

November 28, 2007

Dear Earthwatcher,

On behalf of Ian MacLeod and the rest of the team involved in the '*Diving World War II Wrecks of Truk Lagoon*' fieldwork during August 2007, I would like to reiterate my earlier remarks and thank you for your financial support and your participation in the project. It was a pleasure to meet and work with you on what I believe is a rewarding but complex project. Some of the data collected during the field has been analysed and documented as you will see in the attached report. The rest of the data is still being analysed and will take some time to complete and disseminate. If you would like, I can pass this onto you once completed.

I was also asked by a number of the Chuukese with whom you worked to pass on their regards. They enjoyed meeting you and would also like to thank you for your help.

Bill Jeffery

**Principal Investigator
Diving World War II Wrecks of Truk Lagoon**



Project Title: Diving World War II Wrecks of Truk Lagoon

Principal Investigator (s): Bill Jeffery, Maria Beger, Ian MacLeod

Position/Affiliations: Bill Jeffery, Contract Maritime Archaeologist, National Historic Preservation Office, Federated States of Micronesia and Sessional Lecturer in Maritime Archaeology, James Cook University, Australia;
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Research Site: Chuuk Lagoon in Chuuk state, Federated States of Micronesia; Latitude 7° 27'00" North, Longitude 151° 53'48" East on the island of Weno, the business and government centre of Chuuk state.

Local Management Status of the Research Site:

- Proclaimed as *Chuuk Lagoon Monument* pursuant to *Draft Chuuk State Code, Title 25. Maritime and Marine Resources*;
- On the Register of the USA National Historic Places;
- Designated a USA National Historic Landmark.

Key Research Objectives:

- Describe the cultural heritage values of the underwater World War II sites lying in Chuuk Lagoon;
- Describe the natural heritage found on the same sites and their integrity as compared to the nearby natural reefs;
- Ascertain the corrosion, stability and longevity of the World War II sites;
- Investigate the interaction of the cultural fabric and the marine biota in the corrosion process;
- Provide the stakeholders that manage this cultural and natural heritage resource with a clear understanding of the value of the resource, the current impacts and effects on and longevity of the resource, and a management strategy for their sustainable use;
- Investigate the impact of release of petroleum oils from the shipwrecks on the marine environment.

Date this report was completed: This report was completed by November 30, 2007.

A. Data Collection

Four teams of Earthwatch volunteers were planned for 2007 but only one team was implemented, fielding from July 30 to August 11, 2007. This meant that many planned research objectives were not achieved.

The one team comprised six Earthwatch volunteers, Bill Jeffery, Ian MacLeod and Mike Emslie (acting for marine biologist PI Maria Beger), Jos Hill, Director, Reef Check Australia, Ed Slaughter, Curator Museum of Tropical Queensland, and Jeff Maynard from the Great Barrier Reef Marine Park Authority (GBRMPA) who was responsible for the Dive Master duties (Figure 1).

Biological and conservation surveys comprised the majority of the work during this project period because of the participation of three marine biologists and Ian MacLeod on the project. Some oral histories with the Chuukese Dive Guides were initiated by Ed Slaughter. Eight sites were investigated (Figure 2).

Diving

During the project period, a total of 157 dives were made. Total time underwater was 8,903 minutes, which is equivalent to 6.18 days. No diving related problems were experienced. Three of the Earthwatch volunteers did not dive on one day each, and two staff lost a total of four days due to sickness.

Biological Surveys

During this project period, fish communities were quantified, providing knowledge for a baseline scenario to be set against which future change caused by natural or anthropogenic processes can be measured. Three or four transects per wreck were completed, depending on the size of the wreck and safety limits imposed by diving bottom time and air limits. Fishes within each transect were identified to species level and enumerated. All counts were conducted by the same observer. After completing transects, the observer swam around the site and recorded every species encountered. A comprehensive species list was compiled for each of the wrecks surveyed (Figure 3 and Appendix 1).

As in 2006, surveys of the benthos growing on each wreck were conducted in conjunction with the conservation assessment to examine the relationship between biological complexity and the rate of corrosion. Around each hole drilled by the corrosion team, the biological survey team haphazardly placed four 25 x 25cm² quadrats, which were photographed for later analysis. Measures of rugosity were obtained for each quadrat by draping a chain over the surface of reef across the diagonal length of the quadrat, following all peaks and troughs, and measuring its length.

Reef Check

Marine Biologist Jos Hill implemented the Reef Check recording of the biota and fish found on the submerged WWII sites and some natural reefs. This is a monitoring system that anyone with a small amount of training can undertake and it was introduced to the volunteers as well as to a number of Chuukese divers.

Conservation assessment

The work involved collecting measurements of the dissolved oxygen content of the seawater in the vicinity of the sites, the salinity and the temperature (Table 1). Additional underwater measurements consisted of measuring the voltages of the corroding metal, the acidity of the metal interface underneath the protective layer of marine concretion and the thickness of marine encrustations (Table 2).



