

An underwater photograph showing a large school of silver fish, possibly jackfish, swimming in a clear blue ocean. In the background, two divers are visible, one near a vertical column of bubbles. The bottom of the frame shows a dark, rocky seabed with some coral.

Chuuk Lagoon, Micronesia; a 2018 ecological assessment of the *Shinkoku Maru* wreck

Tom Dallison & Ben Lee

2019





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a 2018 ecological assessment of the *Shinkoku Maru* wreck

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These are our oceans, and as
surely as we fought for our
country, we must now, as that
same 'band of brothers', fight to
save our Oceans.

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Executive Summary

Coral reefs, and their associated ecosystems, are facing unprecedented anthropogenic impacts, with a bleak future forecasted. As such, it is imperative that local, regional and global actions are undertaken to protect marine resource, remediate impacts and build resilience within marine systems to reduce and minimise the potential threats to coastal-dwelling and international communities. In response to coral reef ecosystem service perturbations, the deployment of artificial reefs, including the use of sunken man-made structures, such as shipwrecks, have been highlighted, within the conservation sector, as a possible method of remediation. However, before conservation-actions can be undertaken, it is critical to build an understanding of the ecological community assemblages and structural make-up of these systems. Here, survey teams from Depththerapy, a UK-based charity that provides support and therapy, through SCUBA, to UK military veterans, undertook an ecological assessment of the *Shinkoku Maru* Japanese support vessel wreckage in Chuuk Lagoon, the Federated States of Micronesia.

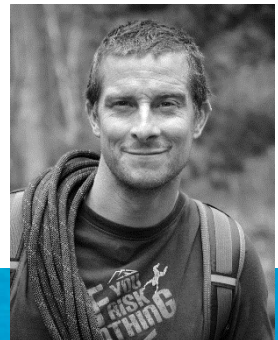
The abundance of indicator fishes was recorded through Roving Diver protocols on two sections of the wreckage (mid and bow-section) and reported as Exposure Per Unit Effort (EPUE). The composition of substrate on the wreckage was recorded through a nested sampling design with the placement of quadrats over three independent survey areas; bow, mid and stern-section. The differences between substrate samples was analysed between sites with Kruskal-Wallis tests followed by Dunn *post-hoc* analysis (*p*-values adjusted with Benjamini-Hochberg (bh) method). The community assemblage between surveyed areas was further examined through Detrended Correspondence Analysis (DCA) with hull-clustering.

Fishes were recorded with a mean EPUE of 2.65 ± 12.67 individuals per survey minute with Acanthuridae (surgeonfish) recorded in greatest abundance (EPUE= 0.84 ± 10.10 individuals per survey minute) followed by Scaridae (Parrotfish), Labridae (Wrasse) and *Chaetodon trifascialis* (Chevron butterflyfish) (EPUE= 0.49 ± 3.15 individuals per survey minute, EPUE= 0.29 ± 3.71 individuals per survey minute, and EPUE= 0.21 ± 2.51 individuals per survey minute, respectively). The majority of fishes recorded were dominated by smaller-bodied individuals with no individuals recorded >40cm (Total Length (cm) (TL)). The mean individual biomass (kg) of Lutjanidae (Snapper) were found to be larger within the mid-section of the wreckage, when compared to the bow-section (Med= 0.74kg individual⁻¹ and Med= 0.27kg individual⁻¹, respectively), (Mann-Whitney $U = 20$, $Z = -2.37$, $p = <0.05$). Scleractinian hard coral ($\bar{x} = 24.62 \pm 17.34$ %, Med = 25%) and sand ($\bar{x} = 47.05 \pm 27.90$ %, Med = 50%) were found to be the dominant substrate throughout the entire wreck (Kruskal Wallis, chi-squared = 172.12, df = 8, $p = <0.05$), with no differences found between each survey section. No differences between survey section samples, or between Scleractinian hard coral lifeforms was found. Furthermore, the sections of *Shinkoku Maru* wreckage could not be independently defined by substrate composition.

The results within this report provide evidence of the ecological community assemblage of the *Shinkoku Maru* wreckage, highlighting its social, economic and ecological value to the resource managers, tourism operators and governing bodies within Chuuk Lagoon. The results present a substrate community assemblage dominated by Scleractinian hard corals with an even distribution of lifeforms that has yet to shift to a *Porites* spp. dominated system, mirroring that which has been observed in adjacent natural reefs. The presence of Whitetip Reef Sharks alongside the dominance of Scleractinia, indicates that the *Shinkoku Maru* wreck is hosting a unique ecological community, that is not experiencing the same perturbations recorded in the area and one that diverges from the regional trends within Chuuk Lagoon.

This is all about enabling Armed Forces' Veterans to take action against the plights suffered by our **Oceans**. It is an inspired and brilliant collaboration and I am proud to be involved.

Bear Grylls OBE
Global Adventurer



Acknowledgements

Deptherapy & Deptherapy Education would like to acknowledge and thank the 2016 Chancellor of the Exchequers' Libor Fund that financed the Chuuk Lagoon Expedition, providing a once-in-a-lifetime experience to members of Deptherapy.

Deptherapy & Deptherapy Education would also like to thank Deptherapy Patron, Alistair Cole, Coral Cay Conservation's Head of Science, Tom Dallison, and the rest of the team at Coral Cay Conservation for their support throughout the undertaking of this project and the work undertaken in producing this report. Deptherapy & Deptherapy Education's gratitude is further extended to the time devoted from Coral Cay Conservation for training the survey team members to enable the collection of ecological data in Chuuk Lagoon.

A special thanks is given to ROOTS Red Sea for their continued support during Deptherapy Red Sea expeditions. Their thoughtful, positive and flexible approach has enabled many Deptherapy members to start their individual journeys on the road to rehabilitation through the medium of diving. Deptherapy & Deptherapy Education will be forever grateful to Steve, Clare and the rest of the team at ROOTS. Thank you also to Dive Worldwide for their logistical support throughout the Chuuk Lagoon expedition.

