on lagoon shores. In the pre-European period, the marae were used for a wide variety of ceremonies and rituals to the gods and ancestors, and were the focal points of religious and social activities. The marae traditionally consist of an enclosed rectangular court surrounded by low walls with an altar at one side called ahu in front of which rituals were directed. Upright slabs were often planted on the ground as a repository of the deified ancestors of the group. Sometimes, individuals were buried in the court of the marae as on the site recently discovered by the lagoon shore of Oroatera motu.

The marae on Tetiaroa have a great architectural variability that is surprising and still needs to be interpreted through further investigations. They display distinctive features indicating multiple cultural influences from Leeward and Windward Islands and also from Tuamotu in the East. This suggests that there were complex migrations over the history of the atoll. The largest marae recorded on Tetiaroa, which is 53 meters long, is located on Rimatu'u motu. Close to it, a stone platform was identified as a council or dancing area where the Arioi class used to perform in honor of the deity Oro and entertain high-ranking families.

An archery platform was discovered on the motu Tiaraunu. As documented by ethnohistorical accounts, this kind of structure was reserved to the high ranks, chiefs and warriors, who practiced this elite sport. Displaying a noteworthy concave shaped-facade made of coral slabs and blocks, the participants of the game kneeled on the platform and, facing the upright stones representing their ancestors, shot an arrow as far as possible. The presence of such prestigious structures as archery and dancing platforms on the atoll evidences that the area was occupied by high-ranking owners, and confirms that the territory belonged to the royal family of Arue.

Based on our current understanding, we believe that Rimatu'u was the socio-religious center of the atoll where the elites lived, while the retainers and lower ranking groups occupied the other islets where they built their own family marae. The division of land among different kin groups is also indicated by the discovery of several upright slabs that played the role of boundary markers.

Threats

The principal threats to the archaeological sites on Tetiaroa are the potential deterioration, damage and loss of sites through human action (careless or insensitive development, looting, etc.), weather (exacerbated by climate change), and erosion and inundation by wave action (which over time may also be exacerbated by climate change).

Desired Outcomes

The ongoing archaeological research potential on Teti'aroa for the coming years is significant. Perhaps the most interesting aspect of the study is how people from a high island culture over time adapted

to the specific idiosyncrasies of an atoll environment. How that society impacted that pristine eco-system at first settlement and over time refined a more balanced sustainable use of resources to optimize their benefits from the carrying capacity of the different atolls. To reveal through controlled excavations the function of each structure, site and thus motu within what was undoubtedly a type of 'transhumance' model across the atolls.

Strategies and Actions

In all over 90 archaeology sites have been recorded, photographed, measured and described on Tetiaroa, and in many instances (23) mapped or plans drawn up. They reveal a very particular history for this island and an adaptation to atoll life that is so far unique to Ma'ohi life in the predominantly volcanic Society Islands of the 18th Century.

Building upon the prior research, the following in-depth archaeological research program is proposed (subject to receipt of all necessary administrative and research authorizations):

Action 1. Conduct an atoll wide (i.e. all 10 with archaeological vestiges) series of preliminary test pits on GPS situated locales to determine the depth of the archaeological deposits that may be encountered. This will allow the archaeologist to evaluate the relative size of an excavation to be undertaken with the contingent logistics of time and cost to excavate. And whether a particular site merits a large 'areal excavation' or, if the deposits are deep and rich enough in artifacts to justify a more focused smaller sized excavation.

Action 2. Conduct deep corings in the fresh water sources and lakes of the motu's as well as in the sunken gardens and maite of Teti'aroa. This will provide sequential sediments with pollens, allowing archaeologists to reconstruct Polynesian impact on the flora and fauna of Teti'aroa from first arrival up to European contact in the late 18th Century. In this way a clear paleontological profile can be reconstituted reflecting the endemic primary forest and general flora present anciently and over time the impact on these of introduced species by Ma'ohi from their horticultural, tree crop and plant pharmacopeia tradition.

Action 3. Conduct a systematic collection, with GPS point plotting, of basalt flakes and adze pre-forms encountered across the islets during a surface collection. Permitting the identification of places of concentration of stone tool production and if possible the motu where this was a favored or predominant activity.

Action 4. Conduct an intensive excavation project on the motu of Onetahi. This motu certainly was one of the three most intensively used anciently or at least with the most impressive and visible sites (Onetahi, Horoatera and Rimatu'u).

During construction of the villa nearest the south east point of Onetahi there was brought to light an extensive food preparation and cooking area where a number of ahima'a or earth ovens were exposed containing shellfish midden. This is in proximity to a seaside coral edged platform and proximal alignment, the latter likely a house site. Nothing comparable has been encountered on the atoll despite intensive survey. The deposits look deep and rich so that the excavation of these

two components of the site will be very useful in determining the date of the structures themselves as there was abundant charcoal present and maybe locating earlier occupation deposits below.

A second site worth excavating in a similar vein is that at the western side of the motu toward its northern end. Here we have set some 100 meters inland a small marae in a stand of tou trees (Cordia subcordata). The marae although noted by both the archaeologists Verin (1963) and Sinoto (1977) never it seems had a plan made, nor does it appear to have been excavated during Sinoto's excavation campaign in 1977.

Complimentary to the excavation of the west coast marae itself would be to open up a unit some 20 meters north from the structure bordering the present airstrip. Here exposed in a cut is a profile we drew at 1/25 scale of a number of occupation layers no doubt associated with the marae but maybe also predating it.

Additionally, the re-excavation of Verins and Sinoto's marae ensemble next to the airstrip is recommended to obtain more reliable and up to date RC14 charcoal samples and a fresher analysis of the history of the site.

Finally a certain number of sunken gardens or 'maite' in the southern part of the motu would merit excavation also and pollen cores to be sunk in them to aid in a general reconstruction of the original flora on Onetahi and see how Polynesians occulted that through their introduced species.

Action 5. Conduct excavations of the archery platform, marae and possible habitation sites in the northeast of Ti'araunu motu. According to missionary sources in the early 19th Century the sport of archery, unique to the Society Islands was practiced on a specific structure a tahua te'a in the proximity of a marae dedicated to the god of the sport and an area for the gathering of men of rank where the structure was associated with this group (as there were separate platforms for children and women of rank). Here we have three associated structures that may be related in just such a way.

