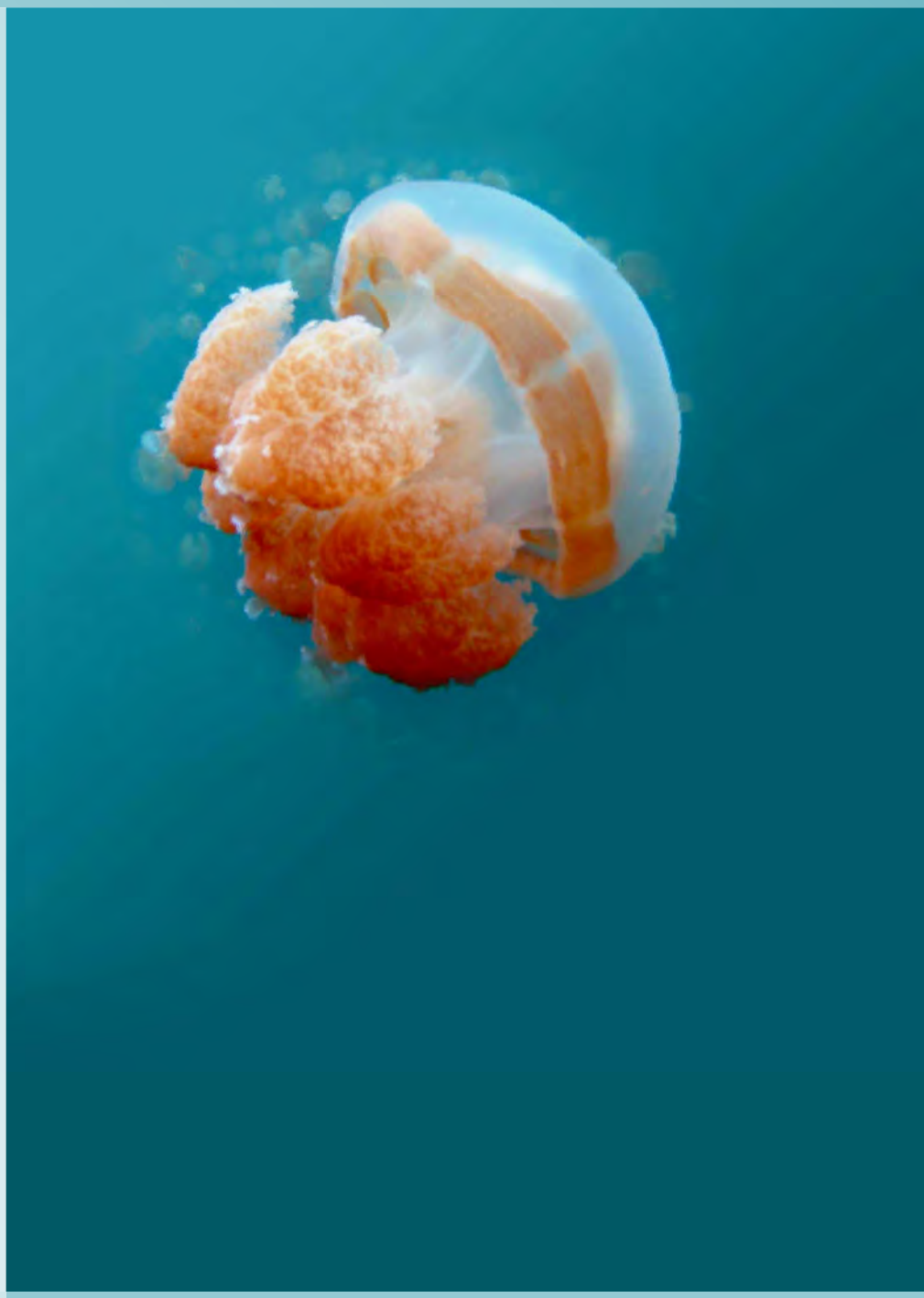
Documenting an Existing Invasion to Prevent Future Introductions of Non-Indigenous Species in the Island-like Marine Lakes, Palau

JANUARY 2011



BIODIVERSITY CONSERVATION LESSONS LEARNED TECHNICAL SERIES

9

CONSERVATION INTERNATIONAL
Pacific Islands

BIODIVERSITY CONSERVATION LESSONS LEARNED TECHNICAL SERIES

9

Documenting an Existing Invasion to Prevent Future Introductions of Non-Indigenous Species in the Island-like Marine Lakes, Koror, Palau

Biodiversity Conservation Lessons Learned Technical Series is published by:

Critical Ecosystem Partnership Fund (CEPF) and
Conservation International Pacific Islands Program (CI-Pacific)

PO Box 2035, Apia, Samoa
T: + 685 21593
E: cipacific@conservation.org
W: www.conservation.org

Conservation International Pacific Islands Program. 2011. Biodiversity Conservation Lessons Learned Technical Series 9: Documenting an Existing Invasion to Prevent Future Introductions of Non-Indigenous Species in the Island-like Marine Lakes, Koror, Palau.
Conservation International, Apia, Samoa

Authors: Sharon Patris, Michael N Dawson, Lori J. Bell, Laura E. Martin, & Patrick L. Colin/Coral Reef Research Foundation

Design/Production: Joanne Aitken, The Little Design Company, www.thelittledesigncompany.com

Cover Photograph: Golden jellyfish, *Mastigias papua etpisoni*.

Series Editors: James Atherton and Leilani Duffy, Conservation International Pacific Islands Program

Conservation International is a private, non-profit organization exempt from federal income tax under section 501c(3) of the Internal Revenue Code.

ISBN 978-982-9130-09-9

OUR MISSION

Building upon a strong foundation of science, partnership and field demonstration, CI empowers societies to responsibly and sustainably care for nature for the well-being of humanity

This publication is available electronically from Conservation International's website:
www.conservation.org

CONSERVATION INTERNATIONAL Pacific Islands

CRITICAL ECOSYSTEM PARTNERSHIP FUND

the David & Lucile Packard FOUNDATION

Coral Reef Research Foundation

ABOUT THE BIODIVERSITY CONSERVATION LESSONS LEARNED TECHNICAL SERIES

This document is part of a technical report series on conservation projects funded by the Critical Ecosystem Partnership Fund (CEPF) and the Conservation International Pacific Islands Program (CI-Pacific). The main purpose of this series is to disseminate project findings and successes to a broader audience of conservation professionals in the Pacific, along with interested members of the public and students. The reports are being prepared on an ad-hoc basis as projects are completed and written up.