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Finally, thank you to the Deptherapy Family, Trustees, Patrons and Ambassadors, without whom none of the work by Deptherapy & Deptherapy Education would be possible.

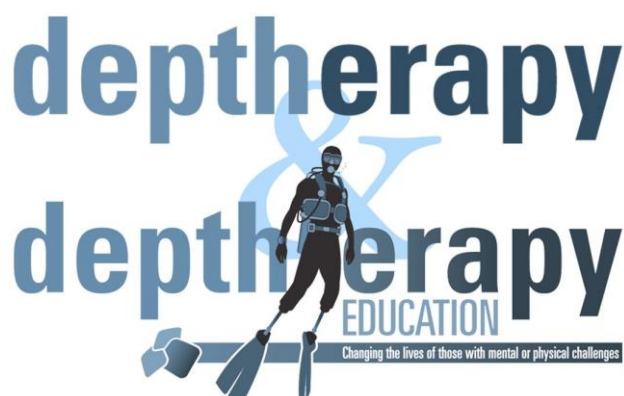
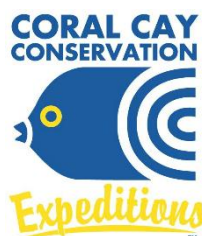


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Deptherapy & Deptherapy Education

Deptherapy & Deptherapy Education are a UK-registered charity that seek to rehabilitate UK armed service personnel and veterans who have suffered life changing physical and or mental injuries and illnesses, through the medium of SCUBA.

The Charity run a developmental process of specially adapted SCUBA diving programmes for Wounded, Injured and Sick serving UK Armed Service personnel and veterans who have suffered life changing ailments. The charity operates a 24/7 support programme for members and an active 'buddy peer' support scheme. Deptherapy & Deptherapy Education's aim is to support, and help injured current and ex-serving members of the British Armed Forces.

Those with physical injuries who have experienced Deptherapy's services reported that the weightlessness that SCUBA diving provides allows them to be pain free, which for many is the first time since their injury. For those with PTSD (Post-Traumatic Stress Disorder), the Ocean and activity of diving provides a calming environment, as one programme member described;

When I put my head
under the water the
demons disappear

Through Deptherapy Education, training and advice is provided to the dive industry and professionals as to how to adapt SCUBA diving skills so that those with disabilities might qualify as SCUBA divers.

Deptherapy operate regular courses, both in the UK and abroad, for programme members, where new members are qualified as PADI Open Water divers. Programme members also have the opportunity to continue their dive training to PADI Advanced Open Water through the PADI Continuing Education programme.

The Charity is active in, and facilitating with, academic research focusing on PTSD. The numerous programmes operated by Deptherapy & Deptherapy Education have proven the benefits for its programme members and such benefits are driving research in the rehabilitative properties of SCUBA diving for the severely wounded.

In 2016 Deptherapy & Deptherapy Education, with The University of Sheffield, evaluated participants with varying degrees of physical injury and 90% reported improvements in their general wellbeing and mental health attributed, in part, to their participation with the charity ^[1]. 60% of participants reported an overall improvement in Psychosocial well-being, relating to anxiety, insomnia and depression ^[1].

Further studies concluded that SCUBA diving greatly assists those with the most serious physical injuries and, in particularly, is exceptionally successful in reducing reported symptoms of PTSD ^[2].



Coral Cay Conservation

Founded in 1986, CCC is an internationally renowned NGO, which provides host countries with appropriate resources for the protection and sustainable use of tropical ecosystems. This protection is established to enable future generations the continued use of local ecosystem resources. These goals are outlined in CCC's mission statement:

Providing resources to help sustain livelihoods & alleviate poverty through the protection, restoration & management of coral reefs and their associated systems

CCC achieves its mission via the formation of long-term programmes of collaborative research with local institutions and governments. These require technical support from CCC, in the form of scientific data collection, data analysis, and the production of reports and integrated coastal zone management plans. CCC also places efforts into strengthening local human resources to the point where research can be continued independently by the host country.

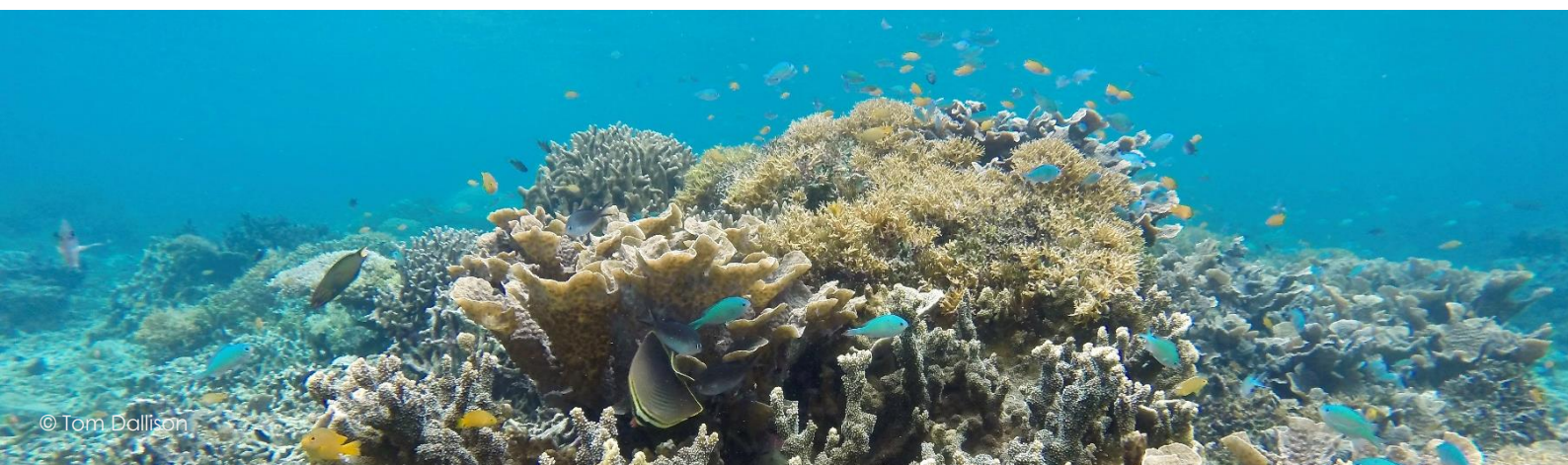
CCC has completed conservation projects all over the world, including the Philippines, the Caribbean, Belize, Honduras, Malaysia, Cambodia and Fiji, resulting in the successful establishment of numerous Marine Protected Areas (MPAs) and the