Figure 1: Project team at the Blue Lagoon

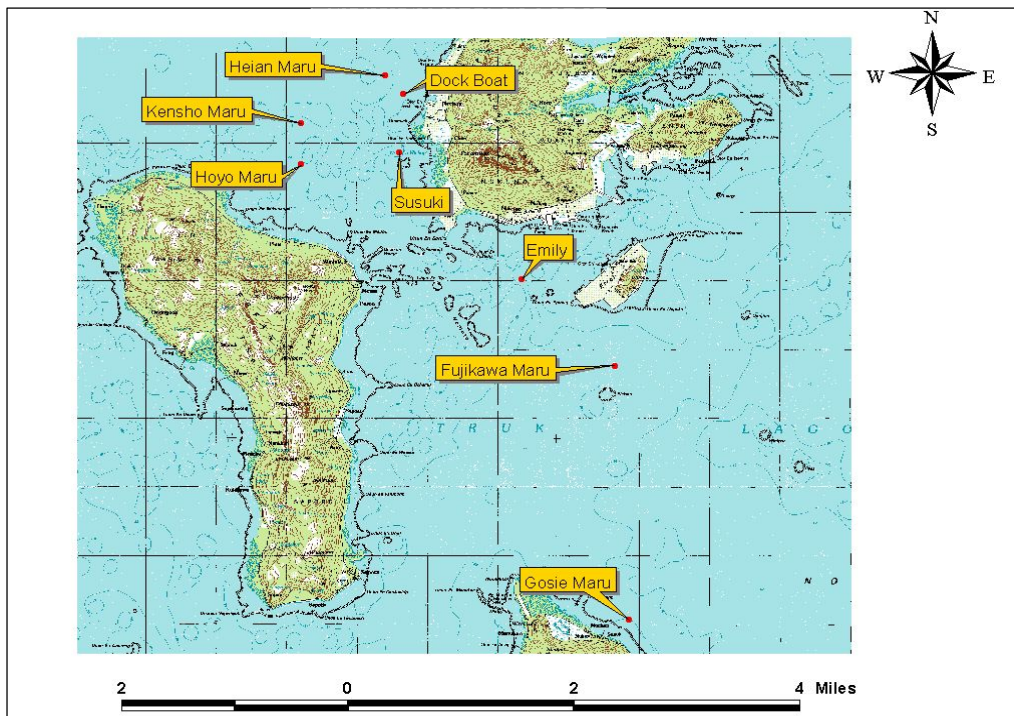


Figure 2: Map of Site Locations



Figure 3: *Caesio caerulea* (scissortail fusilier) and *Pterocaesio tessellate* (one stripe fusilier) swimming over the bow of *Fujikawa Maru*

Table 1: Dissolved oxygen, salinity and temperatures for wreck locations in Chuuk Lagoon

Wreck site	Range of depth (metres)	Mean oxygen ppm (S)	Oxygen standard deviation	Mean salinity ppt	Salinity standard deviation	Mean temperature °C	Temperature standard deviation
Tonoas dock boat	1 – 17	4.24	0.30	35.4	0.3	30.8	0.1
<i>Fujikawa Maru</i>	1 – 39	4.32	0.13	35.3	0.0	30.7	0.1
<i>Gosei Maru</i>	1 – 15	4.40	0.20	38.7	0.3	31.0	0.1
<i>Emily</i> flying boat	1 – 20	4.40	0.26	35.3	0.2	31.2	0.7
<i>Kensho Maru</i>	1 – 18	4.49	0.22	35.6	0.4	30.7	0.0
<i>Hoyo Maru</i>	1 – 24	4.56	0.13	35.5	0.1	30.9	0.1
<i>Heian Maru</i>	1 – 36	4.57	0.08	35.7	0.1	31.6	0.0
<i>Susuki</i> patrol boat	1 – 10	4.63	0.17	35.3	0.1	31.6	0.1

NB. ppm = parts per million; S = surface; ppt = precipitation

Table 2: Corrosion and physical environment of the wreck sites in Chuuk Lagoon, August 2007

Wreck	E_{corr} vs. NHE	pH	Depth (metres)	conc. thickness (mm)
<i>Fujikawa Maru</i>	-0.368	6.45	13.2	12.8
<i>Gosei Maru</i>	-0.361	6.56	10.6	7.7
<i>Susuki</i> patrol boat	-0.355	6.41	6.7	8.7
<i>Heian Maru</i>	-0.354	5.70	13.1	11.9
<i>Hoyo Maru</i>	-0.362	7.03	8.5	10.9
<i>Kensho Maru</i>	-0.370	6.45	17.7	16.4
Tonoas dock boat	-0.355	6.37	14.5	10.9
<i>Emily</i> flying boat	-0.480	7.99	14.6	-

NB. E_{corr} = corrosion; NHE = normal hydrogen electrode; conc. = concretion

Oral Histories

The collection of oral histories from a number of Chuukese was considered a significant factor in better understanding the values of the submerged WWII sites, in addition to providing information about their health. The Chuukese dive guides (by Chuuk law, a guide must accompany every tourist diving the sites) were considered one of the most important groups in this research, and they were targeted during this project period. Two pages of aims and questions were prepared and distributed to a number of dive guides who work with the Blue Lagoon Dive Shop, in addition to collaborating with the owner/manager of the shop, Mr. Gradvin Aisek. Of the estimated 15 dive guides who work with the Blue Lagoon, only two were interviewed, as well as Gradvin Aisek, and also Clark Graham (former American Peace Corp) who ran a dive shop during the 1970s and 80s and has written a report on some of the problems faced in managing the sites. This research was also conducted to test the possibility of having a future Earthwatch team collect oral histories as a major focus for their project activities.

Oil Pollution

Two sites, *Hoyo Maru* and *Kensho Maru* were visited, primarily to assess the impact of petroleum products reported to be leaking from *Hoyo Maru*. These visits were used to record the number and species of fish inhabiting the sites, to implement a conservation assessment in association with benthic surveys and to look for any signs and impacts of oil pollution.

Chuuk Conservation Society

During this project period, contact was made with the newly formed Chuuk Conservation Society, the ninth local conservation society to be established in Micronesia. The society was keen to discuss joint, mutually beneficial projects, and Jos Hill from Reef Check Australia commenced a dialogue with their Director, Curtis Graham.