Action 6. Excavate marae and habitation sites lagoon side Hiraana'e motu. Relatively few surface sites were visible on this motu. However one small marae was located inland from the lagoon with an unusual orientation, its axis is along the length of the motu and not towards the external sea or internal lagoon bordering as is usual. The marae and surrounding area again warrants excavation to discern the role of this structure and activities associated anciently.

Action 7. Intensively study and excavate selected sites on the atoll of Horoatera. This atoll along with Onetahi and Rimatu'u has among the most numerous above surface remains visible of Teti'aroa. And they are diverse including at least six marae sites with different architectural makeup, an assembly ground, possible dance/oratory platform, 'maite' sunken gardens and a funerary site.

Action 8. Conduct an in-depth study of the ensemble of sites on the motu of Rimatu'u that I believe represent a collection of structures relating to the cult of the paramount god 'Oro and his acolytes the 'arioi. This is a unique ensemble in the Society Islands composed of diverse platforms, a paramount chiefs marae (marae ari'I nui) and others structures that have a clear association to an individual named in important ethno-historic sources, Tu-Teina-Mate or the 'first' Pomare.

Action 9. Systematically map and excavate selected settlement sites on Reiono motu. This motu is, within the ensemble of the islets of Tet'iaroa, perhaps the most unique.

Action 10. Provide an ongoing and systematic sharing of the knowledge that is gained, through local and international communication on the Tetiaroa Society website and through Facebook (with maps, pictures, explanations of significance and meanings, etc.).

Action 11. Create a system of stewardship of sites across the motu's over time that is in the hands of and directed by local Tahitians. Hopefully this will grow out of both the use of locals in overseas researchers projects in archaeology, as has been the case recently. But also in association with the creation of an outreach cultural program that seeks to educate Tahitian children and youth about their ancient culture in the setting of Teti'aroa. This will lay the way for a person growing up with a close relationship to Teti'aroa who by early adulthood one hopes will want to be directly involved in the educational program created and take on the role of steward of archaeological and cultural sites there. So that eventually all our collective archaeological, historic and linguistic knowledge returns to its source, the Tahitians themselves.

Educational Program

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Background and Current Situation

Education is a key part of any conservation plan. In this case education will also promote community involvement, understanding, and support, which are important to a long-term conservation plan. On Tetiaroa there will be a local education program that brings students from local schools to the atoll, and facilities that can be used by these local schools as well as community groups and international schools.

There are four stakeholders for which the Education Program is particularly important. The community is interested in having access to Tetiaroa and understanding what is going on there. The Brando estate, The Brando, and Tetiaroa Society are interested in sustainable business and conservation plans in order to maintain the physical and biological integrity of the island. One of the best ways to fulfill those all of those interests is through an education program that is mainly for the schools but also for community organizations.

Tetiaroa Society's educational mission cuts across all major uses of the atoll including: science, conservation, culture, and tourism. The Educational programs are primarily aimed to benefit local Polynesian students but also engage international students and all visitors to Tetiaroa. Broadly, our goal is to encourage

community engagement through the combination of traditional knowledge and modern science in a common pedagogic framework. They seek to promote the rich cultural heritage of Polynesia and modern science as they relate to living sustainably on atolls.

Threats

The Community in general has very little access to Tetiaroa, partly because of the difficulty of physical access, and partly because of the legal limitations of visiting a private island. At present there is very little information available to the public about conservation programs on Tetiaroa. Lacking access and information the community will at best be uninvolved with, and at worst opposed to, operations and programs on Tetiaroa. All conservation efforts on Tetiaroa need the support of an informed community. An Education Program would allow the community an access point to the island and the information to become engaged in conservation programs there. It would also take advantage of an opportunity to use Tetiaroa as an open-air classroom to teach local and international students about sustainable development and the nature and culture of atolls.

Desired Outcome

A regular education program for the schools and community organizations, hosted and partly financed by the Brando Estate, The Brando and Tetiaroa Society, would be a win/win situation for all involved. Many children/people on Tahiti will never have a chance to see an atoll, let alone Tetiaroa, and inviting classrooms and groups to visit the island would give some of them this opportunity. Visiting the island would also create awareness of the importance of conserving the atoll and what the Brando Estate, The Brando and Tetiaroa Society are doing about it. Tetiaroa can be used to teach students and community about the nature and culture of atolls and also about sustainable development. The renewable energy, waste disposal, and conservation programs being used on Tetiaroa can serve as a model not just for hotel/reserve development, but also for community development.

A camp/center should be created on one of the motu. It should be built from local materials in a "traditional" style. At minimum the camp would consist of a couple of large *fare pote'e* for meeting/sleeping, a *fare ahima'a* for cooking, modern compost toilet facilities, and a secure storage building. Water from the motu could be used for cleaning, and water for drinking and cooking could be brought from Onetahi. A botanical garden with representative motu plants should surround the camp. This camp would be used for all student groups. Part of every school program could be spent maintaining the facilities in order to learn how people live on motu. At best this camp could be a working model of a traditional Paomotu village with as much of the cultural components as possible included.

Education programs will be developed for local schools that bring middle school and high school students to the island for one or two night stays. These programs should feature atoll natural and cultural history, in particular Paumotu culture. Regular programs, possibly one per month, could run with the intention of including as many schools per year as possible. Associations and community groups could also be invited to apply for a limited number of available time slots.

International Schools – There is already a long history of international school visits to Tetiaroa. Santa Monica Community College ran programs there from the late 70s using the old hotel as a base. Glendale Community College brought a class there in 1980 as well. Beginning in 1991 the UC Berkeley Moorea field course began bringing students there for day trips and has continued that almost every year to the present. In 2010 The UCB class stayed on Onetahi for 2 days using the worker housing. In 2013 and 2014 a field course from the International Community School visited the atoll, and in 2014 the Ross School stayed four days on the island. Also in 2014 a group from University of Redlands spent 6 days on the island.

In the future visits by international schools would be allowed to use the education camp for overnight programs. A simple field lab with work benches could be constructed if need be.

Hotel guests – Tours from the hotel could visit the camp, learn about Paumotu culture and ideally see it in action with students. Family groups could use the camp for a remote island "camping" experience.

Strategies and Actions

Strategy 1: Create an education program with local schools.

Action 1.1: Create an education team to develop nature/culture/sustainable development curriculum ideas and goals.