provision of scientific data for the development of conservation management plans.

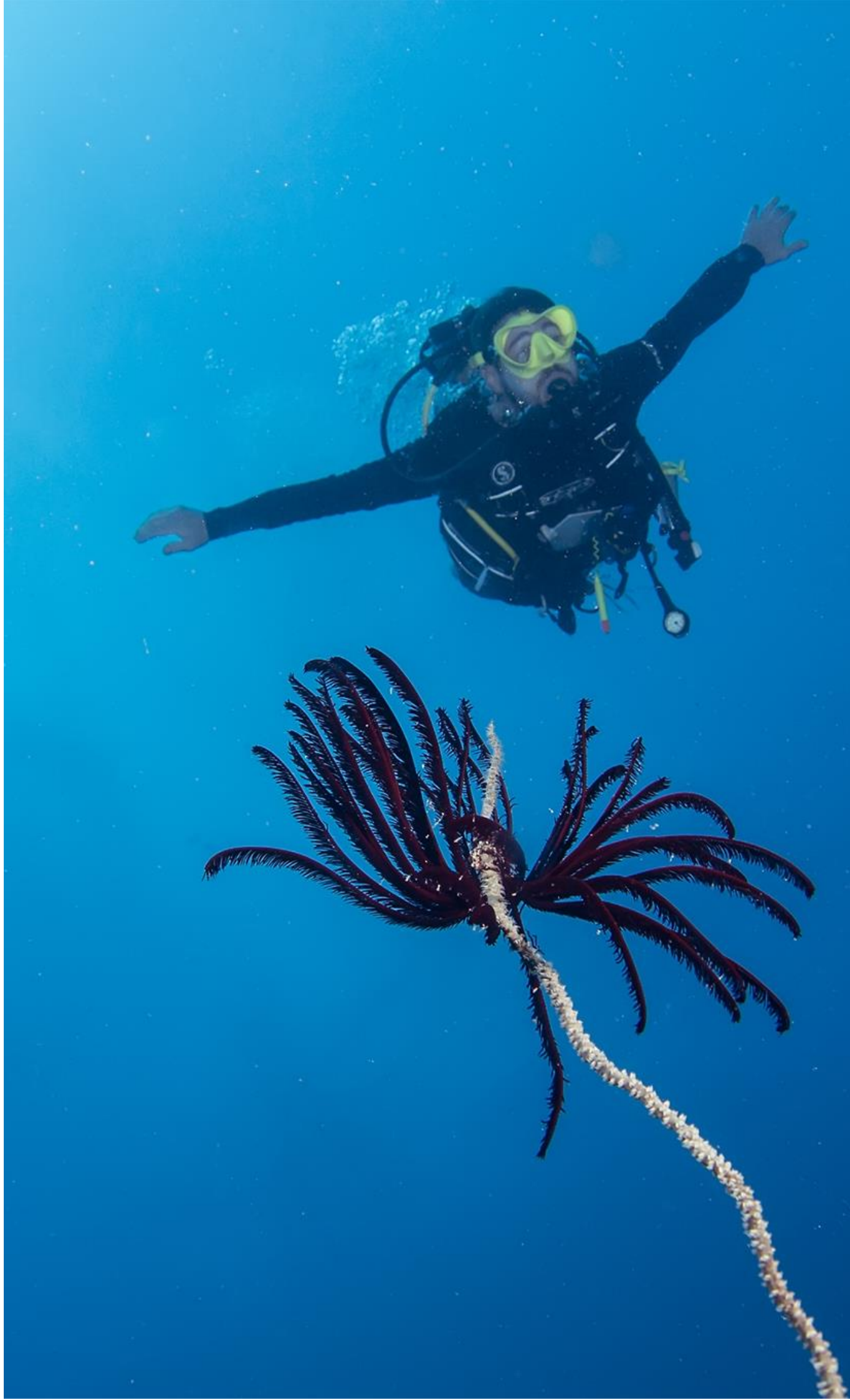
Operating under a three-tiered citizen-science framework, CCC builds scientific capacity within active regions, whilst ensuring equal efforts are placed into the provision of education opportunities to project beneficiaries. This equips project stakeholders with the necessary tools and skills to efficiently and effectively manage their own marine resources.

Undertaking an ecosystem-based approach to conservation, CCC is pivotal in driving policy change at the local level. Through the development of long-term conservation projects in developing countries, CCC's efforts aim to generate alternative livelihoods, whilst protecting and supporting cultural and traditional values, ensuring that marine resources, coral reefs and their associated ecosystems, and ecosystem services are sustainably utilised. By ensuring that gender mainstreaming is included in conservation strategies, coupled with education efforts, CCC build social responsibility and environmental stewardship, ameliorating the lives of future generations.

CCC formed a relationship with Deptherapy through the NGOs CEO, Alistair Cole, in his role as Charity Trustee. Alistair offered CCC's services to Deptherapy for the facilitation of the charity's Protecting Our Oceans Campaign. CCC provided ecology-focused training to Deptherapy in the Red Sea, Egypt in May 2018.