In most cases the reports are composed of two parts, the first part is a detailed technical report on the project which gives details on the methodology used, the results and any recommendations. The second part is a brief project completion report written for the donor and focused on conservation impacts and lessons learned.

The CEPF fund in the Polynesia-Micronesia region was launched in September 2008 and will be active until 2013. It is being managed as a partnership between CI Pacific and CEPF. The purpose of the fund is to engage and build the capacity of non-governmental organizations to achieve terrestrial conservation. The total grant envelope is approximately US$6 million, and focuses on three main elements: the prevention, control and eradication of invasive species in key biodiversity areas (KBAs); strengthening the conservation status and management of a prioritized set of 60 KBAs and building the awareness and participation of local leaders and community members in the implementation of threatened species recovery plans.

Since the launch of the fund, a number of calls for proposals have been completed for 14 eligible Pacific Island Countries and Territories (Samoa, Tonga, Kiribati, Fiji, Niue, Cook Islands, Palau, FSM, Marshall Islands, French Polynesia, Wallis and Futuna, Eastern Island, Pitcairn and Tokelau). By late 2010 more than 35 projects in 9 countries and territories were being funded.

The Polynesia-Micronesia Biodiversity Hotspot is one of the most threatened of Earth's 34 biodiversity hotspots, with only 21 percent of the region's original vegetation remaining in pristine condition. The Hotspot faces a large number of severe threats including invasive species, alteration or destruction of native habitat and over exploitation of natural resources. The limited land area exacerbates these threats and to date there have been more recorded bird extinctions in this Hotspot than any other. In the future climate change is likely to become a major threat especially for low lying islands and atolls which could disappear completely.

For more information on the funding criteria and how to apply for a CEPF grant please visit:

- www.cepf.net/where_we_work/regions/asia_pacific/polynesia_micronesia/Pages/default.aspx
- www.cepf.net

For more information on Conservation International's work in the Pacific please visit:

- www.conservation.org/explore/asia-pacific/pacific_islands/pages/overview.aspx

or e-mail us at cipacific@conservation.org

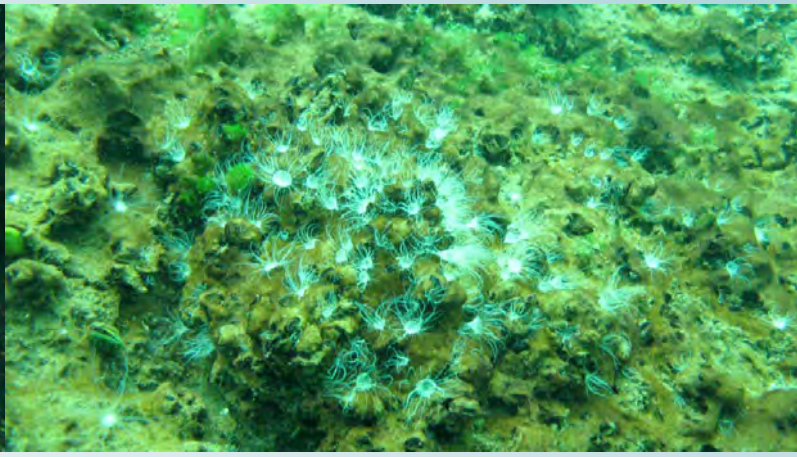
CRITICAL ECOSYSTEM PARTNERSHIP FUND

CONSERVATION INTERNATIONAL Pacific Islands

Location of the project in the Polynesia-Micronesia Biodiversity Hotspot

Contents

Native and invasive animals in Ongeim'l Tketau.
Foreground: Endemic sponges and algae.
Background: The invasive *Aiptasia* anemone growing among native mussels.



Warming events in Ongeim'l Tketau can cause bleaching in some patches of invasive anemones.

Lessons Learned

Project Design Process

Aspects of the project design that contributed to its success/shortcomings.

There was no control experiment, therefore it is not possible to say for sure what the project design successes or shortcomings were, but the project design was certainly helped by the experience of the team in the topic, the existing collaborations, and the fit of the proposal to meet a specific need.

Project Implementation

Aspects of the project execution that contributed to its success/shortcomings.

Once again, there was no control but the project implementation was probably helped by the small group, the existing collaborations, a clear management structure and open communication.

BIODIVERSITY CONSERVATION
LESSONS LEARNED TECHNICAL SERIES

CEPF Small Grant Final Project Completion Report

Documenting an Existing Invasion to Prevent Future Introductions of Non-Indigenous Species in the Island-like Marine Lakes, Koror, Palau

Organization Legal Name

Coral Reef Research Foundation

Project Title

Documenting an Existing Invasion to Prevent Future Introductions of Non-Indigenous Species in the Island-like Marine Lakes

Date of Report

31 May 2010

Report Author and Contact Information

Michael Dawson, mdawson@ucmerced.edu

CEPF Region

Polynesia-Micronesia Hotspot

Strategic Direction

(1) prevent, control, and eradicate invasive species in key biodiversity areas.

Grant Amount

$17,653

Project Dates

1 February 2009 – 31 January 2010

Implementation Partners for this Project

Please explain the level of involvement for each partner

Koror State Government and Koror State Department of Conservation and Law Enforcement facilitated the research in Ongeim'l Tketau during the project period and were integrally involved with the design of posters and information booklet, providing feedback on content during the development of these publications and approving and endorsing final products.

Conservation Impacts

Please explain/describe how your project has contributed to the implementation of the CEPF ecosystem profile

The project has "empower[ed] the stewards of the biodiversity of the Polynesia-Micronesia Hotspot … to conserve biodiversity more effectively" (CEPF Ecosystem Profile Conclusion) by providing [1] additional information to Koror State Department of Conservation and Law Enforcement on the magnitude of the threat to the jellyfish lake ecosystem by the invasive anemone, [2] media to increase awareness in visitors to the region of the threats that they may unwittingly carry, and [3] further training to a Palauan marine scientist.