Action 1.2: The education team should meet with the Brando Estate, The Brando and Tetiaroa Society to consider options and guidelines for the Education Camp and program operations.

Action 1.3: The education team should meet with selected education officials (Hinano Murphy can advise) to determine interest, feasibility, logistics, content of education program.

Action 1.4: Assuming there is interest then the education team can design a program description and schedule for start of the program.

Strategy 2: Construct an education camp in 2016.

Action 2.1: The education team will decide on physical needs of the camp, and work with the Brando Estate, The Brando and Tetiaroa Society to decide on a site.

Action 2.2: The education team will work with architect/builder to create a design of the education camp along with a material list, construction plan, and budget.

Action 2.3: All interested parties will reach agreement on a budget.

Action 2.4: All interested parties will seek to obtain funding for the education camp based on the approved budget.

Action 2.5: Official architectural plans will be submitted to Government (Mairie Arue?) and permit obtained.

Action 2.6: Commence construction.

Strategy 3: Begin the education program.

Action 3.1: Inaugural ceremony planned and executed with the Brando Estate, The Brando and Tetiaroa Society and government officials attending. Goals of the Education Program and larger conservation goals of the Brando Estate, The Brando and Tetiaroa Society are featured.

Action 3.2: First school groups are brought in and program begins.

Fisheries

Lead Author: Serge Planes

Principal Contributing Authors: David Lechini, Yannick Chancerelle, Gilles Siu

Background and Current Situation

Tetiaroa is close to Tahiti and is regularly used by fishermen from Arue and elsewhere who fish for and harvest marine life from fish to clam and crayfish.

Tetiaroa atoll in a small atoll; one of the smallest of French Polynesia, and in light of that we can consider that it will be very sensitive to overfishing, especially if only few species are targeted.

A new ZPR (i.e. Zone de Pêche Réglementée) was established by the Ministry for Natural Resources in June 2014. This ZPR is only located inside the lagoon and segregates the atoll in two equal areas with one being restricted to any fishing activity and the other remaining open to fishing.

This ZPR was already in perspective, but as a conservation zone by the Direction of Environment in 2008 and in that respect, the CRIOBE has been in charge of a first global inventory of the lagoon and the outer reef biodiversity. In this survey, six sites were defined and several stations (6 per sites) were surveyed. The objective of this specific survey were:

- To collect basic data on the distribution and abundance of fish and macro-invertebrates targets to estimate stock of organic inside the lagoon and on the outer slopes

- To establish a long-term monitoring program for this atoll with a view to the establishment of a development plan for the lagoon through marine protected areas on the one hand but also because of the development an important tourist facility on the other.

In the continuity of the ZPR established in 2014, the CRIOBE has been contracted to achieve a new survey. To test the effectiveness of protection in terms of evolution of the densities and biomass of target species, different protocols have been proposed in the past. It is now clearly recognized that the strongest of these protocols leverages IP model "Before-After-Control-Impact" (BACI), which reduces the impact of natural variations in space and time, stands. So based on this work, with BACI type of methodology, 2008 and 2014 surveys will be considered a before impact to evaluate the impact of the ZPR.

Threats

In the context of fisheries, the major threat is over-fishing and the disequilibrium this can create in the ecosystem.

Desired Outcomes

The objectives are:

1- To show increase in fishery yield (i.e. targeted fish species);
2- To show an increase of top predators (i.e. proxy of equilibrium in the ecosystem); and
3- To develop a dialogue and collaboration with local fishermen to improve the quality of Tetiaroa ecosystem for a sustainable fishery in a harmonized ecosystem.

Strategies and Actions

Strategy 1: Promote a consultation committee involving local fishermen, scientist and other users of the ecosystem.

Action 1.1: Organize yearly meeting

Action 1.2: Evaluate from consultation fishery yield

Strategy 2: Evaluate ecosystem change due to the establishment of the ZPR.

Action 2.1: Evaluate fish stock change both in the ZPR and the surrounding non protected area.

Strategy 3: Enhance fish stocks through a "Post-Larvae Capture and Culture" ("PCC") program.

Action 3.1: Develop a PCC program and evaluate impact of cultured post-larvae release.

Tourisme

Lead Author: David Seeley
Principal Contributing Author: Frank Murphy

Background and Current Situation

Tourism operations on Tetiaroa should follow Sustainable Tourism (ST) guidelines. According to the UN World Tourism Organization (www2.unwto.org), sustainable tourism practices include:

1) Make optimal use of environmental resources that constitute a key element in tourism development, maintaining essential ecological processes and helping to conserve natural heritage and biodiversity.

2) Respect the socio-cultural authenticity of host communities, conserve their built and living cultural heritage and traditional values, and contribute to inter-cultural understanding and tolerance.

3) Ensure viable, long-term economic operations, providing socio-economic benefits to all stakeholders that are fairly distributed, including stable employment and income-earning opportunities and social services to host communities, and contributing to poverty alleviation.

Because Tetiaroa is a private atoll, many different stakeholders should be involved in the management of tourism operations that impact its environment.

Tetiaroa's land (all land above the public domain line) is owned in fee simple by SA Frangipani and is technically considered private property. In 2005 SA Frangipani signed a lease agreement with Tahiti Beachcomber SA (TBSA), the developer of The Brando. This lease agreement impacts two of Tetiaroa's motus--Onetahi and Honuea. Due to this lease agreement, TBSA controls the tourism activities on these two motus. SA Frangipani controls the tourist activities on the remaining ten motus that make up the atoll. Therefore, all tourist activities that directly impact the private property of either SA Frangipani or TBSA need to be reviewed and approved by these entities first.

The government of French Polynesia controls the use and access of the public domain in and around the atoll of Tetiaroa. This public domain includes the barrier reef, the lagoon, the air above Tetiaroa, and the beaches of each motu below the private property line (or all land below the public domain line).

Threats

The major threat is that unregulated tourism operations and uncontrolled public access could damage both the marine and land environments that make up the atoll of Tetiaroa. Overuse of sites could disturb natural processes. High levels of lagoon and motu use could create pollution problems from fossil fuels, solid waste, and sewage. Construction of trails, picnic areas, and other tourism infrastructure could have harmful effects on the surrounding natural environment on the motus of Tetiaroa. Unregulated tourism on the public domain could also negatively impact marine life and sea birds.