B. Progress in achieving objectives

While this one field season for 2007 made limited overall progress, it still advanced some of the project objectives. A more comprehensive list of fish species and numbers was produced and compared to some natural reefs. The conservation assessment obtained considerable data in association with the benthic surveys to further analyse the relationship between the marine biota and corrosion, in addition to the impacts of anchoring and dynamite fishing on the cultural fabric and longevity of the sites. The collection of oral histories, working with a local conservation society toward more Chuukese community input, and further collaboration with our Chuuk government partners, Chuuk Historic Preservation Office and Department of Marine Resources, have strengthened Chuukese involvement in the project.

C. Summary of results

Marine Biology

A total of 266 species from 33 families of reef fishes were recorded during the surveys. *Kensho Maru* and *Fujikawa Maru* had the highest density of reef fishes whilst the Emily flying boat and Tonoas Dock Boat had the lowest density (Figure 4). Species richness however (number of species present), revealed different patterns. Fonomu MPA and the outer reef sites had higher species richness than any wreck site, with the exception of the *Fujikawa Maru* (Figure 5).

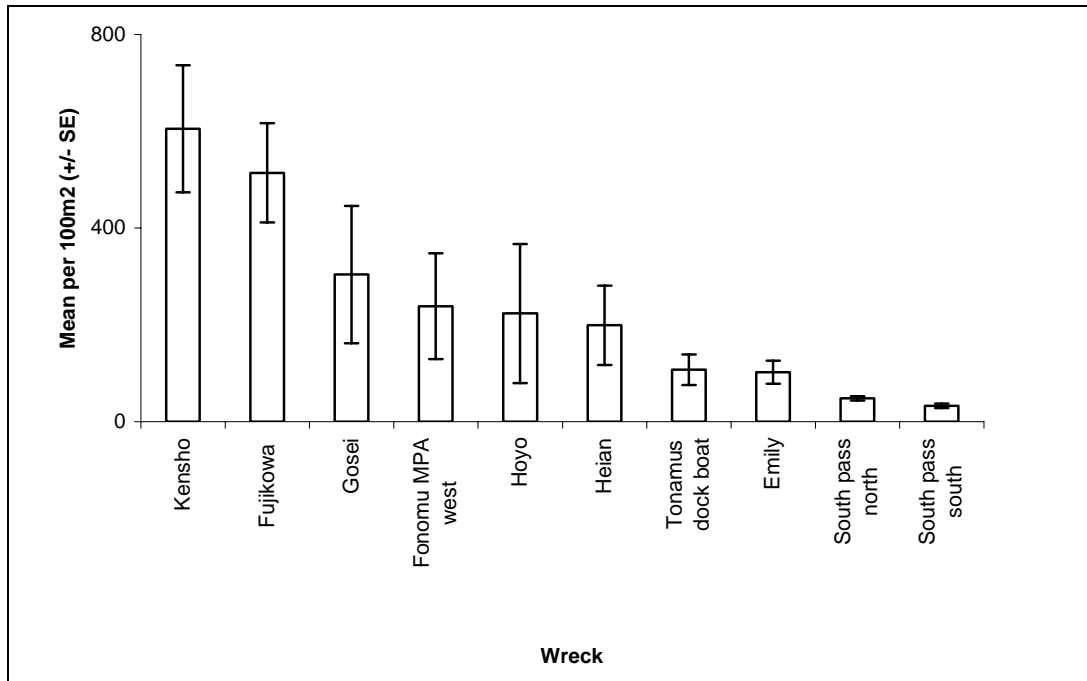


Figure 4: Average number of fish per transect for each wreck surveyed.

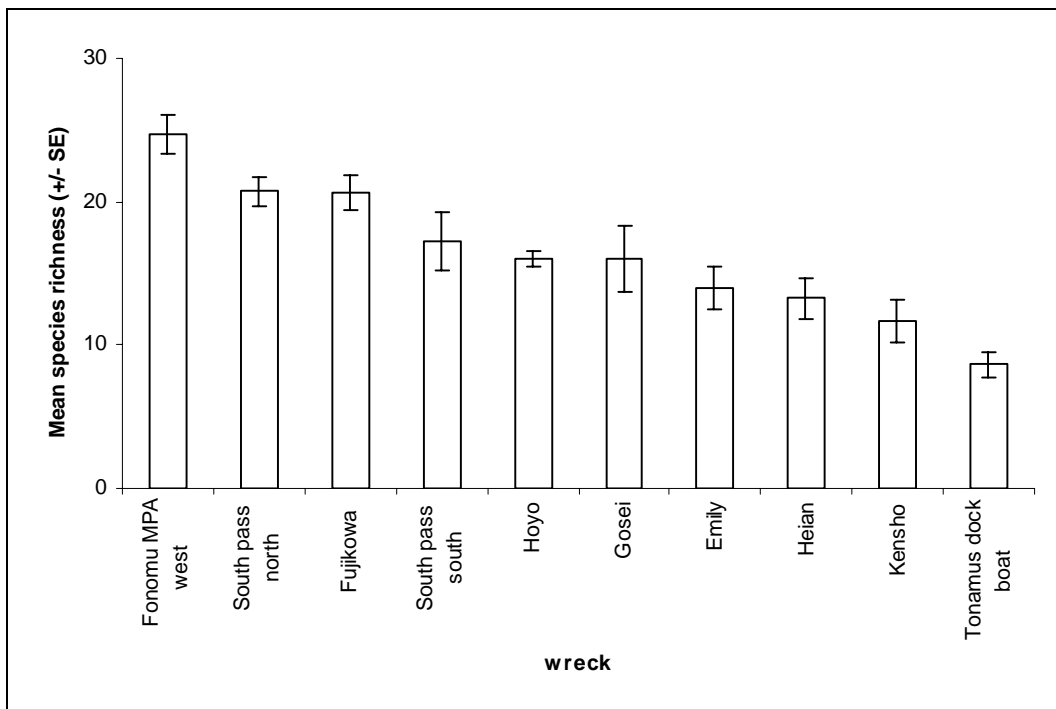


Figure 5: Average species richness per transect for each wreck surveyed.