In terms of links to the CEPF Investment Strategy, we met each of the following goals:

1. "Strengthen defenses against the introduction and spread of invasive species and pathogens that threaten biodiversity" (CEPF investment strategy 1.1) by raising public awareness through public posters and a brochure.

2. "Control or eradicate invasive species in key biodiversity areas, particularly where they threaten native species with extinction" (CEPF investment strategy 1.2) by contributing to awareness of practices that will prevent introductions of species to other marine lakes.

3. "Perform research, provide training in management techniques, and develop rapid response capacity against particularly serious invasive species" (CEPF investment strategy 1.3) by describing scientifically and quantifying experimentally the impact of the current invasion, and continuing training of Ms. Sharon Patris in marine science.

Please summarize the overall results/impact of your project against the expected results detailed in the approved proposal

[1] Assessment of impact of taking no action.

Our surveys have shown continued expansion of the anemone population around the perimeter of the lake. From experiments and observations completed or underway (see below) we infer expansion will continue unless there is human or natural intervention and that such expansion could reduce population sizes of endemic populations, with attendant increased risk of extirpation due to stochastic environmental and population events.

[2] Comparison of efficacy of two treatment methods (in terms of removal of invasive and damage to natives).

This comparison was not undertaken due to logistical constraints.

As an alternative, we have begun an experiment to determine the extent of refuges for native species against invasive anemones (e.g. putatively shallow-water, shaded, rock surfaces). Due to difficulties getting invasive *Aiptasia* to settle on ceramic and plastic plates – the start of this experiment unfortunately coincided with the die-off of *Aiptasia* described in [6] below – the start of the transplant experiment has been delayed to summer 2011.

[3] Assessment of whether eradication is feasible (i.e. high chance of successful eradication or permanent diminution by a method that has acceptably small impacts on the native biota).

Our ability to answer this question is somewhat constrained by the lack of results from the original comparison planned for #2, above. However, given the current spatial extent of the anemone and the degree to which it co-occurs with native biota, oftentimes in structurally complex microhabitats such as mangrove root systems, it is evident that trying to control anemones using any approach that treats swathes of benthos would also remove endemic species. The magnitude of the effect on native biota (relative to no action) is yet to be calculated based on

[4] Greater diversity of media raising awareness of the anemone (posters, brochure, and consultation).

Production of posters and booklet (physical copies have been provided) will increase awareness, although the degree is as yet unquantified. Posters and booklets have been distributed to schools, tour agencies, government offices and posted in public areas in Palau (posters distributed to 85 locations; booklets distributed to 27 locations). These posters will be translated into additional languages (currently only in English) in the coming months, furthering their reach. In addition, existing signs have been replaced at Ongeim'l Tketau (see Fig. 1).

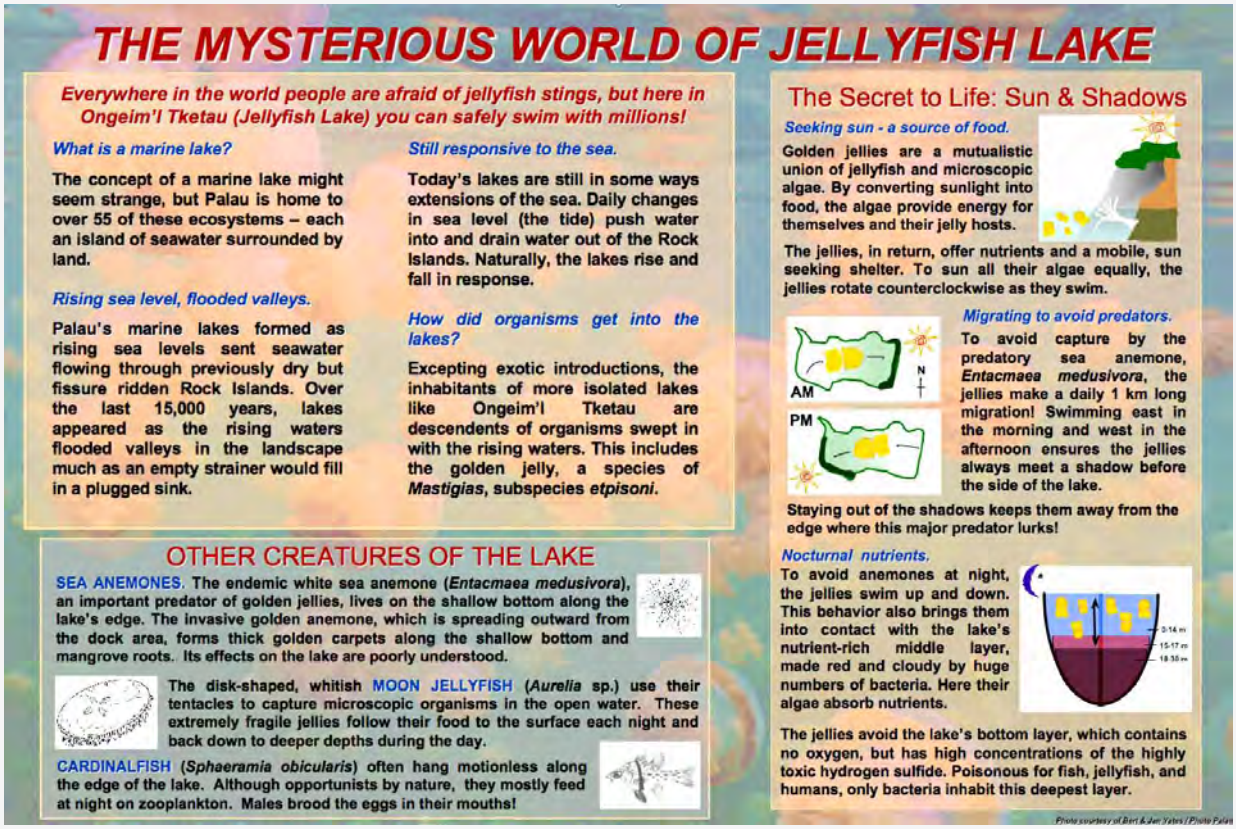


FIGURE 1. The information sign replaced at Ongeim'l Tketau as part of this project.

[5] Description of the anemone distribution in 2009 and indications of altered distributions of native organisms.