Desired Outcomes

The desired outcome for Tourism Activities on Tetiaroa is that all tours and activities on the atoll should both focus on and respect the environment, the private property rights of the owner, the rights of TBSA, the rules and regulations regarding the public domain, and the culture of the atoll. Sites of interest on land and water should be identified and then approved by the owner and prepared in such a way (trails, tables, toilets, etc.) that visitors don't need to disturb any of the surrounding vegetation, cultural sites, or marine life. The usage of sites of interest should be monitored and limited to levels that do not disturb vegetation, wildlife, or marine life. All stakeholders should agree upon and follow the same ecotourism philosophy and guidelines. A trip to Tetiaroa should be promoted and operated as a privileged visit to a place of special natural and cultural heritage that should be enjoyed, understood, cared for, and protected for future generations to come. All visitors to the atoll should at a minimum follow the attached guidelines. See Exhibit A.

Strategies and Actions

Strategy 1: Create a tourism working group among active stakeholders (presently working with SA Frangipani) that will set guidelines with advice from experts in many different fields, and then meet with all stakeholders to seek a consensus.

Action 1.1: Obtain descriptions of all current tourist activities occurring on Tetiaroa. Work to develop and set guidelines for visitation. Review and revise guidelines set forth in Exhibit A.

Action 1.2: Obtain descriptions of all local tourism operations and activities on Tetiaroa and work with active members of this group to review guidelines. These tourism activities will mainly occur on Rimatuu and Bird Island.

Action 1.3: Meet with all stakeholders to try and create a consensus on guidelines and monitoring of future tourist activities.

Action 1.4: Meet with lagoon committee to coordinate future tourist activities on the public domain. Discuss potential threats from jet skis, sea/float planes, floating homes, fishing, kitesurfing, windsurfing, and drones. Develop comprehensive regulation strategy for tourist activities on the atoll.

Built Environment – The Brando

Lead Author: Stanley Rowland

Background and Current Situation

The built environment on Tetiaroa consists of The Brando and its related infrastructure and the Tetiaroa Society Ecostation.

The Brando is a luxury eco-resort located on the motu of Onetahi. It consists of 35 villas, two restaurants, two bars, boutiques, a spa, a marine sports center, an airstrip, a reef dock, an island dock, staff housing and supporting infrastructure. The supporting infrastructure includes a sea water air conditioning system that circulates cold water throughout the resort for air conditioning, a photo voltaic array alongside the airstrip, a biofuel electricity generating system which uses coconut oil for generating electricity, a waste water treatment system that uses natural processes to clean waste water before it is reused in irrigation, a

passive rainwater collection system, a desalination facility, and an underground water collection system on Tiaruanu.

The Tetiaroa Society Ecostation, which was donated to Tetiaroa Society by Pacific Beachcomber, consists of dry and wet labs and a dormitory for up to 20 researchers. Tetiaroa Society also has a Visitor Center at the resort center which is used for educational and fund raising purposes.

The Brando project also includes a planned residential component (The Tetiaroa Residences) consisting of approximately 20 residences on the east side of Onetahi, between 1-10 residences on Honuea, and up to 10 residences on the north shore of Onetahi. Construction of the residences will begin in 2016 and construction thereafter will be based on sales.

As part of their commitment to preserve and protect Tetiaroa, the Brando Estate and Pacific Beachcomber have agreed that there will be no commercial development on any of the motus of Tetiaroa other than Onetahi and Honuea.

The Brando was built with the goal of setting a new standard in sustainability and environmental sensitivity. Its environmental efforts and programs include:

- Construction of the resort in accordance with Platinum LEED standards.
- Avoidance of all overwater construction and maintenance of a minimum 30 meter construction setback from the ocean and lagoon.
- Operation exclusively with renewable, non-fossil energy sources, including the sun and coconut oil.
- Use of sea water air conditioning (SWAC), which uses the cold of the ocean to provide low-energy, efficient cooling for all buildings, reducing energy necessary for air conditioning by approximately 90% and overall energy demands by approximately 60%.
- A waste water treatment system that uses a tidal process to cleanse waste water naturally with aeration, plants and beneficial bacteria to provide water for irrigation.
- A passive low-energy rain water collection system to aid with water independence.
- Direct solar heating for hot water.
- A robust recycling and composting program to minimize waste and provide compost.
- An organic garden and honey farm to provide locally produced fruits and vegetables.
- Contribution of a million dollar scientific research facility, including dry and wet labs and a dormitory for researchers (the Ecostation) to Tetiaroa Society to facilitate scientific research on Tetiaroa.
- Provision of a visitor education and fund raising center (the Visitor Center) for use by Tetiaroa Society, which helps in guest education and in efforts to raise funds for conservation, scientific and cultural activities on the atoll.
- Funding of the Tetiaroa Society naturalist guide program, which provides environmental and cultural education and helps fund raising efforts to support conservation, scientific and cultural activities on the atoll.
- Implementation of an "opt-out" guest contribution program whereby all resort guests automatically contribute to Tetiaroa Society unless they opt out, which provides an important base of funds to support conservation, scientific and cultural activities on the atoll.

Threats

Human development, if not properly managed, provides a number of potential threats to the environment including the following:

- Visual pollution by the construction of buildings and infrastructure that is obtrusive or not in harmony with the natural environment.
- Damage to marine or terrestrial habitats.
- Pollution of ground water and water bodies.
- Damage to the ground-water lens from salt water intrusion.
- Introduction of invasive plant and animal species.
- Damage to or overuse of natural resources, such as by overfishing and destruction of corals and reefs.
- Disturbance of plant and animal species such as birds, whales, rays and sharks and their nesting and nursery areas.

Desired Outcomes

Following are some of the key objectives and outcomes for development on the atoll:

- The built environment should be in harmony with nature, both in appearance and in operation.
- The built environment should blend and harmonize with, and not dominate or deter from, the surrounding natural beauty.
- The built environment should help support the conservation, scientific and educational programs on Tetiaroa, both operationally and financially.
- The built environment should strive to achieve a net zero carbon impact.
- There should be no air, land or water pollution from the built environment.
- The island should be ecologically better off after human development.

Strategies and Actions

Strategy 1: Limit future development on Tetiaroa to the motus of Onetahi and Honuea (with exceptions for cultural, educational, scientific programs (e.g., a children's cultural and educational fare on Rimatu'u) and recreational activities (e.g., bird watching platforms).