INTRODUCTION



Coral Reefs; Importance & Threats

Human-induced climate change, species depletion [3] and the unsustainable exploitation of marine resources are having a profound effect on the marine environment, altering key ecosystem processes, detrimentally influencing biodiversity and community composition [4], and inhibiting their capacity to provide ecosystem services [5], with undisputed consequences for humanity [6]. For example, the Intergovernmental Panel on Climate Change (IPCC) in 2018 stated that human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, which is likely to reach 1.5°C from 2030 [7]. The projections forecasted by the IPCC are set to be devastating for the status of the marine biome with major shifts to the range of many marine species, increases in damage to many systems and, at an increase of 1.5°C, a decline by a **further** 70-90% of coral reefs (with larger losses of 99% with 2°C increase (predicted with *very high confidence*)) [7]. The ever-threatening impact of global climate change, coupled with more localised, acute, perturbations place coral reefs, their associated ecosystems, the health of the oceans and the respective supported economies, in serious jeopardy, further threatening the livelihoods and health of billions of people.

Coral reef ecosystems hold critical importance to the human population through the many ecosystem functions and services they provide (e.g. habitat, protein provision, coastal defence, recreation and tourism), and are key components of coastal economies [8]. In addition to fishery-related services, coral reefs provide substantial services through coastal protection and tourism, with an estimated economic value of US\$ 30 billion per annum, globally [9]. The mean economic value of reef systems, specifically regarding tourism, range from US\$482,428 to US\$7 million per km², annually [10], highlighting their importance to coastal dwelling communities, national economies and the international community. As such, in the face of global and local threats, as well as

varying projections on the future of coral reefs, it is imperative that resources are protected, ecosystem impacts remediated, and resilience built.

The Pacific Region, Chuuk Lagoon & Shipwrecks

The coral reefs, and associated systems, of the Pacific region, including the Federated States of Micronesia (FSM), are in relatively good health and account for approximately 25% of the world's coral reefs due to the varying climatic and geographic conditions [11]. Furthermore, the reefs throughout the Pacific experience low exposure to human impacts due to the remoteness of specific reefs [11], however reefs near human population centres experience various localised anthropogenic threats [12] [13] [14]. Cyclonic activity (including hurricanes), Crown of Thorns Seastar (*Acanthaster planci*) outbreaks and coral bleaching, coupled with rising Sea Surface Temperatures (SST), are experienced throughout the region [13] [15] [16] [17]. Supporting the label of 'good health', Moritz *et al.* in 2018 [11] found that the coral cover of the Pacific region has been relatively stable over the past two decades and despite data presenting increasing levels of variability in coral cover between sites, the overall mean coral cover is 25.6%. The value of these systems to the Pacific region, specifically to the Northern Mariana Islands, Guam, Pulau, the FSM and the Marshall Islands, is well recognised; evidenced through the launching of The Micronesia Challenge that aims to conserve 30% of all coastal waters by 2020 [11].

Chuuk Lagoon, within the FSM, constitutes an important biogeographical link between the particularly diverse area of the Coral Triangle and other Pacific island groups (e.g. Mariana Islands, Marshall Islands and Polynesian Islands) [18]. It is one of the largest lagoons in the world, composed of over 2,000km² of coral reef and lagoon habitat (with an additional 200km of barrier reef) [12]. The lagoon is geographically located within the Caroline Islands and is situated in the north-west



region of the Pacific Ocean, at approximately 1,500km north of Papua New Guinea. With an estimated 2010 human population of 36,000, Chuuk Lagoon provides one of the highest coral-reef habitat per-capita within Micronesia, whilst hosting one of the smallest population densities [12] [13]. Due to its proximity to the global hotspot for marine diversity (the Coral Triangle), the Chuuk Lagoon contains some of the most extensive coral reef systems across Micronesia [13]. The reef systems within the lagoon are considered to have a good ecological status, when compared to other Micronesian reefs, however various reefs within the atoll are exhibiting signs of stress, specifically within denser population centres [12] [13]. For example, reefs in proximity to populated islands within the lagoon demonstrate some of the lowest fish abundances throughout Micronesia, whereas the reported abundances on the lagoon's barrier reefs is amongst the highest in Micronesia; indicating growing pressure on the marine resources from subsistence, and commercial fisheries [13] [14]. In addition to more recent impacts

through increasing human populations [12], the large-scale bleaching event in 2004 [11], a major COTS outbreak in 2009 [11] and an increase Sea Surface Temperatures (SST) of 0.5°C [16], Chuuk Lagoon has a rich military history resulting in more localised, physical impacts to the present reefs through the bombing, grounding and wrecking of WWII ships in 1944 [19] [20].

Derelict vessels have also been intentionally sunk by environmental managers to compensate for natural reef habitat loss and the loss of biodiversity due to human activities [25]. As such, artificial reefs have often been compared to natural reefs, and in many cases, high abundances of fish and biomass have been found on these artificial reefs [24]. However, there is evidence that artificial reefs should not be directly compared to their respective natural counterparts, as a means of replicating natural reef ecosystems, and that in fact, they host distinct reef-associated fish and benthic fauna community assemblages [24] [25]. Therefore, whilst not only providing an incentive to the touristic dive sector, shipwrecks that host an array of ecological

When I was going through the engine room of the Shinkoku [Maru], I could just picture all these little fellows scurrying around and all of a sudden, a torpedo hitting.

communities, may provide further resilience within regions to environmental impacts.

Chuuk Lagoon is well known within the dive tourism sector, and amongst shipwreck diving enthusiasts, for its high quantity (50-60) of WWII shipwrecks, namely Japanese merchant ships, due to the lagoon's strategic positioning in WWII [19] [20]. The majority of wrecks within the lagoon, including 12 aircraft wrecks, were sunk by American forces in 1944, in retaliation to the Japanese attack on Pearl Harbour [19]. As such, due to the high number of shipwrecks, the lagoon is also the final resting place for an estimated 5,000 Japanese and 123 Chuukese naval personnel and civilians highlighting the social, cultural, military and historical value of the area [19] [21].