Preliminary analyses of quadrat and transect data indicate diversity of native species is inversely correlated with density of invasive *Aiptasia* anemones.

[6] Anemone population response to natural environmental variation.

During the award period, a warming event was observed in the lake. Coincident with this period, we observed a bleaching event in some patches of invasive anemones. Anemones died and/or decreased in size, and although patches were reduced they generally did not disappear completely. As the lake cooled, they subsequently regained the brown coloration typical of healthy zooxanthellate *Aiptasia* and again increased in size and abundance (see Fig. 2). We infer that natural events are most likely insufficiently extreme to cause extirpation of the invasive anemones. In fact, intermittent environmental stress which may exert a weak-to-moderate selective pressure, coupled with our observation that some anemones have symbionts similar to those in the endemic *Mastigias* jellyfishes, raises the possibility of local adaptation of the invasive anemones, including adoption of a new photosymbiont.

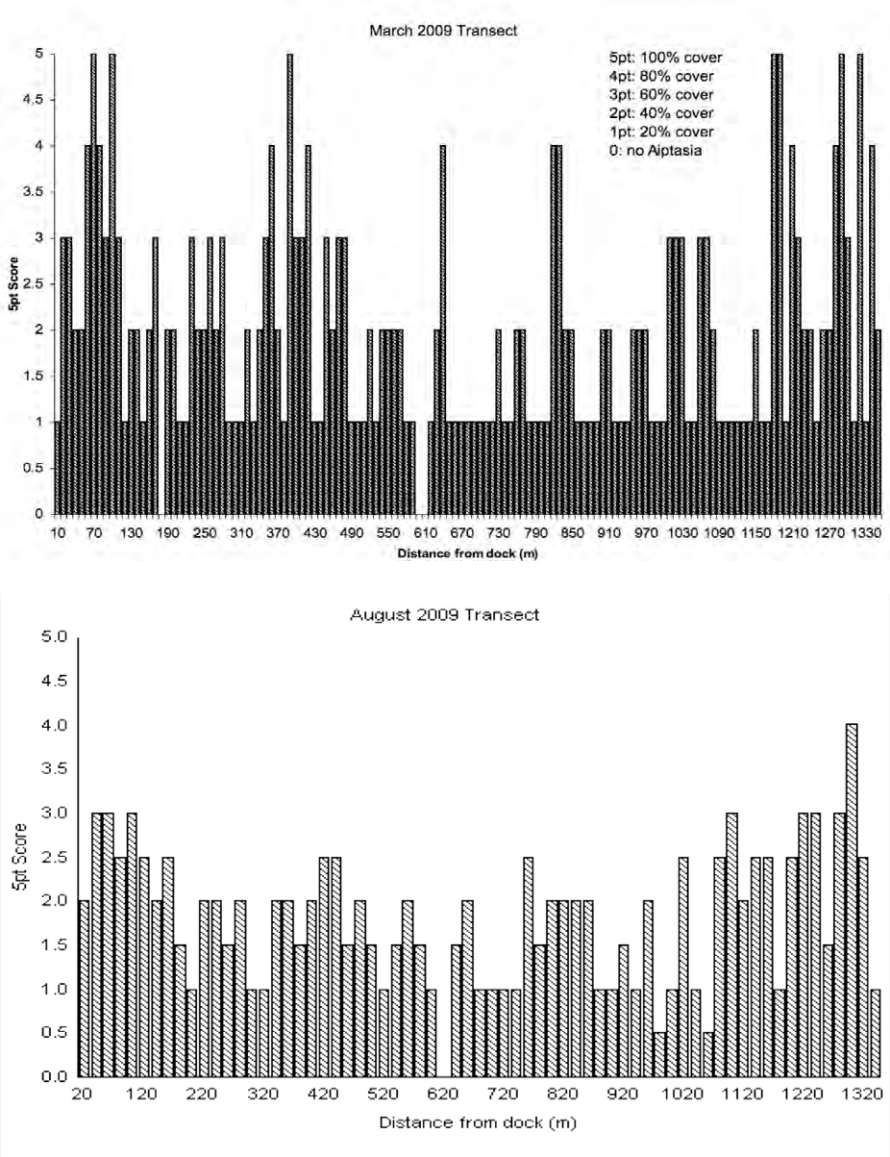


FIGURE 2.
Temporary reduction in *Aiptasia* abundance due to a natural warming event in Ongeim'l Tketau. (Upper) The March 2009 transect around the lake perimeter shows *Aiptasia* occurs in low to high abundance throughout the lake, coincident with cool temperatures. (Lower) August 2009 transect shows *Aiptasia* abundance around the lake perimeter, coincident with warmer lake temperatures. Comparison of the two transects shows *Aiptasia* density (but not extent) was reduced in August, also coincident with bleaching of some anemones (see text [6] above).

Please provide the following information where relevant

- *Hectares Protected*: No additional area (not a goal of the project).
- *Species Conserved*: Species to which this effort contributes protection include *Mastigias papua etpisoni,* an endemic subspecies of jellyfish.
- *Corridors Created*: None (not a goal of the project).

Describe the success or challenges of the project toward achieving its short-term and long-term impact objectives

The project was successful in that continuing to document the invasion achieved the short-term goals, and describing the genetic diversity of the invasive zooxanthellae has revealed new avenues for studying the long-term impact of the invasive anemone on the native species in Ongeim'l Tketau.

Were there any unexpected impacts (positive or negative)?

Most invasive surveys done in Palau are on terrestrial species. This is the first quantitative survey on a marine invasive species, and this may serve as a guideline for future surveys. The invasive species in Jellyfish Lake serves as a model case study to show Koror State and public of the threat of invasive species, and may help in careful decision making of policies regarding the other 50 marine lakes that are currently closed.

Lessons Learned

Project Design Process: (aspects of the project design that contributed to its success/ shortcomings)

There was no control experiment, therefore it is not possible to say for sure what the project design successes or shortcomings were, but the project design was certainly helped by the experience of the team in the topic, the existing collaborations, and the fit of the proposal to meet a specific need.

Project Implementation: (aspects of the project execution that contributed to its success/ shortcomings)

Once again, there was no control but the project implementation was probably helped by the small group, the existing collaborations, a clear management structure and open communication.