Strategy 2: Use the built environment to help support conservation, scientific and educational programs.

Action 2.1: Use the Ecostation and its facilities, resources and unique setting as an opportunity to bring world-class scientists and researchers to French Polynesia to engage in cutting edge and potentially world changing research.

Action 2.2: Use the Ecostation and other buildings and facilities on Tetiaroa for cultural, scientific and educational programs for local school children.

Action 2.3: Use the Ecostation and facilities on Tetiaroa to bring students from around the world to learn about tropical atolls, conservation and local culture.

Action 2.4: Use the resort's unique access to deep ocean water to conduct scientific research that is not possible elsewhere, such as ocean acidification research.

Action 2.5: Use the facilities on Tetiaroa as a base for providing environmental protection to the atoll, such as programs to deter turtle poaching and overfishing.

Action 2.6: Maintain a guest Visitor Center at The Brando for educational purposes and to generate donations for conservation, scientific and educational programs as well as to enhance the Tetiaroa Society naturalist guide program and increase guests' truly personal experience with them.

Action 2.7: Maintain a guest "opt-out" donation program at The Brando to generate donations for Tetiaroa Society's conservation, scientific and educational programs.

Action 2.8: Follow up with guests of The Brando for donations and provide them an option list from which they can choose to make general donations or donations to support specific conservation, scientific, cultural or educational programs.

Strategy 3: Take steps to ensure that all construction blends harmoniously with the environment.

Action 3.1: Maintain a 30-meter construction setback from the ocean and lagoon wherever possible.

Action 3.2: Use construction designs and style that blend harmoniously with the natural environment and with the cultural history of the atoll.

Strategy 4: Avoid all over-water structures including piers, floating platforms, floating hotels and restaurants, houseboats and long-term anchorages in the lagoons.

Action 4.1: Avoid over-water construction that may interfere with the natural and pristine appearance of the atoll.

Action 4.2: Prohibit floating restaurants, floating hotels and houseboats in the lagoons which are non-sustainable and potentially destructive to the ecosystem and natural environment.

Strategy 5: Avoid the destruction or impairment of any natural habitat or resource on which plants or animals depend.

Strategy 6: Use mitigation, restoration and enhancement programs in all construction to achieve a net benefit to the natural environment.

Strategy 7: Maintain an extensive recycling and composting program to minimize waste products and reuse natural resources.

Strategy 8: Operate exclusively with renewable, non-fossil energy sources using the sea, sun, coconuts and other renewable resources.

Strategy 9: Avoid the introduction of, and control, reduce or eliminate, exotic species that threaten the natural equilibrium on the atoll, carry diseases or make life on the atoll less pleasant.

Action 8.1: Establish a biosecurity program to avoid the introduction of, and control, reduce or eliminate, exotic species.

Action 8.2: Establish programs to control mosquitos.

Action 8.3: Establish programs to eradicate rats.

Strategy 10: Determine the carrying capacity of the atoll for different activities and maintain a sustainable level of human activity vis-à-vis the natural environment.

EXHIBIT 1: APPENDIX TO SCIENTIFIC RESEARCH PROGRAM

Contents

Tetiaroa IDEA - Data Science Infrastructure

Goals & Objectives

The Tetiaroa '*Island Digital Ecosystem Avatar*' (IDEA) will be a sustainability simulator modeling links and feedbacks between climate, environment, biodiversity, and human activities across the atoll's coupled marine-terrestrial landscape. It will facilitate query, analysis, modeling, simulation, forecasting, and visualization across domains. It will guide, utilize, and communicate all the physical/chemical, biological, and social science research conducted on Tetiaroa, as well as providing a digital platform for citizen science efforts, natural resource management, and conservation programs. We will address the following objectives: (1) What is the physical, biological, and social state of the atoll today? (2) How did it get to this point? (3) What is its future under alternative scenarios of environmental change and human activity, including conservation efforts?

Activities

Tetiaroa Society is part of the *IDEA Consortium*, an open science initiative in systems ecology. Researchers associated with the CRIOBE and Gump Station initiated the consortium through a workshop at ETH Zurich in November 2013. It now includes more than eighty scientists from around the world involving over 20 institutions. The consortium's primary mission is to conduct the basic scientific research needed to build use-oriented simulations (avatars) of entire social-ecological systems. Islands are the most scientifically tractable places for these studies and the consortium is beginning with Tetiaroa and Moorea in French Polynesia. Core activities under the Tetiaroa IDEA include:

1. **Data and Maps** The first task is to build a place-based data science infrastructure integrating all models and data on Tetiaroa. It spans scales from genome to society and includes sensor-based observations, imagery, map layers, social surveys, archaeological and paleoecological findings, information on life forms, and scientific publications. The availability of these data and models, presented in a common format, is the core of the avatar project - it provides a solid foundation for all research and conservation programs on the island.
2. **Simulations and Synthesis** The next task is to enable the integration of models and simulations across disciplines, combining the physical, chemical, biological, and social aspects. The goal is to take the first steps towards predictive modeling of potential states of the Tetiaroa social-ecological system under alternative scenarios of human activities and environmental change. A major component of developing this predictive capability is hindcasting socio-ecosystem dynamics following Polynesian colonization. Guided by the success of such postdiction (hindcasting), coupled models can explore trajectories leading to alternative states of the reef and terrestrial ecosystems and the consequences and inter-dependences between these states.
3. **Services** User needs provided via the atoll's Conservation and Sustainable Use Plan (CASUP) will inform the design of the avatar's key interfaces, visualizations, and simulations. The project will provide immersive learning experiences to foster a new generation of students and scientists capable of working across domains, disciplines, and cultures through the common language of data science. An educational ethos will pervade the avatar, including local schools and students worldwide through innovative cyber-learning modules on sustainability science and complex dynamical systems. An apprenticeship program will match students from the project with industry partners and encourage corporate mentoring.

The project contributes to and complements the Moorea IDEA[2] enabling comparison of high-island and atoll systems. Eventually the IDEA platform will be deployed to aid other islands around the world (IDEA Network) in developing a Predictive, Preventive, Personalized, and Participatory approach to achieve their sustainability goals (see P4-IDEA Sustainability Forum).