Other clear differences were also discernable in the community structure of wreck and reef sites (Figure 6). Wreck sites had communities dominated by small fishes, most notably damselfishes (Pomacentridae), with a distinct paucity of larger food fishes (Lutjanids, Lethrinids, Serranids, Scarids and Acanthurids).

Whilst the surveys were conducted, it was noted that about 50% of large *Lobophyllia* coral colonies had been damaged, presumably by being struck by anchors (Figure 7). Of further concern was the presence of crown-of-thorns starfish (COTS), *Acanthaster planci*, in large numbers on many of the reefs and wrecks surveyed. Although not quantified, the frequency of feeding scars and the number of animals seen in casual observation, particularly on branching *Acropora* colonies, suggests these starfish are present in numbers that would be considered outbreak or plague proportions on Australia's Great Barrier Reef (Figures 8 & 9).

Conservation Assessment

One of the more popular wrecks of the *Fujikawa Maru*, the *Gosei Maru*, showed extensive evidence of anchor and mooring damage to its structure, made obvious by the fresh red-brown fluffy rust deposits that form as iron corrosion products react with the surrounding seawater and precipitate on the surface of freshly exposed metal.

Preliminary analysis of concretion data from *Susuki* is consistent with the wreck having been subjected to damage by dynamite fishing. Evidence of this damage is seen across the upper works of the vessel, with exposure of different "layers" of concretion. The expected amount of concretion on the *Susuki*, based on the average depth of the site is 19mm, whereas in reality it is only approximately 9mm. The loss of concretion means that the site will have been subjected to periods of accelerated corrosion and its expected lifetime will have diminished.

Although evidence of dynamite fishing is often anecdotal, there is clear evidence of the impact of the catastrophic events on vessels such as the *Susuki* and the *Fujikawa Maru*.



Figure 7: A Lobophyllia colony on the Fujikawa Maru after suffering anchor damage.



Figure 8: COTS feeding scars on a Platygyra colony on Gosei Maru. It is unusual for COTS to feed on this type of coral.



Figure 9: Feeding scars from crown-of-thorns starfish on branching Acropora corals near Etten Island.

***Fujikawa Maru* corrosion patterns**

The apparent impact of site orientation and water flow across the surface of a wreck is demonstrated by the map of concretion thickness shown on the *Fujikawa Maru* site. The size of the * symbol shown in Figure 10 represents the relative thicknesses of concretion found at these locations. It is likely that the water flow across the site, which is located in the shipping channel, simply cuts across the wreck to provide the observed differences in the microenvironment.

The apparent impact of dynamite fishing on the *Fujikawa Maru* can be observed by the differences in pH of seawater and is illustrated in Figure 11 where the heights of the columns represent the acidity differentials between alkaline sea water at pH of 8.2 and the metal surface. Lower pH values mean higher acidity and higher local corrosion rates, thus columns with greater height reflect times of greater corrosion activity, as this is when there is a bigger difference in the pH values of sea water and the underlying metal.

Conclusion and Conservation Management Options

The Earthwatch program of continued monitoring of the marine ecological and corrosion environment represents a significant opportunity to obtain more data on the way in which the planes and the shipwrecks are interacting with the sea. Refinements in corrosion modelling and further development of the biodynamic interaction model will enable a detailed conservation management strategy plan to be completed by the end of 2009. With data gained during the initial survey in 2002, which was sponsored by the US National Parks Authority and three sets of data obtained under Earthwatch sponsorship, clear trends are emerging.