Additional Funding

Provide details of any additional donors who supported this project and any funding secured for the project as a result of the CEPF grant or success of the project.

Donor	Type of funding*	Amount	Notes
The David & Lucile Packard Foundation Western Pacific Program	A	$15,087	Salary support for Ms. Sharon Patris, boat fuel & rental.
Koror State Department of Conservation and Law Enforcement	A	$220	Purchase additional information booklets
UC Merced	A	$3500	Contributed to bring sample sizes to publishable standard

**Additional funding should be reported using the following categories:*

A Project co-financing (Other donors contribute to the direct costs of this CEPF project)

B Grantee and Partner leveraging (Other donors contribute to your organization or a partner organization as a direct result of successes with this CEPF project.)

C Regional/Portfolio leveraging (Other donors make large investments in a region because of CEPF investment or successes related to this project.)

Sustainability/Replicability

Summarize the success or challenge in achieving planned sustainability or replicability of project components or results.

Methods are replicable. Experience gained making posters and booklet can be applied again in the future. True test would be transferring to other groups in other locations (not part of this project).

Summarize any unplanned sustainability or replicability achieved.

None.

Safeguard Policy Assessment

Provide a summary of the implementation of any required action toward the environmental and social safeguard policies within the project.

None.

Performance Tracking Report Addendum

CEPF Global Targets (01 February 2009 – 31 January 2010)

Provide a numerical amount and brief description of the results achieved by your grant. Please respond to only those questions that are relevant to your project.

PROJECT RESULTS	Provide your numerical response for results achieved during the annual period.	Provide your numerical response for project from inception of CEPF support to date.	Describe the principal results achieved from 1 February 2009–31 January 2010. (Attach annexes if necessary)
1. *Did your project strengthen management of a protected area guided by a sustainable management plan? Please indicate number of hectares improved.*	N/A		
2. *How many hectares of new and/or expanded protected areas did your project help establish through a legal declaration or community agreement?*	N/A		
3. *Did your project strengthen biodiversity conservation and/or natural resources management inside a key biodiversity area identified in the CEPF ecosystem profile? If so, please indicate how many hectares.*	Potentially strengthened existing 55000 sq.m.	Potentially strengthened existing 55000 sq.m.	Putatively have increased awareness of threats from introduced species. Impact has not been quantified in terms of # of people with raised awareness.
4. *Did your project effectively introduce or strengthen biodiversity conservation in management practices outside protected areas? If so, please indicate how many hectares.*	Not quantified	Not quantified	May have generally raised awareness of threats from introduced species. Visitors to Palau may return to their home nations with increased awareness, and apply this knowledge to their own neighborhoods.
5. *If your project promotes the sustainable use of natural resources, how many local communities accrued tangible socioeconomic benefits?*	N/A		

Information Sharing and CEPF Policy

CEPF is committed to transparent operations and to helping civil society groups share experiences, lessons learned, and results. Final project completion reports are made available on our website, www.cepf.net, and publicized in our newsletter and other communications.

Full contact details:

Name: Michael Dawson

Organization name: Coral Reef Research Foundation

Mailing address: PO Box 1765, Koror, Palau PW96940

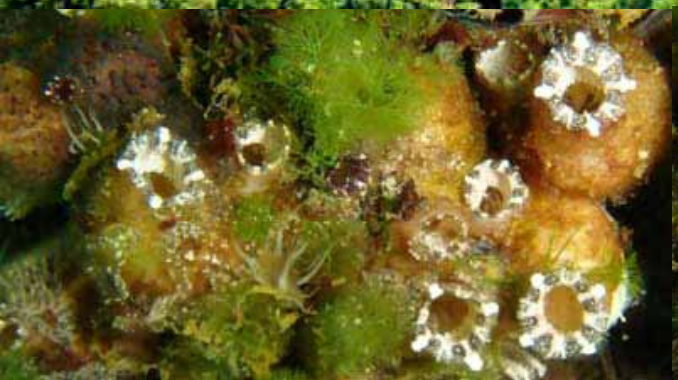
Tel: 1-209-228-4056

Fax: 680-488-5513

E-mail: mdawson@ucmerced.edu / crrf@palaunet.com

Jellyfish Lake (*Ongeim'l Tketau*)

Koror, Palau



This booklet is a product of Coral Reef Research Foundation with support from the Critical Ecosystem Partnership Fund (CEPF). A large part of this research would not have been possible without the help of the David & Lucile Packard Foundation.

For more information visit:

www.CoralReefResearchFoundation.org

www.marinelakes.ucmerced.edu

Sharon Patris, a marine biologist at the Coral Reef Research Foundation and graduate student at the University of California, Merced, completed a photographic survey of the *Aiptasia* anemone invasion and its impact on endemic biodiversity in Ongeim'l Tketau.

Message from the Honorable Yositaka Adachi

Governor of Koror State

The well-known biodiversity of the Republic of Palau lies in the marine environment of the famous Rock Islands where important habitats for the threatened and endangered species are situated. Koror State Government is vigilant to effectively conserve and manage our ecological integrity of the marine environment and its resources. This is crucial for the economy, culture and biodiversity of Palau, mostly for Koror State. Thus, a Management Plan was established to establish a comprehensive conservation program for the Rock Islands Southern Lagoon area covering all marine and terrestrial environments, including the seawater lakes such as Ongeim'l Tketau, known as Jellyfish Lake.

Jellyfish Lake is a well-known tourist destination offering an unforgettable experience of swimming among millions of harmless jellyfish. We want to raise public awareness of the natural heritage of Jellyfish Lake and the threats of non-native species. Non-native species pose a continuous threat to endemic ecosystems globally, particularly to small isolated ecosystems including oceanic islands, such as Palau, and marine lakes, such as Jellyfish Lake. Non-native species, once introduced, have the potential to become invasive and cause irreparable damage to this ecosystem.

To experience the wonders of Jellyfish Lake is a privilege that gives us an indelible duty to protect it. We can all play a role in protecting Jellyfish Lake by following simple guidelines like *not carrying a rock or shell from the lagoon into Jellfish Lake*.

Let us enjoy the beauty of Palau and help preserve these natural environments as part of our heritage and culture.