Tetiaroa Observatory

Goals & Objectives

The Tetiaroa Observatory collects data to establish baselines, reconstruct past conditions (i.e., to put modern baselines in historical context), assess the success of contemporary management actions, understand the influence of global change, and to monitor the status of key sustainability sectors - Water, Energy, Health, Food, Biodiversity, and Nutrients - on Tetiaroaa.

[2] Nature 517, 255–256 (2015) Tropical paradise inspires virtual ecology lab. doi:10.1038/517255a

Activities

The SAB oversees the observatory with a Chief Scientist responsible for implementation. Technicians (funds permitting) carry out day-to-day operations using TS facilities (including boats and other major equipment), assisted by the TS Rangers, Guides, and volunteers (e.g., from The Brando staff). Studies over the initial 5-year period will include close collaboration with members of the IDEA Consortium to:

- **Monitor key physical and chemical drivers of the ecosystem -** this includes the flow of freshwater, nutrients, sediments, and contaminants into the lagoon and their residence times and transport in the surrounding coastal ocean. We will model multi-component water, sediment, and reactive contaminant transport, linking existing numerical codes and developing new ones. Climate models provide the parameters for weather simulations that determine rainfall, wind, and temperature as inputs to hydrologic models of transport from streams into the lagoon and coupling to marine circulation models. These models provide physical and chemical predictions that can be coupled to population dynamic and other whole-island physical and biological models. To parameterize the models we will rely on various sources of remotely sensed and in situ data. Ground-truthing will be facilitated by on-going and new observations on Tetiaroa and Moorea.

- **Assess the structure and function of the coupled terrestrial-marine ecosystem -** this includes all the biodiversity (Tetiaroa Biocode) and ecological interactions on the island (Tetiaroa Interactome). We will build upon existing biotic understanding by initiating data collection, field experiments, and simulations concerning the ecology of foundational tree and coral species along physical and biological gradients. This will determine where and why these species thrive (or not), as well as how other organisms and the environment interact with them. Data collection will determine biological associates (including microbes, epiphytes, fungi, invertebrates and vertebrates) and their interactions using data intensive sequencing (Tetiaroa Genomic Observatory) and imaging techniques along a ridge to reef transect. The transect will document species occurrence and their physical/chemical context to enable inference of species' ranges throughout the island.

- **Establish long-term marine and terrestrial experiments** (eventually as part of an Experimental Garden Array) along natural and artificial gradients to illuminate interactions between foundational species of corals and trees, their competitors, and other key species such as fish, turtles, and rats. Modeling will help develop broadly applicable theory that integrates these data and experiments. Statistical modeling will infer range maps and effects of foundation species' genotypes on their phenotypes including fitness among invasive species and diversity of associated species. Mechanistic modeling of the ecological networks will illuminate interdependencies and thresholds responsible for trophic cascades and sustenance of native ecosystems.

- **Develop socio-economic indicators** related to water, health, energy, food, and biodiversity that track the dynamic interaction between humans (all the major user groups on Tetiaroa) and this unique atoll ecosystem over time - including research to reconstruct the evolution of key metrics since Polynesians first discovered Tetiaroa. Contemporary studies will quantify the coupled natural-human system, including the responses and trajectories of biodiversity/ecological indices and associated goods and services under different management measures, environmental, and other pressures.

Major Science Themes

Goals & Objectives

Tetiaroa Society through its SAB will engage world-class research teams to study the complex processes that shape social-ecological systems across scales of organization from genomes to society. The holistic approach includes basic "discovery driven" and applied "use inspired" research. Human activities are key to understanding social-ecological systems and achieving sustainability goals, the social sciences and humanities are thus fully integrated from the outset.

Activities

All scientific activities build on the Tetiaroa Observatory and Tetiaroa IDEA, which represent foundational research infrastructure. While projects from the broader scientific community are welcome, these will generally need to be self-funded. **TS will focus its scientific fundraising on a number of priority programs identified by the SAB.** Some will emphasize basic research of regional or global significance, while others will address the knowledge gaps prioritized through the CASUP to support conservation efforts on Tetiaroa. The SAB will develop these priority science programs (in early 2016) starting with short "Concept Notes" (~4 pages), which outline the broad scientific interest of the program, its local and/or global benefits, the lead investigators (a collaborative team including but not limited to SAB members), and a rough budget for (i) a pilot project and (ii) a fully funded project. **In addition to the cross-cutting Tetiaroa IDEA and Tetiaroa Observatory, initial priority programs include:**

Conservation Biology

Tetiaroa is an important place for many threatened species of conservation importance, including birds, sharks, and turtles, among others. Conservation of these species is a major priority of the CASUP. Research programs focused on these species will contribute to their global protection as well as advancing general scientific understanding. Tetiaroa has a vital role to play as a sanctuary for these species. Furthermore, given its relative accessibility and the available scientific capacity, Tetiaroa can also provide a testing ground for next-generation autonomous technologies, which once proven on Tetiaroa, could be deployed to much more isolated atolls.

An Atoll in History

Understanding the history of Tetiaroa is a crucial component of almost all of Tetiaroa Society's programs, for example, restoration projects need to know what the atoll's natural state might have been. Studying the evolution of Tetiaroa's coupled natural-human system is of particular importance and archeological research will investigate several topics including the timing and process of initial Polynesian colonization, the development and distribution of ceremonial architecture on the various islets (motus), and

how traditional Polynesian society managed natural resources. On a longer timescale, studies of climate change should consider how Tetiaroa responded to sea level changes over the millennia, putting today's rising ocean in context. Geology, paleo-ecology, historical biogeography, and paleo-environmental research are all vital for understanding the contemporary functioning of the atoll.

Genetic Control of Disease Vectors

Field trials will test novel genetic control techniques, initially targeting the mosquito Ae. polynesiensis, a species that has not received much attention from the global health community despite its great importance in the Pacific Islands. We build on technology developed by ILM and Oxford University and a previous pilot project on Tetiaroa with support of French Polynesia, Pacific Beachcomber, TS, UPF, and others. The research has clear benefits for everyone on Tetiaroa but also provides an excellent opportunity for developing and testing novel approaches that can then be scaled to larger islands across the region.