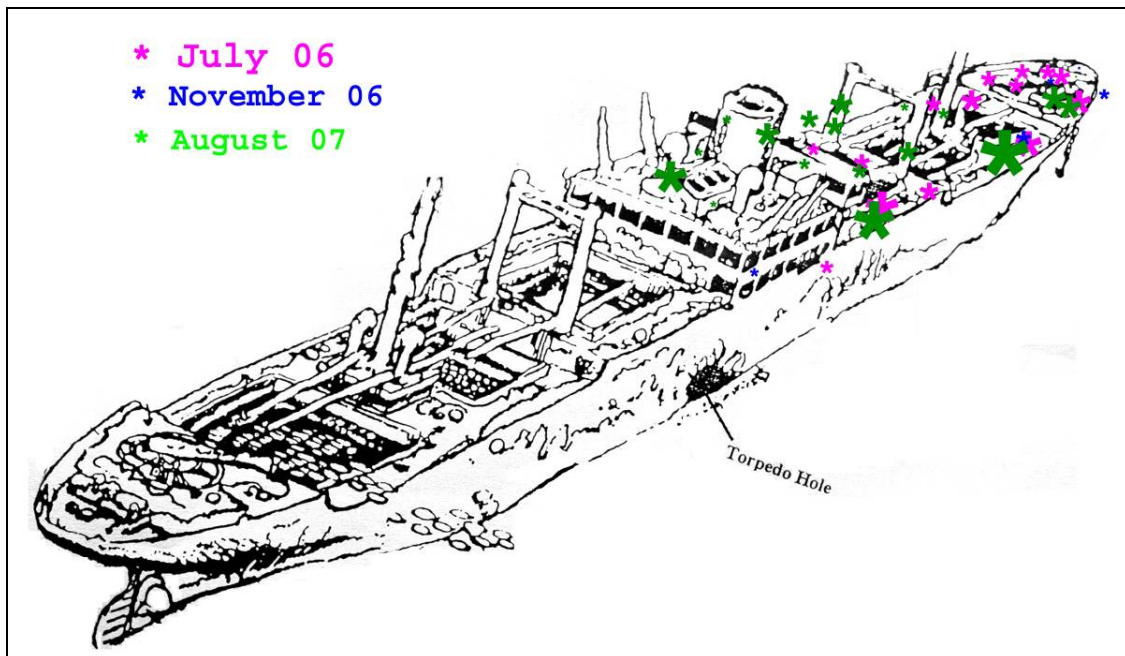


Figure 10: Isometric sketch of the *Fujikawa Maru* with concretion thickness as a function of location

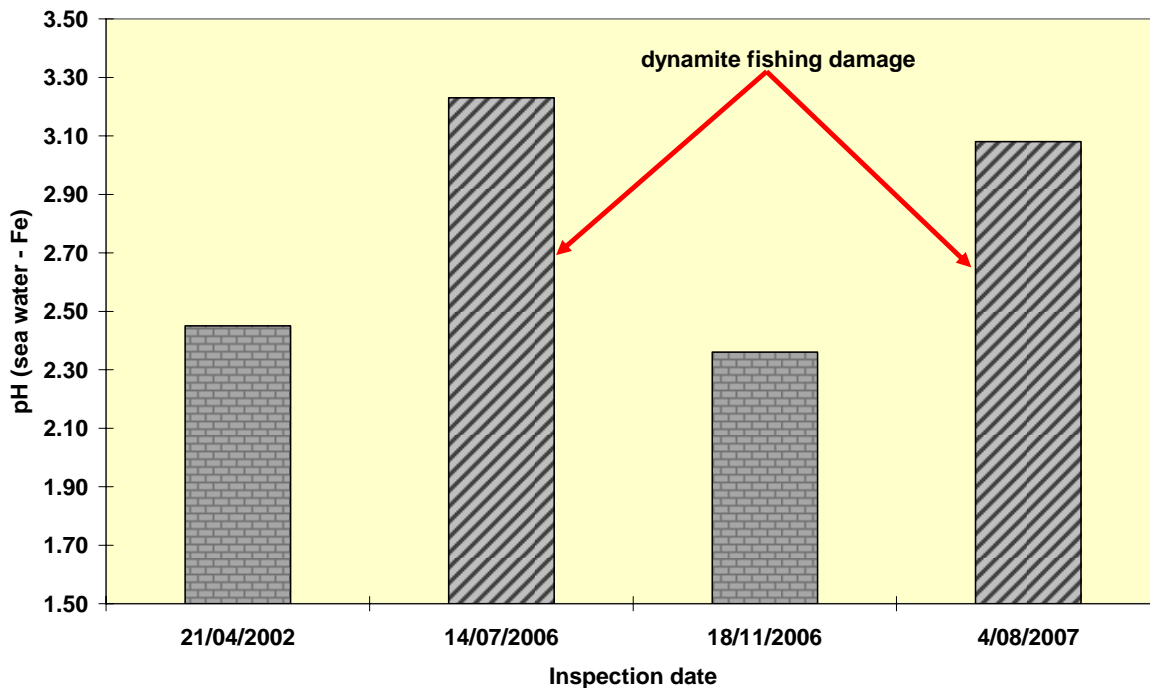


Figure 11: Changes in acidity differential on the Fujikawa Maru before and after dynamite fishing

Oil pollution

A further survey was carried out on the *Hoyo Maru* and *Kensho Maru* to investigate leaking oil, which was reported again after our previous visit in December 2006. Our investigation failed to find any evidence of leaking oil or gasoline on either site. On a latter occasion however, when going past the location of these shipwrecks, an oil slick was noticed and followed to confirm its source, found to be the *Hoyo Maru* (Latitude 7.37108°; Longitude 151.84467°). With the wind blowing from the west, the 1-2km long oil slick was flowing toward the north-west coast of Tonoas, and the large area of mangroves located there. A water sample was taken by the Department of Marine Resources. Mangrove death, possibly from oil leaking from the *Hoyo Maru* with the wind blowing from the east/north-east, was found on the north-east coast of Fefan.

On three other occasions, members of the Earthwatch teams have also noticed oil leaking from *Nippo Maru* and *San Francisco Maru*.

Collection of Oral Histories

While there was a poor response to the trial of collecting oral histories from dive guides, it is still considered an important area of research and will be pursued in 2008 projects, but not as a 'sole' Earthwatch project objective for one team. There could be a number of reasons why there was a poor response. Some Chuukese are, as are some Micronesians, known to be reticent about public communications which means an alternative method may be required. The interviews were conducted during working hours and while the dive shop was not busy; few dive guides offered their time to talk. There are also other aspects of this subject that may have dampened further input, such as the likelihood of discussing illegal artefact trading and dynamite fishing - topics that were intentionally avoided.

D. Significance/Benefits of Research

This research has benefits at local, national and international levels.

The research will help to develop a plan of management that is inclusive of local, national and international site values, the social issues associated with the sites, and the scientific analysis that has helped to illustrate the values and impacts of the uses and their deterioration. It is anticipated that this research which is conducted in collaboration with various sections of the Chuukese community will assist in empowering the local community to seek and implement sustainable management with various management partners. Current management is not sustainable due to the many conflicts in site values and uses with other stakeholders, such as the Japanese, American and international communities. In addition, this research will demonstrate the need for a holistic approach to submerged historic site management where the sites have become important artificial reefs that attract a diverse and significant natural heritage.