Yositaka Adachi,
GOVERNOR

The rock islands are managed and maintained by the Koror State Government and the Koror State Department of Conservation and Law Enforcement. For information regarding laws and regulations for the rock islands contact the Koror State Rangers: +680 488 2150.

The Legend of Chuab

Long ago, when the Earth was young, and this world was still being created, a goddess named Latmikaik, gave birth to Chuab. Being a demi-god, the boy grew rapidly, so rapidly that he became an enormous, ravenous giant, gulping in large amounts of food faster than it could be supplied to him. In order to feed him, the people had to scramble up tall bamboo poles and throw large baskets of food – whole chickens, pigs and more, into Chuab's mouth. As the people's supplies ran low, Chuab started feeding on the humans themselves, causing the remaining villagers to beg Latmikaik to do something about her son.

In the end, the goddess reached the difficult decision that her son must be killed, or the beginnings of humanity would suffer extinction. Tearfully, she told the people to pile wood around the giant. When Chuab asked her what was happening, Latmikaik lied that the villagers were preparing a feast, and since it was in his honor, they were going to cook him some special dishes, all around him. Happily, the giant leaned back, anticipating what he thought lay ahead. However, when the people finished adding the kindling, they lit the wood, and Chuab, bellowing in pain, fell face first into the ocean and died. He hit the water with such a force that parts of his body split from the whole, creating new islands. His privates became Aimeliik, which is why, the Palauans believe, that rain always begins there; his feet formed Peliliu and Angaur, who are reputed for their fleetness; his stomach became Ngiual, where the phrase "Seven eat, nine soup time" originated, giving rumor that the people from Ngiual eat more than three meals a day; and so on.

At Latmikaik's request, the people tried to cover the corpse with woven shrouds, but the body was too immense, leaving many areas exposed; so while the covered areas grew into forests, the uncovered areas served as open fields and plains. Also, from the maggots that crawled out of the decaying flesh, more people sprouted, replacing the ones lost during Chuab's reign.

This is why the people named the islands Belau, deriving it from the native word, "Aibebelau," meaning "a fairytale."

Taken from Aibebelau: Legends of Belau compiled and illustrated by Ucheliou

What are Marine Lakes?

Marine lakes are bodies of sea water that are variously connected with the ocean through tunnels and cracks under the porous rock islands. Every marine lake has a different story, as each lake is physically and biologically different from one another.

The degree of difference between lakes depends on how isolated these lakes are from the ocean and from each other.

Some lakes are connected to the ocean through big tunnels, and these lakes have colorful corals and fish. These lakes are very similar to the surrounding ocean and to each other. In contrast, other lakes that are connected to the ocean only through small cracks and crevices do not have corals; these lakes have colorful sponges and sometimes jellyfish very different from the ocean.

Some lakes have great visibility, while in others you can't see past your outstretched hand! There are over 50 marine lakes, and all are like different worlds!

Top: Ongael Lake: One of the smallest marine lakes (150m long, 4m deep).

Centre: L-shaped Lake: Stratified lake deep inside Mercherchar island.

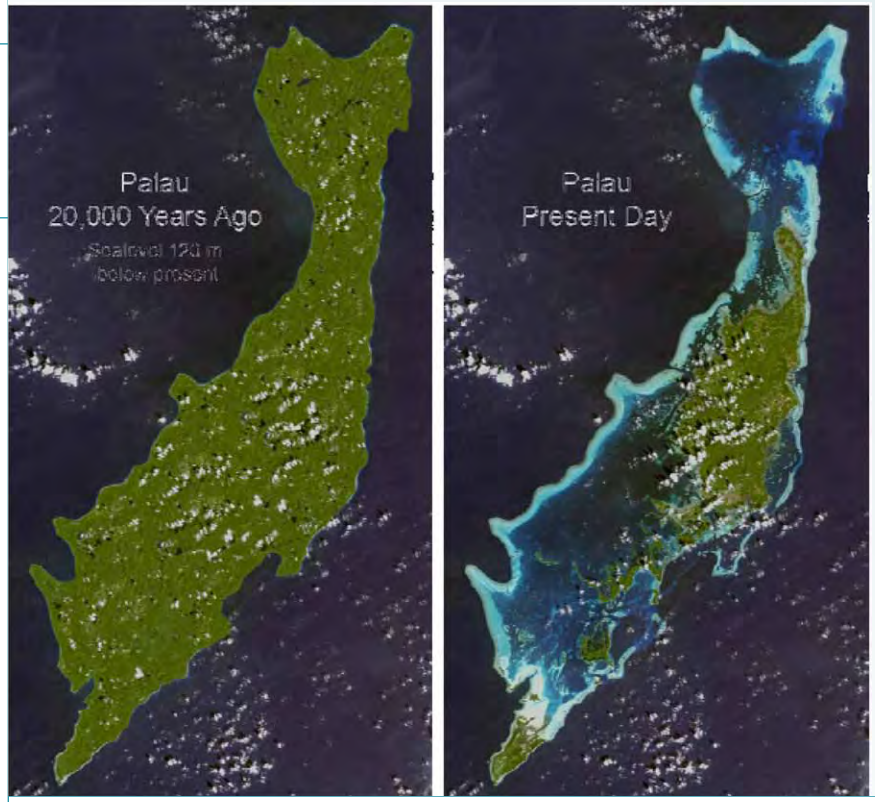
Bottom: Tketau Lake: Largest marine lake in Palau (2000m long, 60m deep).

How did Marine Lakes form?

Over a period of many millions of years, volcanic activity formed submerged islands on which coral reefs grew. These reefs were subsequently raised out of the water by the continued tectonic activity of the colliding Pacific and Philippine plates. These uplifted coral reefs became the rock islands as we know them today. Can you imagine that? While looking at rock islands, you are basically looking at coral reefs that formed millions of years ago underwater!

About 20,000 years ago, sea level started rising. During the last glacial maximum when sea level was lower, there was dry land instead of the lagoon. From that time to the present day, melting ice caused the sea to rise ~120m. The sea flooded onto parts of the island that we know as the lagoon today and into the natural depressions and valleys found within the rock islands. As water filled these depressions, larvae of organisms came in with the water. These organisms populated and formed unique biological systems in what are known today as marine lakes. All the lakes are less than 20,000 years old!