Tetiaroa Biocode & Genomic Observatory

Tetiaroa has a subset of Moorea's biodiversity. The Moorea Biocode Project established a reference database of photos and genetic identifiers for all the animals and plants on Moorea3. Leveraging this unique database and applying advanced imaging and genomic approaches, we will inventory the entire Tetiaroa biota with unprecedented speed. The Tetiaroa Biocode will also enable a Genomic Observatory where genetic data are recorded over time to map the distribution of biodiversity and to document biological interactions (thus characterizing the atoll's "interactome"). To cite just two examples: (a) the deployment of sampling devices such as Autonomous Reef Monitoring Stations (ARMS) to survey benthic marine biodiversity and (b) the implementation of 'metabarcoding' approaches to document trophic interactions (food webs) and pollination networks.

Climate Change, Sea Level Rise and Ocean Acidification

The very existence of Tetiaroa, like all atolls, is fundamentally threatened by global change. Of particular concern are rising sea levels, which will interact with warming waters and ocean acidification (OA). What will these global drivers, coupled with local human activities, mean for the future of the atoll, its biodiversity and human society over the coming decades? We will study this vital question from various perspectives. In addition to simulating likely outcomes under various scenarios using sophisticated computational approaches (Tetiaroa IDEA), we will also conduct process-oriented experiments, and compare how an atoll responds in comparison to high islands (specifically comparing Tetiaroa with neighboring Moorea).

To study OA in particular, we propose to build a "reef of the future". Specifically, we will design, construct, test, and perform a Free Ocean CO2 Experiment (FOCE) using the deep SeaWater Air - Conditioning (SWAC) system constructed by The Brando Resort on the atoll of Tetiaroa. Until now, the few attempts to establish FOCE have been limited to very small scales (~ 2 m2) due to the amount of CO2

[3] Check E: Treasure island: pinning down a model ecosystem. Nature 2006, 439:378–9

needed to modify the marine environment with experimental precision over long periods of time. We propose to create replicate "future reefs" in Tetiaroa's lagoon implementing FOCE at unprecedented scale - at least 800 m2. Tetiaroa is the only atoll in the world where such an experiment can be launched today for two reasons: The Brando is making deep ocean water from its SWAC available for scientific research via the Tetiaroa Society's Ecostation and (2) we are able to take immediate and full advantage of this opportunity because all the knowledge, expertise, and infrastructure necessary is already available in French Polynesia through the research stations on Moorea.

Restoration, Replenishment, and Resilience

Scientifically, Tetiaroa offers an excellent opportunity to develop innovative holistic approaches to (a) restoring or replenishing degraded ecosystems and (b) enhancing the resilience of still relatively intact ecosystems. For example, the numerous motus and the uneven distribution of invasive rat species among them offer an opportunity to combine conservation with basic research. Complete rat eradication on Tetiaroa is feasible (quote has been obtained) and could set the stage for a decadal ecological experiment – essentially rendering Tetiaroa a "major research infrastructure". The effort would leverage all the other research themes described earlier. It would follow a protocol designed to elucidate the functioning of complex ecosystems and the role of keystone species (e.g., rats), while delivering significant conservation (e.g., seabirds), health, and economic benefits for Tetiaroa. Other projects under this program could focus on enhancing resilience. For example, developing a coral farming facility to carry out experiments with clonal coral colonies to identify non-genetic processes in responses to changing environments, as well as 'common garden' experiments that vary genetic variation while holding the environment constant. Results of such work would guide restoration efforts to use genotypes that are most resilient to expected environmental conditions in the future (e.g. future sea temperature and pH).

Educational Programs

Goals and Objectives

Tetiaroa Society's educational mission cuts across all major uses of the atoll. An educational program in "Island Sustainability" primarily aims to benefit local Polynesian students but also engage international students and all visitors to Tetiaroa. Broadly, it will combine traditional ecological knowledge and modern science and technology in a common pedagogic framework, as they relate to living sustainably on atolls. The program is partially guided by the SAB but also by the CASUP committee and the Cultural Advisory Board.

Activities

The "Island Sustainability" program will include (a) on-site "experiential" hands-on activities (leaning through doing), ideally at a Cultural Center on Tetiaroa, and (b) innovative cyber-enabled distance

(remote) learning opportunities (e.g. employing virtual reality technology). These programs will include close collaboration with local schools. Initial projects include:

1. **Tetiaroa Cultural Center** inspired by the success of the Atitia Center on Moorea - this project will build partnerships with traditional knowledge leaders to establish an educational program on Tetiaroa involving practical pedagogic activities in building a community-based cultural center (e.g., ethnobotanical garden, amphitheater, traditional thatched structures). The first step will be a planning phase to determine the best site on Tetiaroa and a road-map for building up the full vision.
2. **Tetiaroa as a Complex Dynamical System** - this project builds on an existing collaboration with the Ross Institute and Google through the IDEA Consortium to develop a curriculum that integrates the concept of complex dynamical systems into educational programs in French Polynesia. Course modules will use Tetiaroa as a key use case to address issues surrounding Energy, Water, Food, Nutrients, and Biodiversity. They will highlight the innovative technologies used at The Brando and will explore how these might be used on other islands too. This program would engage local students (e.g., through UPF) as well as students worldwide.
3. **Cyber-learning at the Tetiaroa Ecostation** - this project builds on an existing collaboration with the University of Hawaii and Google through the IDEA Consortium to develop multi-lingual (English, French, Polynesian…) distance-learning programs that enable students to experience the benefits of immersive field experiences. It recognizes that not all can physically experience Tetiaroa, or indeed any coral reef island, and yet it is vital that citizens worldwide appreciate these critical ecosystems. Applying modern communications technology, this project aims to bring Tetiaroa and its rich knowledge base to the world's classrooms.
4. **Turtles in Nature and Society -** building on key TS partner Te Mana o Te Moana's many years of experience leading educational programs on Moorea and research on Tetiaroa, this program will focus on teaching Polynesian schoolchildren about turtle ecology and conservation including the place of turtles in Polynesia's cultural heritage (this program is largely in place already).
5. **Tetiaroa Ethnocode and Traditional Knowledge Avatar -** this project will teach schoolchildren and inform the general public about the common names of animals and plants on Tetiaroa and associated traditional ecological knowledge and folklore. It will link to scientific knowledge (genetics, ecology, and evolution) through the parallel Tetiaroa Biocode that assigns the Latin Linnaean names. The initial emphasis, for example, might be on birds and could contribute to the Ethno-Ornithology World Archive (www.ew-archive.net) in collaboration with Oxford University, SOP Manu, and Birdlife International.