With over 3,200 similar WWII shipwrecks located throughout the Pacific, many of which are located in communities that are similarly marginalized in site value assessment and management, this research has relevance beyond Chuuk. The research includes a better awareness of the ever growing threat of pollution from oil leaking from shipwrecks, and it is the only scientific assessment of the timescale over which sites may start to collapse, which could create very large amounts of oil leakage and have major environmental impacts.

E. Dissemination of Results

The project has contributed to the following outcomes:

Scientific papers:

1. Beger, M., Richards, Z., 2007, Rare coral colonises new artificial niche. *Coral Reefs*. In Press.
2. MacLeod, I.D., Beger, M., Richards, V., Jeffery, B., and Hengeveld, M., 2007, Dynamic interactions of marine ecosystems with wrecks in Chuuk Lagoon, Federated States of Micronesia. In: Degryny, C., Ankersmit, B., Yolanda, I., and van Langh R., (eds.), *Metal 07, Preprints of the ICOM-CC Metals Working Group meeting, Amsterdam*, **3**: 51-54.
3. Maynard, J.A., 2007, Severe anchor damage to *Lobophyllia variegata* colonies on the *Fujikawa Maru*, Truk Lagoon, Micronesia. *Coral Reefs*. Access online SpringerLink, 27 November 2007.

Management plans and reports

1. Report submitted to Chuuk government:
Emslie, M., Jeffery, B., MacLeod, I., Maynard, J., 2007, Chuuk Lagoon World War II submerged sites: Earthwatch project report, July 30 to August 11 2007.

Presentations

1. MacLeod, I., 2007, A presentation titled 'Dynamic interactions of marine ecosystems with wrecks in Chuuk Lagoon, Federated States of Micronesia' was made at the Metal 07, ICOM-CC Metals Working Group meeting, Amsterdam in September 2007.
2. Jeffery, B., 2007, A summary of the 'Diving World War II wrecks of Truk Lagoon' project made to the Micronesian Historic Preservation Offices, Annual Consultative meeting in Palau, 14 September.

3. Jeffery, B., 2008, Presentation proposed on Chuuk Lagoon shipwrecks including some analysis of this project at the third International Conference on Underwater Archaeology (IKUWA3), London, July.

Popular articles or films

1. Jeffery, B., 2007, Chuuk Lagoon World War II submerged sites: Report on 2006 Earthwatch project. *Newsletter of the Australasian Institute for Maritime Archaeology*, **26.1** Accessed online at <http://aima.iinet.net.au/frames/aimavtframe.html> 10 May 2007.
2. Documentary film produced by Thalassa during this 2007 field season for viewing on the TV5 (France) in November 2007 and as a stand alone documentary, date unknown. http://www.tv5.org:80/TV5Site/programmes/universal/pop_programme.php?id=145717

Books, chapters, illustrations

1. Jeffery, B., 2007, *Values and conflicts in Chuuk Lagoon, Micronesia: A post-colonial perspective*. Doctoral Dissertation, James Cook University, Australia. (To be submitted December 2007).

Volunteer Tasks and Accomplishments

a) This one season for 2007 saw two father/son combinations (the first time this has occurred with this project) and a husband/wife couple. This was a very good mix of experience, skills, motivations and young eyes and thoughts. A number of 'routine' underwater tasks needed to be implemented each dive, of which some varied and some remained the same for the whole project, but they were accomplished enthusiastically and skilfully. A limited number of computer related analytical tasks were performed in a similar manner. Beyond that, volunteers were keen to assist with cooking and generally helping out, including some medical advice and support from the two doctors who came as volunteers. It was good to have the mix of ages, although with only one female volunteer and one female field team leader out of a total of 12 participants, the mix of gender was limited.

b) Two buddy pairs of divers who were involved in recording the benthos surrounding the corrosion holes have greatly contributed to the investigation into the interaction between the marine biota and corrosion of the cultural fabric. This research is ongoing and cannot be quantified at present but without the volunteers recording this data, this analysis would not be possible. Other volunteer support roles during fish counts and site mapping were essential to the success of these tasks. The interaction of the volunteers with Chuukese divers and community, and an awareness of the social issues associated with the submerged WWII sites seems to have been well received. This is a small start in visiting divers going back to their home countries and instead of taking away souvenirs or memories of bad management practices, volunteers will be able to pass on to the larger international community the many social issues and local values associated with the sites.

Project Development

- a) With only one team out of four being run in 2007, the most pressing problem seems to be how the project can be adequately filled during the year. However, there is a need for more equipment and trained field team leaders to record more diverse oceanographic and environmental parameters. The need to gain additional funding to support these activities is being investigated through grants.

- b) Some additional strategies, such as contact with the US Navy about attaching sacrificial anodes to some sites, are being investigated. Communication is also being implemented with other groups, such as the Micronesian Conservation Society and the South Pacific Region Environment Program (SPREP) with regard to their regional conservation strategies and how this project can fit into them, and how they may be able to assist us in our objectives. A PhD candidate in anthropology at James Cook University is keen to consider a Chuuk outer island 'global warming, sea-level rise' topic linked to our project commencing in 2008, with a preliminary visit planned for January 2008.
- c) Before the next project in July 2008, work will be carried out to see what additional support from US and FSM governments, NGOs and granting bodies can be obtained to enhance next year's field work. This will also include investigating additional academic involvement. Analysis of the marine biota/corrosion relationship will be implemented, which may suggest alternative or additional work to be implemented during the next field work.