It is easier to imagine uplifted corals from an airplane when you see the peaks, ridges and depressions in the modern-day reef.



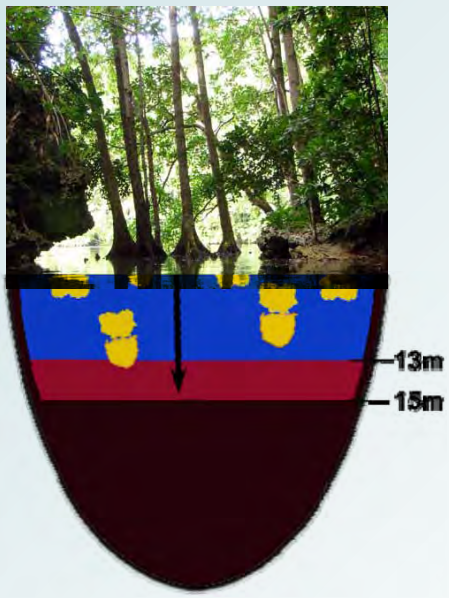
Sea level has changed over evolutionary and geological time.

Jellyfish Lake (*Ongeim'l Tketau*)

Jellyfish Lake is the only marine lake open to visitors. It is a 45 minute boat ride from downtown Koror, and is found on Mercherchar island.

Jellyfish Lake is far inland within the rock island of Mercherchar. It is one of the isolated lakes. Along the lake's edges are mangrove trees with roots covered with an assortment of marine life.

Jellyfish Lake is 400m long, 150m wide and 30m deep. Large animal life in Jellyfish Lake is limited to the top 15m. Between 13–15m, there is a pink layer of bacteria. Below that, there is no light and no oxygen. The bottom layer is filled with the poisonous dissolved gas hydrogen sulfide. For this reason, there is no SCUBA diving allowed in Jellyfish Lake. Even the lake's most famous occupant – the one-of-a-kind golden jellyfish *Mastigias papua etpisoni* – doesn't go below the bacterial layer!



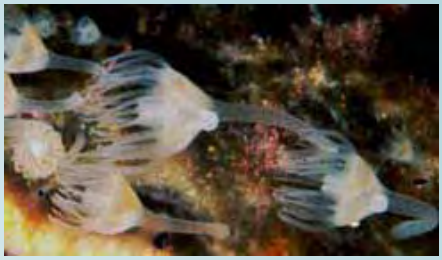
Most life in Jellyfish Lake is found in the upper 15m on mangrove roots and along edges on the shallow bottom.

Most life in Jellyfish Lake is found in the upper 15m on mangrove roots and along edges on the shallow bottom.

What is the golden jellyfish?

Mastigias papua etpisoni is a unique jellyfish found only in Jellyfish Lake. It is named after one of Palau's former presidents, Ngiratkel Etpison.

It is a subspecies of *Mastigias papua* which occurs in the lagoon; other subspecies are also found in other marine lakes of Palau. These jellyfish have zooxanthellae, i.e. symbiotic dinoflagellates or algae, living in their tissues. The jellyfish and zooxanthellae have a special and beneficial relationship. The jellyfish rotates and swims around the lake to ensure that the zooxanthellae get enough sunlight for photosynthesis, and the zooxanthellae gives jellyfish some energy and nutrients.



These jellyfish have two main life stages—the medusae and polyp stage. The medusae life form is the golden jellyfish people see when they go swimming in the lake. The tiny polyp form (right) lives at ten meters along the sides of the lake.

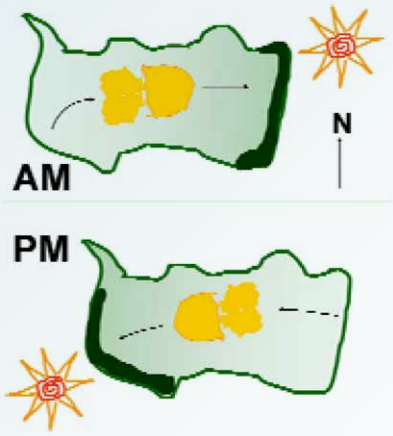
Contrary to common myth, these jellyfish do have stinging cells to capture other tiny organisms for food. They inherited the stinging cells from their ancestor, *Mastigias papua*, in the lagoon. However, you're unlikely to feel it because they *did not* evolve for eating large vertebrates like you! Unlike the Portuguese-man-of-war, golden jellyfish are harmless to humans.

Mastigias papua etpisoni and four different subspecies of the golden jellyfish found in separate marine lakes have evolved in other ways. In their new and isolated environment, their shape and color, genetic makeup and behavior have changed over time.

Left: Mastigias papua found in the lagoon.
Right: Mastigias papua etpisoni found in Jellyfish Lake.

How do the jellyfish in Jellyfish Lake migrate?

These unique jellyfish swim in a special migratory pattern seen only in this lake. As the sun rises, jellyfish swim towards the east shoreline, where they stop at the shadow line formed by the surrounding rock island and trees. They stop at that shadow line, making sure that they are always in the sunlit seawater. As the sun passes overhead around noon, the jellyfish turn and swim towards the west shoreline where again they stop at the shadow. This phenomenal behavior can form large masses of jellyfish swimming in one area.



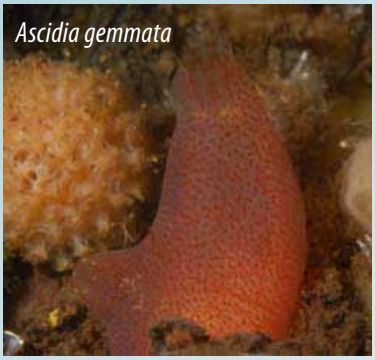
Why do they do swim in this particular pattern?

One idea is that the jellyfish swim this way to avoid the real edge of the lake where their natural predators, *Entacmaea medusivora,* wait. "*Medusivora*" means medusa eater, and these medusa-eating anemones sit at the edge of the lake, patiently waiting for jellyfish to brush up against their outstretched tentacles. When this happens, these medusa-eating anemones shoot out nematocysts to immobolize and 'catch' the jellyfish and then slowly engulf their prey.

What else can be found in Jellyfish Lake?