The wrecks of Chuuk Lagoon first gained the attention of the tourism and diving sector in 1970 following the televised Jacques Cousteau documentary "Lagoon of Lost Ships" [20]. The region quickly gained publicity and interest from the diving community, driving tourism within the area. This led to a surge of 10,000 visitors in 1996, a 2008 estimate of 6,000 annually [22], which grew to an estimation of 13,737 tourists per annum in 2018 [11]. The draw of the wrecks to tourists and wreck diving enthusiasts is of high economic value to Chuuk Lagoon, and adjacent communities. Studies have highlighted that the sociodemographic of divers that visit Chuuk Lagoon are predominately male, often higher-than-average earners, and experienced divers [20]. It is reported that the divers attracted to wreck dives are often seeking new challenges, due to the more demanding conditions associated with wreck dives [20] [23], coupled with the presence of historical artefacts, a sense of discovery [20] and the unique ecological assemblages supported by wrecks [24] [25], wreck diving within Chuuk Lagoon provides a clear motivation to divers and the dive tourism sector.

Classified as Chuuk's main tourist attraction and source of revenue [20] [26], it is estimated that dive permits alone generate approximately US\$90,000 annually [27]. As

dive permits constitute a minor proportion of diver expenditure, and without a quantified economic contribution from tourism, it can be assumed that the draw of the lagoon's wrecks (as well as the natural ecological attraction of the region) generate a large annual revenue for the lagoon and the FSM, highlighting their respective value to the region.

The conditions of wrecks within Chuuk Lagoon are variable. Wrecks such as the Fujikawa Maru, a historically popular dive site within the lagoon, have corroded to such an extent (46%) [28] [29] that other wrecks, such as the *Shinkoku Maru* attract more divers, mainly due to the intact historical artefacts, structure of the wreck and rich ecological assemblages. Furthermore, corrosion surveys have indicated that the primary metals of wrecks are iron, steel and/or aluminium [19], with varying rates of corrosion driven by natural and anthropogenic activity.

The Shinkoku Maru

The *Shinkoku Maru* (Fig. 1) is a large Japanese oil tanker (capacity of 32,000 tons of oil) sunk in 1944 [30] with a recorded length of 152m and gross tonnage of 10,020 [19]. The meaning of *Shinkoku Maru* translates, in Japanese, as; *Shin* – faith or cause, *Ko* – honour of country, and *Ku* – salute to the emperor [31]. The wreck is located at depths between 11 – 37m and was categorised by Bailey (2000) [30] following the combination of physical surveys and historical records. It must be noted that the wreck of the *Shinkoku Maru*, as well as many other sites within Chuuk Lagoon, are considered as Japanese war graves. It is reported that human remains are found on various wrecks within the



Figure 1. The *Shinkoku Maru*, Special Number 53, Japanese Support Vessel, September 1941. Credit: Imperial Japanese Navy [34].

lagoon, with two human bones being photographed in 1979 on an operating table within the Shinkoku Maru (Fig. 2a) [32]. The remains and artefacts present within the *Shinkoku Maru* are a stark reminder of the deep history associated with such shipwrecks (Fig. 2b). Areas of the wreck exhibit signs of older damage from diver activities, dynamite fishing and typhoon Haiyan [33]. The presence of oil within wrecks and subsequent leaking has been continually documented [19] [32] [33]. Oil deposits were recorded in the *Shinkoku Maru* in 2017, and following further tests, were identified as aviation fuel, diesel and bunker fuel [33]. Macleod *et al.* (2017) [33] further noted that the surface of the *Shinkoku Maru* wreck demonstrated minimal signs of recent damage with intact coral colonies present highlighting the wreck as an attractive structure for wreck divers.

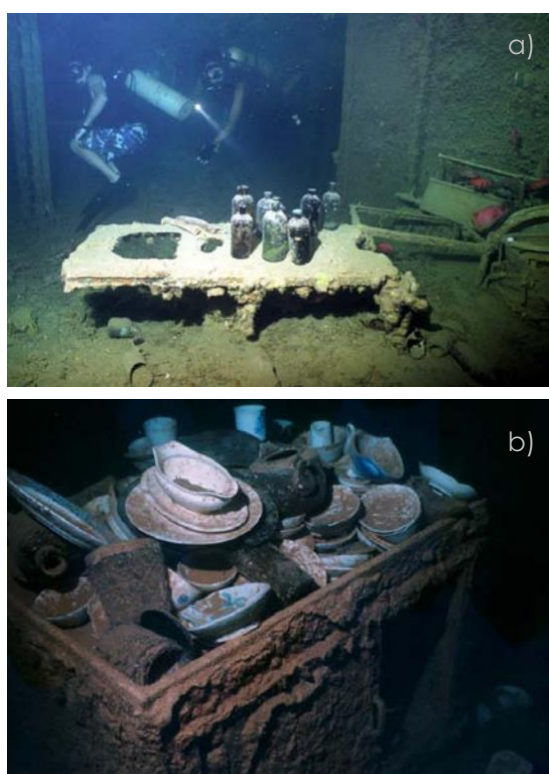


Figure 2. Human remains (a) and artefacts (b) recorded inside the *Shinkoku Maru* shipwreck, Chuuk Lagoon, Federated States of Micronesia. a) photographed by Greg Adams, 2001, b) photographed by Colin Hodson 1978. [32]

Deptherapy

Prior to undertaking this study, a team of 6 personnel from Deptherapy were trained in basic reef ecology and data collection techniques at the ROOTS resort, Egypt by Coral Cay Conservation. Throughout this training process, participants were trained in underwater fish species identification to a set target list and the estimation of fish sizes (cm) *in-situ* through a Roving Diver protocol. Participants were also trained in reef substrate identification to set categories as well as how to identify Scleractinian coral lifeforms utilising an interrupted belt transect with quadrats.