Educational Opportunities

- a) The project involves the following groups:
 - Local communities
 - Early career scientists
 - Conservation Societies, government agencies (US, FSM and Chuuk).While we have attempted to involve local students, this has not been possible but will continue to be investigated.
- b) The research helps the above groups to better understand the conservation of a sustainable environment through their participation in the project, the documentation of site values, health and uses, the problems associated with current site uses and an investigation into alternative uses.
- c) The project has played a role in the completion of a Doctoral Dissertation by PI, Bill Jeffery, which is being submitted for examination in December 2007.

Partnerships

- a) Chuuk Historic Preservation Office, Chuuk Department of Marine Resources, FSM National Historic Preservation Office, US National Park Service Micronesian Program, James Cook University, Western Australian Museum.
- b) The organizations have supported the project through bureaucratic, equipment and personnel assistance.
- c) A plan of management will be developed after the next field work which will outline some actions that are considered achievable in the complex social and political climate of Chuuk.

Acknowledgements

Earthwatch volunteers for funding the work and for their participation in the fieldwork; Kurassa Hotel in Chuuk for provision of accommodation at a reduce rate; and the Blue Lagoon Dive Shop, for the provision of diving equipment at a reduced rate.

Appendix 1: Chuuk Fish Species List, August 2007

Acanthuridae (Surgeonfish):

Acanthurus blochii, *Acanthurus lineatus*, *Acanthurus mata*, *Acanthurus nigrafuscus*, *Acanthurus nigricans*, *Acanthurus nigricauda*, *Acanthurus nigroris*, *Acanthurus olivaceus*, *Acanthurus pyroferus*, *Acanthurus triostegus*, *Acanthurus thompsoni*, *Ctenochaetus binotatus*, *Ctenochaetus striatus*, *Ctenochaetus strigosus*, *Naso anularis*, *Naso brevirostris*, *Naso lituratus*, *Naso unicornis*, *Naso vlamingii*, *Zebrasoma scopas*, *Zebrasoma veliferum*

Apogonidae (Cardinalfish):

Apogon exostigma, *Apogon fragalis*, *Apogon quinquelineata*, *Archamia furcata*, *Cheilodipterus artus*, *Cheilodipterus isostigma*, *Cheilodipterus macrodon*

Aulostomidae (Flutemouthes):

Aulostomus chinensis

Balistidae (Triggerfish):

Balistipus undulates, *Balistoides conspiculum*, *Sufflamen chrysopterus*, *Melichthyes vidua*, *Odonus niger*, *Rhinecanthus aculeatus*

Blennidae (Blennies):

Blenninella paula, *Blenny Sp A*, *Escenius bicolour*, *Meiacanthus atrodorsalis*, *Plagiotremus laudandus*, *Plagiotremus rhynorhynchus*, *Salarias sp*, *Salarias fasciatus*

Caesionidae (Fusiliers):

Caesio caerulea, *Pterocaesio pisang*, *Pterocaesio marri*, *Pterocaesio tile*, *Pterocaesio trilineata*

Carangidae (Trevallies or Jacks):

Carangoides bajad, *Carangoides ferdau*, *Caranx melampygus*, *Caranx orthogrammus*

Carcharinidae (Whaler Sharks):

Carcharhinus amblyrhynchus, *Carcharhinus melanopterus*, *Triaenodon obesus*

Chanidae (Milkfish):

Chanos chanos

Chaetodontidae (Butterflyfish):

Chaetodon auriga, *Chaetodon bennetti*, *Chaetodon citronellus*, *Chaetodon ephippium*, *Chaetodon kleinii*, *Chaetodon lunula*, *Chaetodon melonnotus*, *Chaetodon rafflesi*, *Chaetodon reticulatus*, *Chaetodon trifascialis*, *Chaetodon trifasciatus*, *Chaetodon ulietensis*, *Chaetodon unimaculatus*, *Chaetodon vagabundus*, *Forcipiger flavissimus*, *Heniochus acuminatus*, *Heniochus chrysostomus*, *Heniochus monoceros*, *Heniochus varius*

Cirrhitidae (Hawkfish):

Cirrhitichthys falco, *Cirrhitichthys oxycephalus*, *Paracirrhites arcatus*, *Paracirrhites forsteri*

Fistularidae (Cornetfish):

Fistularia commersoni

Gobiidae (Gobies):

Amblygobius dessucatus, *Amblygobius rainfordi*, *Briananops natans*, *Briananops yongei*, *Coryphopterus sp.*, *Cryptocentrus cinctus*, *Coryphopterus signipinnis*, *Eviota sebreei*, *Gobiadon okinawae*, *Ctenogobiops crocineus*

Haemulidae (Sweetlips):

Plectorhinchus lineatus

Holocentridae (Squirrelfish and Soldierfish):

Myripristis violacea, *Myripristis kuntee*, *Neoniphon opercularis*, *Neoniphon opercularis*, *Neoniphon summara*, *Sargocentrum caudimaculatum*, *Sargocentrum praslin*, *Sargocentrum spiniferum*

Kyphosidae (Drummers):

Kyphosus cinerascens

Labridae (Wrasses):