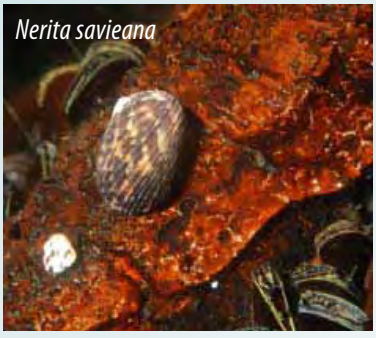
Jellyfish Lake is home to a one of a kind jellyfish, *Mastigias papua etpisoni*, and many other species including new species that are not yet named and still being described! There are over 60 species of algae and animals in Jellyfish Lake.

SEASQUIRTS

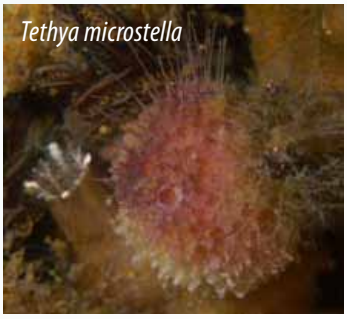


SEASTARS

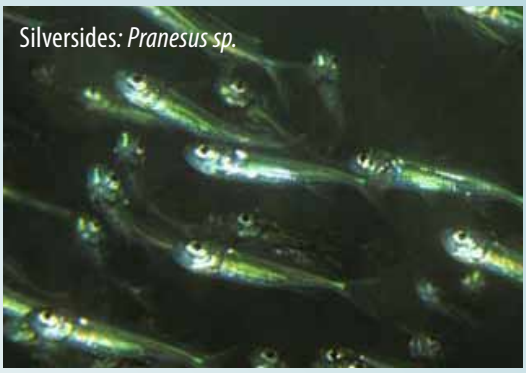
MOLLUSCS



SPONGES



FISH


Silversides: *Pranesus sp.*


Cardinalfish: *Sphaeramia orbicularis*

ALGAE


Caulerpa fastigiata


Caulerpa verticillata


Avrainvillea lacerata


High diversity benthic (bottom) assemblage of native species in Jellyfish Lake.

Non-native and invasive species in Jellyfish Lake

Non-native species are species that do not occur naturally in a particular place. Most non-native species usually have been introduced through human activity. Once introduced, non-native species have the potential to become invasive, overtaking space and other vital resources from native species.

There are two known and one suspected non-native species in Jellyfish Lake, two of which are classified as invasive.

Aiptasia sp. are anemones with symbiotic zooxanthellae in their tissue. The zooxanthellae found in *Aiptasia* are a different species than those found in the golden jellyfish. *Aiptasia* have brown tentacles and a white stalk. These characteristics clearly distinguish *Aiptasia* from the endemic *Entacmaea medusivora* anemone, which have no zooxanthellae and are entirely white or occasionally blue.

Aiptasia sp. anemone and its zooxanthellae are the two invasive species in Jellyfish Lake. First spotted in 2003, these invasive species have spread rapidly across the lake.

Haliclona acoroides sponge is the third species in Jellyfish Lake that is increasing in abundance and is suspected to be non-native.

Aiptasia are well known aquarium pests that are difficult to control and eradicate. These anemones were first spotted in 2003 near the dock inside the lake. From there, they have spread rapidly across the shallow bottom and mangrove roots.

The invasive *Aiptasia* anemones and their zooxanthellae now form carpets of brown and white over mangrove roots and the shallow sides almost all around the lake. Currently, the *Aiptasia* grow only on hard substrates in sunlit areas rather than muddy and dark areas. There are still areas of high native diversity in patches around the lake.

Some *Aiptaisa* are already forming a new symbiosis with native zooxanthellae from the golden jellyfish. To what extent *Aiptasia* will adapt to this lake and how much more of an impact they will have on the native species in the lake remains to be seen.

The sharp contrast between roots with native species and those overtaken by *Aiptasia* can be seen in different areas of Jellyfish Lake.

Disappearing jellyfish?

While famous for the golden jellyfish, Jellyfish Lake is also home to one other native species of jellyfish called *Aurelia*, or the moon jellyfish. *Aurelia* do not have zooxanthellae and appear colorless or white. *Aurelia* are usually bigger than the golden jellyfish and are more graceful swimmers, using slow balletic pulses rather than the busy swimming of *Mastigias papua etpisoni*.

It is now well known that in 1999 during the strongest El Niño/La Niña event recorded (1997-1999), the golden jellyfish, *Mastigias papua etpisoni*, disappeared from Jellyfish Lake, later to return as new medusae were produced by polyps as the lake cooled.

It is less well known that moon jellyfish were present in millions during the 1980s and '90's, and also when the golden jellyfish disappeared but have since declined in numbers. It is unknown what is happening to the moon jellyfish, but it has been noticed by certain tour guides that moon jellyfish are regularly harder to find in Jellyfish Lake.

How the native communities of organisms in marine lakes were assembled in less than 20,000 years, how the impact of the invasive anemones can be minimized, and what happened to cause the moon jellyfish to decline are just some of the questions scientists are currently trying to answer about Palau's enigmatic marine lakes.

Upper left shows a close of the tentacles of an *Entacmaea medusivora* anemone containing eggs; lower left shows a particularly blue anemone. Upper right: One of the eight rhopalia, or "eyes" , along the lower bell margin of Mastigias papua etpisoni, seen in a dense school (lower right).

How can we make a difference?

Help keep Jellyfish Lake healthy and pristine by...

1. Empty your pockets. Do NOT bring anything over the island including rocks, shells, corals and sea grass.

2. Minimize the amount of sunscreen used OR apply sunscreen 30 minutes before going to Jellyfish Lake.

3. Do not throw cigarette butts and trash into Jellyfish Lake. Carry your trash out of Jellyfish Lake.

4. Preferably, wear a mask and snorkel, fins and floatation devices to help you control your movement when swimming. Keep your gear clean by rinsing off sand and sea grass before hiking into the lake.

5. When swimming in the lake, keep as horizontal as you can, using gentle and slow movements to move in the water.

Empty your pockets.

Enjoy Jellyfish Lake with care.

CONSERVATION INTERNATIONAL

Pacific Islands

BIODIVERSITY CONSERVATION LESSONS LEARNED TECHNICAL SERIES

9