Following the training programme at ROOTS, participants were required to train survey divers in Chuuk Lagoon, tailoring the target fish and substrate lists to better represent the fauna and benthic assemblages associated with the Pacific region.

"Before we conducted the survey, the team ran a few dry runs of quadrat laying and the protocol we were going to use to conduct the survey. The other half of the survey team, responsible for doing fish id, had a fish id presentation on the target fish we were looking at to collect fish abundance and biomass data. All parties were happy with target species and the order of how we were conducting the quadrat data collection protocol."

- Ben Lee

Prior to arriving in Chuuk Lagoon, Deptherapy launched their conservation-focused campaign; Protecting Our Oceans. This campaign was established by Ben Lee and serves as a means of enabling Deptherapy members to pay back for what the Ocean and Deptherapy have given them. This study is a contribution of this campaign and adds a new element to the means of therapy and rehabilitation provided by Deptherapy.

"The Red Sea and Deptherapy changed my life forever. If I could, I would live underwater – the tranquillity, the beauty, it just blows your mind. You feel at one with nature.

I want to help teach my son to dive. I want him to enjoy the oceans, but we are killing our seas; global warming, pollution, over fishing and plastic waste are destroying our reefs and our aquatic life.

These are our oceans, and as surely as we fought for our Country, we must now, as that same 'Band of Brothers,' fight to save our oceans. We stood to arms in Afghan or Iraq, we now stand to arms, united in our

determination to fight for the future of our oceans."

Ben Lee, 2018

The aim of this study was for members of Deptherapy to undertake preliminary data collection protocols through SCUBA to ecologically map the fauna and benthic community residing on the *Shinkoku Maru* shipwreck in Chuuk Lagoon, FSM. The data are intended to be submitted to resource managers in Chuuk lagoon, to provide greater clarity on the ecological assemblages present on the wreck whilst providing evidence to facilitate management practices.



METHODOLOGY



Survey Site Description

Deptherapy's assessment of the *Shinkoku Maru* shipwreck was conducted between 3rd – 17th August 2018, by trained survey teams. The *Shinkoku Maru* Wreck ($7^{\circ} 24' 0.324''$ N, $151^{\circ} 46' 44.832''$ E) is located North-East of Udot Island, in Chuuk (Truk) lagoon, FSM (Fig. 3).

"The Shinkoku Maru wreck was located approximately 25-minutes by boat from the Truk Blue Lagoon Dive Resort and Dive Shop, Weno Island, in the lagoon in between two other large islands."

The bow's shallowest point was around 10m dropping down to approximately 35m. The boat was on a slight slope with the bottom of the stern sat at around 45-50m on the sea bed. At the time of the survey we had heavy rain fall days before and on the day. Visibility was clear to

about 20 m, but a lot of particles were floating, and it was murky at the same time as being clear. "

- Ben Lee

Data Collection

Fish

Data were collected by two trained survey teams; one team recording fish abundance and size with the other undertaking substrate composition protocols.

The abundance of pre-determined set target indicator fishes, based on those highlighted under the Reef Check protocol, were recorded through Underwater Visual Census (UVC) Roving Diver Technique (RDT) protocols. Indicator fishes are intended to indicate fishing pressure, aquarium collection and reef health, highlighting the ecological status of the surveyed reef