Anampses caeruleopunctatus, *Anampses twistii*, *Cheilinus chlorurus*, *Cheilinus fasciatus*, *Cheilinus oxycephalus*, *Cheilinus trilobatus*, *Cheilinus undulates*, *Cirrhilabrus luteovittatus*, *Coris batuensis*, *Coris gaimard*, *Epibulus insidiator*, *Gomphosus varius*, *Haliichoeres hortulanus*, *Haliichoeres margaritaceus*, *Haliichoeres marginatus*, *Haliichoeres melanurus*, *Haliichoeres richmondi*, *Haliichoeres trimaculatus*, *Haliichoeres ornatissimus*, *Hemigymnus melapterus*, *Hologymnosus doliatus*, *Labrichthyes unilineata*, *Labroides dimidiatus*, *Macropharyngeodon meleagris*, *Oxycheilinus celebecus*, *Oxycheilinus diagramma*, *Oxycheilinus orientalis*, *Oxycheilinus unifasciatus*, *Pseudocheilinus hexataenia*, *Pseudodax moluccensis*,

Stethojulis bandenensis, *Stethojulis strigiventor*, *Thalassoma amblycephalus*, *Thalassoma hardwicke*, *Thalassoma janseni*, *Thalassoma lunare*, *Thalassoma lutescens*, *Thalassoma quinquevittatum*

Lethrinidae (Emperors):

Gnathodentex aureolineatus, *Lethrinus erythracanthus*, *Lethrinus harak*, *Lethrinus olivaceous*, *Lethrinus ornatus*, *Lethrinus xanthochilus*, *Monotaxis granoculis*

Lutjanidae (Snapper):

Aphareus furca, *Aprion virescens*, *Lutjanus argentimaculatus*, *Lutjanus bohar*, *Lutjanus fulvus*, *Lutjanus gibbus*, *Lutjanus monostigma*, *Lutjanus semicinctus*, *Macolour niger*

Microdesmidae (Dartfish):

Pteroleotris evidans, *Pteroleotris microlepis*

Monacanthidae (Leatherjackets or Filefish):

Alutera scriptus, *Catherhines paradalis*, *Oxymonacanthus longirostris*

Mullidae (Goatfish):

Mulloidichthyes flavolineatus, *Parupeneus bifasciatus*, *Parupeneus barberinus*, *Parupeneus cyclostomus*, *Parupeneus multifasciatus*

Nemipteridae (Monocle Breams):

Pentapodus aureofasciatus, *Scolopsis lineata*, *Scolopsis bilineata*

Pomacanthidae (Angelfish):

Centropyge bicolour, *Centropyge flavissimus*, *Centropyge loriculus*, *Centropyge vroliki*, *Pomacanthus bicolour*, *Pomacanthus xanthometapon*, *Pygoplyges diacanthus*

Pomacentridae (Damsel fish):

Abudefduf sexstriatus, *Abudefduf vaigenensis*, *Amblyglyphidodon curacoa*, *Amblyglyphidodon leucogaster*, *Amblyglyphidodon ternatensis*, *Amphiprion chrysopterus*, *Amphiprion melonopus*, *Amphiprion perideraion*, *Chromis atripes*, *Chromis atripectoralis*, *Chromis margaritifer*, *Chromis ternatensis*, *Chromis viridis*, *Chromis xanthura*, *Chrysiptera biocellata*, *Chrysiptera brownriggi*, *Chrysiptera leucopoma*, *Chrysiptera traceyi*, *Dascyllus araufus*, *Dascyllus reticulatus*, *Dascyllus trimaculatus*, *Plectroglyphidodon dickii*, *Plectroglyphidodon johnstonianus*, *Plectroglyphidodon lacrymatus*, *Pomacentrus amboinensi*, *Pomacentrus auriventrus*, *Pomacentrus brachialis*, *Pomacentrus coelestis*, *Pomacentrus grammorhynchus*, *Pomacentrus nagasakiensis*, *Pomacentrus pavo*, *Pomacentrus philippinus*, *Pomacentrus vaiuli*, *Stegastes albifasciatus*, *Stegastes nigricans*

Scaridae (Parrotfish):

Bolbometapon muricatum, *Calatomus carolinus*, *Cetoscarus bicolour*, *Chlorurus bleekeri*, *Chlorurus japanensis*, *Chlorurus microrhinus*, *Chlorurus sordidus*, *Hipposcarus longiceps*, *Leptoscarus vaigenensis*, *Scarus altipinnis*, *Scarus chameleon*, *Scarus dimidiatus*, *Scarus festivus*, *Scarus flavipectoralis*, *Scarus forsteri*, *Scarus frenatus*, *Scarus ghobban*, *Scarus globiceps*, *Scarus niger*, *Scarus oviceps*, *Scarus psittacus*, *Scarus rivulatus*, *Scarus rubroviolaceous*, *Scarus schlegeli*, *Scarus spinus*

Serranidae (Groupers and Trout):

Aethaloperca rogaea, *Cephalopholis argus*, *Cephalopholis urodeta*, *Epinephelus corallicola*, *Epinephelus fuscoguttatus*, *Epinephelus merra*, *Epinephelus polyphekadion*, *Epinephelus quoyanus*, *Plectropomus areolatus*, *Plectropomus laevis*, *Plectropomus oligacanthus*, *Variola louti*

Siganidae (Rabbitfish):

Siganus argenteus, *Siganus doliatus*, *Siganus puellus*, *Siganus punctatissimus*, *Siganus spinus*, *Siganus vulpinus*

Sphyraenidae (Barracuda):

Sphyraenia barracuda, *Sphaerania flavicaudata*, *Sphyraenia quenie*

Syngnathidae (Pipefish):

Banded Pipefish, *Corythoichthyes schultzi*

Synodontidae (Lizardfish):

Synodus binotatus, *Synodus sp.*, *Synodus variegatus*

Tetradontidae (Pufferfish):

Arothron mappa, *Canthigaster papua*, *Canthigaster solandri*, *Canthigaster valentini*

Zanclidae (Moorish Idol):

Zanclus cornutus