P4 Island Sustainability Forum

Goals and Objectives

Small islands are disproportionately affected by global change. They also epitomize the coastal regions where most of humanity increasingly lives. Pacific Beachcomber has offered Tetiaroa Society the use of The Brando hotel on Tetiaroa to host a high-impact island sustainability conference each year. Our key

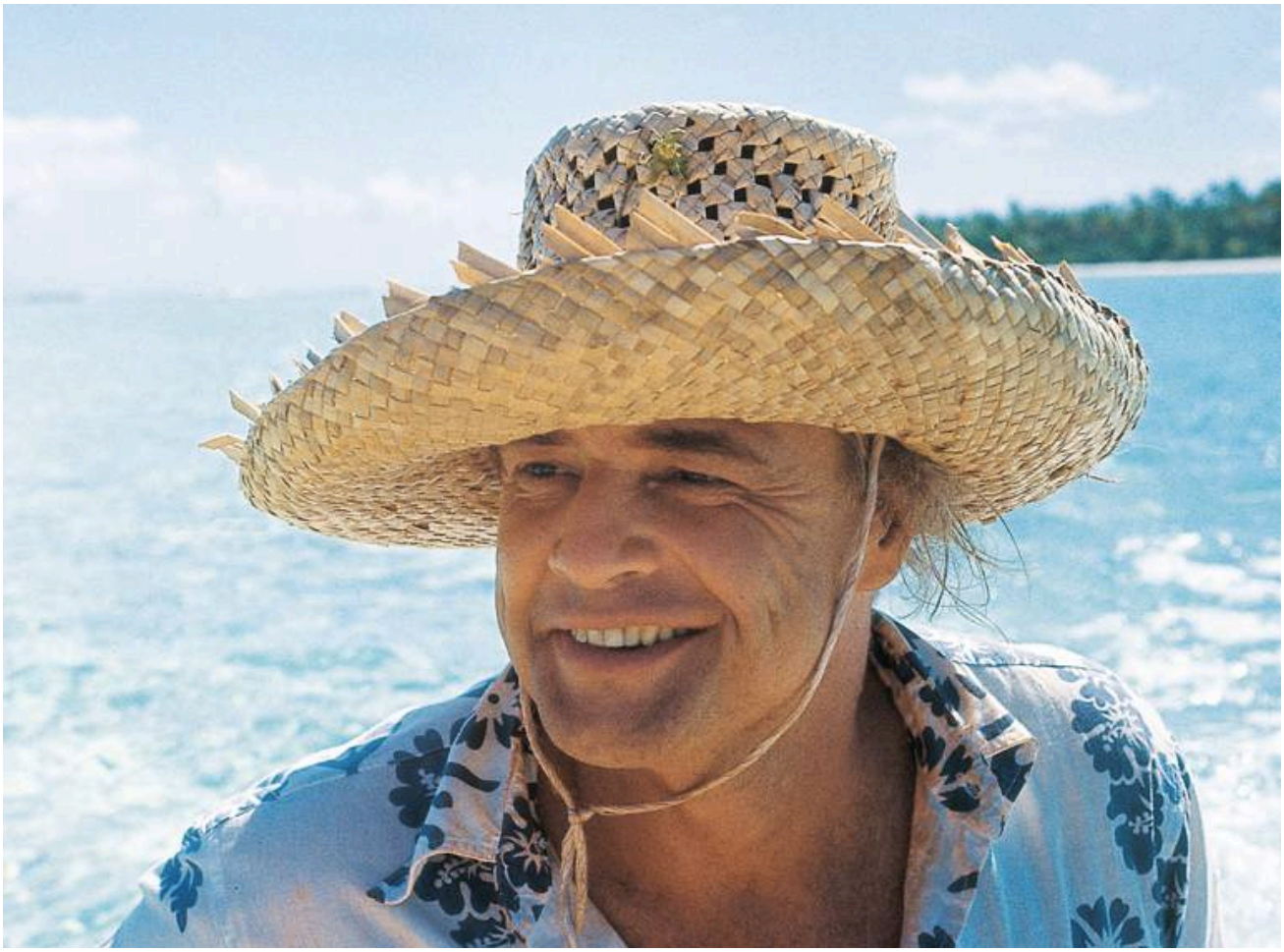
goal for the conference is to improve the status of island social-ecological systems, including their coastal oceans and massive marine Exclusive Economic Zones. In so doing, we believe that islands can serve as models for other regions, up to and including our common island home: planet Earth.

Technology provides the means to empower individuals and local communities. Global environmental sustainability is not going to come from global governance alone, it must also come from the ground up by empowering local communities to take control of their own future. Aggregation of local adaptation efforts worldwide might lead to more effective global mitigation than intergovernmental instruments, which so far have been spectacular only in their failure. Like many cities, islands are well placed to provide global leadership and showcase successful transitions.

A grassroots solution to global change is possible but a significant barrier remains developing local knowledge management systems that can interact seamlessly with national and international management infrastructure and policy instruments. Through its work in French Polynesia, the Tetiaroa Society is supporting efforts that will demonstrate such an ambitious goal is within reach today for relatively small islands. Given the rapid growth in scientific and technological capacity across the globe, these demonstrations offer hope for all. Tetiaroa, for example, has already shown it is possible to achieve near net carbon neutrality without compromising comfort. Neighboring Moorea and Tahiti, however, remain largely oil powered despite being bathed in the same sources of renewable energy. How can advances on small private islands help large places transition to a sustainable future?

Activities

With such an exceptional venue as The Brando, Tetiaroa Society has an incredible opportunity to attract leading experts, philanthropists, and decision makers - those who can help achieve lasting change. We propose to organize the world's first "P4-IDEA Sustainability Forum" to promote a Predictive, Preventive, Personalized, and Participatory approach to management and public policy on islands. Such an approach will benefit small privately owned islands, the island territories of G7 countries, and Small Island Developing States (SIDS) alike. A representative range of island owners/leaders will be invited to the Forum each year, drawing initially on members of the emerging IDEA Network. A core component of the conference will be to monitor progress in building the Tetiaroa IDEA and the underlying avatar software, which will be applicable (and applied) in other islands worldwide. Deployment of this common data science platform will enable comparison among islands and analysis of success factors, accelerating the spread of best practice globally.



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