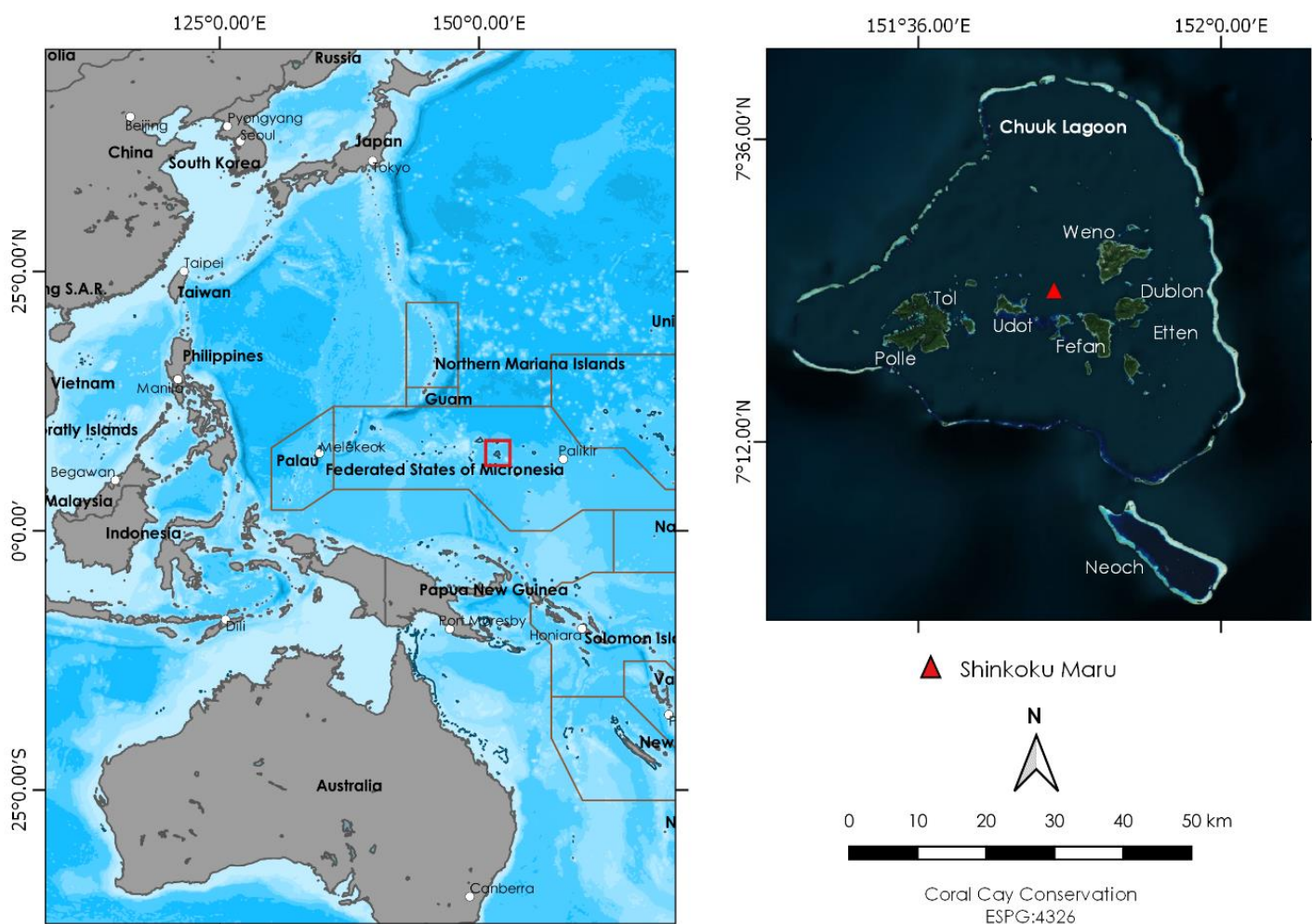


Figure 3. The location of Chuuk Lagoon (a) and the respective survey site, the *Shinkoku Maru*, Chuuk Lagoon, the Federated States of Micronesia (b). Map produced with QGIS.

system. The fish abundance survey team was separated into buddy pairs to survey the *Shinkoku Maru* wreck over the course of 2 survey dives. The survey area was separated into 2 independent sites (which were limited by respective team member ability and dive restrictions); mid-section and bow-section (Fig. 4). Surveys were conducted between 09:00 – 10:15, and 15:00 – 16:00, respectively.

Due to the ability of survey divers, including physical ailments, the RDT protocol was selected to minimise the requirement of equipment. As such, once descended to the desired depth, the survey team waited for 5 minutes (to allow for fauna to return to their natural behaviour) and 2 observers swam in a controlled manner with steady fin-kicks, or propulsions, as to limit influence on present fishes. Observers ensured to remain within the boundaries of the identified survey area.

Throughout the dive, observers were required to record their total bottom time of the survey, maximum depth and the abundance of target fishes. Additionally, the length (Total Length (cm) (TL)) of Grouper (Epinephelinae), Snapper (Lutjanidae), Parrotfish (Scaridae) and Butterflyfish (Chaetodontidae) individuals were estimated and subsequently placed into size categories of 10cm increments; 0-10cm, 11-20cm, 21-30cm, 31-40cm, 41-50cm and >50cm. Fish biomass (kg) estimates were determined through Length-Weight relationships for commercial fish species (Equation 1). Allometric co-efficients (Table 1) were determined through the process highlighted in Dallison & Ferguson (2017) [35].

(1)

$$W = aL^b$$

Equation 1. Length-Weight relationships were used to determine the biomass (kg) of Butterflyfish (Chaetodontidae) and commercially important fishes (Grouper (Epinephelinae), Snapper (Lutjanidae), Parrotfish (Scaridae)) recorded where w = mass (g), a = the condition factor, L = Total Length (cm), and b = the species-specific growth factor.

Target Butterflyfish (Chaetodontids) were selected, and recorded, due to their obligate corallivorous feeding trait (feed exclusively on coral), since the presence of obligate corallivores on reefs can be used as an indicator of hard coral abundance; Eastern Triangle Butterflyfish (*Chaetodon baronessa*); Chevron Butterflyfish (*Chaetodon trifascialis*); and Redfin/Oval Butterflyfish (*Chaetodon lunulatus*).

The abundance of any fauna considered 'rare' were also recorded; Bumphead Parrotfish (*Bolbometopon muricatum*); Humphead Wrasse (*Cheilinus undulatus*); Sharks (Carcharhinidae, Hemiscylliidae and Sphyrnidae), Rays (Rajiformes) and Turtles (Cheloniodea).

Table 1. Allometric co-efficient used to determine target fish biomass (kg) through Length-Weight relationships (LWR).

Target Fish	a	b
<i>Chaetodon baronessa</i>	0.0234	3.0100
<i>Chaetodon lunulatus</i>	0.0229	3.0100
<i>Chaetodon trifascialis</i>	0.0209	2.9600
Epinephelinae	0.0145	3.0225
Scaridae	0.0152	3.0398
Lutjanidae	0.0147	3.0312
<i>Bolbometopon muricatum</i>	0.0018	3.3440
<i>Cheilinus undulatus</i>	0.0145	2.9900

Substrates

The percentage (%) substrate composition of the *Shinkoku Maru* was recorded using quadrat sampling protocols where $n= 15$ quadrats (0.75 x 0.75m) were placed within the nested parameters of 3 sections of the wreck (equating to a total of $n= 45$ quadrats); bow-section, mid-section and stern-section (Fig. 4 & 5). Due to environmental conditions and diving restrictions, only $n= 9$ quadrats were sampled in the mid-section.

Biotic and abiotic substrates were collated into 9 categories pre-survey; HC (Scleractinian Hard Corals); SC (Soft Coral); SP (Sponge); AL (Nutrient Indicator Algae); SI (Silt); RC (Rock); RB (Rubble); SD (Sand); and OT (Other). Scleractinian corals were further categorised, to provide an indication of complexity and diversity, into various lifeforms; AB (*Acropora* branching); AD (*Acropora* digitate); AT (*Acropora*

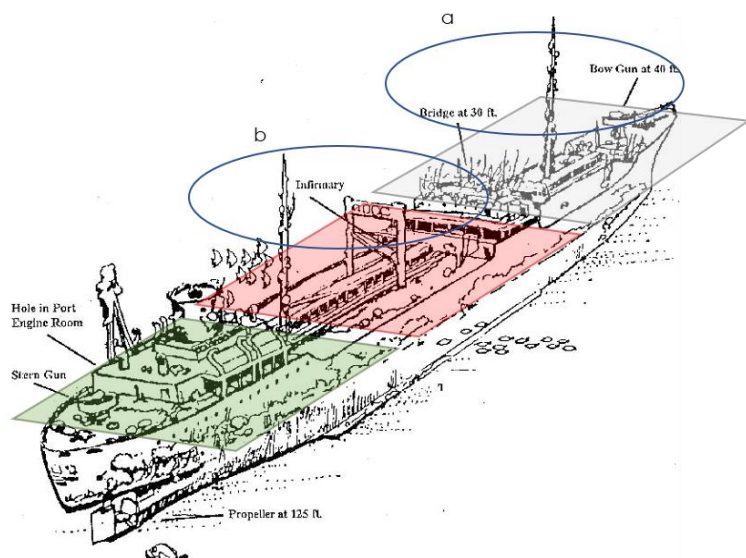


Figure 4. Sketched map of the Shinkoku Maru with highlighted areas of survey for the collection of fish abundance data (blue) on the bow (a) and mid-section (b) of the wreck. Substrate focus areas are also highlighted; grey (bow), red (mid), and stern (green). Map provided by Cpt. Lance Higgs, SS Thorfinn (2019) [32].

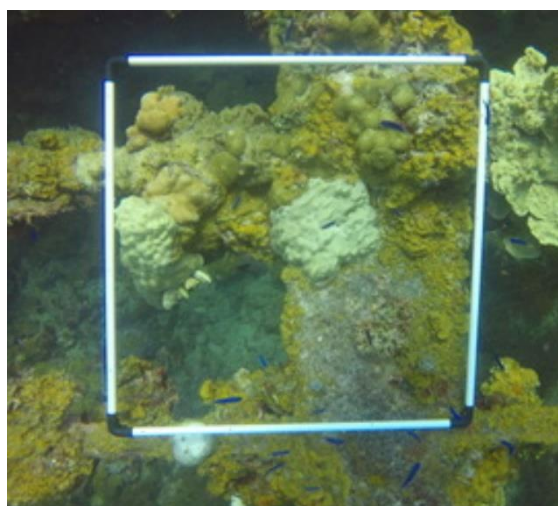


Figure 5. Quadrats (0.56m²) were utilised by survey teams to quantify the substrate community composition throughout 3 sections of the Shinkoku Maru shipwreck, Chuuk Lagoon.

tabulate); AE (*Acropora* encrusting); NAB (Non-*Acropora* branching); NAF (Non-*Acropora* foliose); NAM (Non-*Acropora* massive); NAMu (Non-*Acropora* mushroom (*Fungia* spp.)); and NAS (Non-*Acropora* sub-massive).

The survey team placed each quadrat within the parameters of the survey area (Fig. 5). A nominated survey member subsequently used a GoPro Hero Black 4 to photograph the substrate within the

quadrat, remaining parallel and central to the quadrat to minimise variation between images. The images were analysed *ex-situ* by the survey team to provide percentage (%) compositions of the pre-determined substrates and HC lifeforms. Percentages were rounded to the nearest 5%.

Data analysis

Due to an error during the data collection process, individual observer fish abundance data were not available resulting in $n = 2$ samples (1 sample each surveyed area (bow and mid)), minimal analysis could be undertaken on fish abundance or length data (any length data that exceeded the species-specific max length (cm), as given by Fish Base, were adjusted to the appropriate size category).

Fish abundance for each section and the entire survey area was calculated as an exposure index (EPUE) (Equation 2) with total diver time against recorded abundance to calculate the rate of exposure, per unit of diver effort (minute) for each respective target fish.

(2)

$$EPUE = \frac{n}{dt}$$

Equation 2. Exposure Per Unit of Effort (EPUE) where n is the recorded abundance of target fish and dt is the total recorded dive time (minute).

Means ($\bar{x}$) for the total survey area are reported with sample standard deviation ($\pm SD$) based on assumed normal distribution with two-sided 95% Confidence Interval's for two samples with a multiplicative factor of $t = 12.71$.

Individual fish biomass (kg) data were tested for skewness, kurtosis and normality. The data did not conform and could not be forced through transformation. As a result, to analyse the variance in individual fish biomass, non-parametric Mann-Whitney U tests were used.

Substrate data (including HC lifeforms) were also tested for skewness, kurtosis and normality and failed to conform to parametric requirements. Due to the non-parametric nature of the data, medians (Med) are presented (alongside means ($\bar{x}$) with standard deviation ($\pm$ SD) to provide further clarity) with Kruskal-Wallis tests undertaken followed by Dunn *post-hoc* analysis (*p*-values adjusted with Bejamini-Hochberg (bh) method) to analyse variance in substrate compositions between survey sites.

Detrended Correspondence Analysis (DCA) with hull-clustering was performed on substrate composition data between survey sites.

All analysis was conducted in R [36] with additional packages; Vegan [37]; dplyr [38]; FSA [39]; lattice [40]; r-companion [41]; ggplot2 [42]; and ggpubr [43].



RESULTS



Fish Abundance

Over the total sample area (Bow and Mid-section), a total of 252 individual target fishes were recorded equating to a mean EPUE of 2.65 ± 12.67 individuals per survey minute. Of the target fishes, Acanthuridae (Surgeonfish) were recorded in greatest abundance, EPUE= 0.84 ± 10.10 individuals per survey minute (Table 2), with Labridae (Wrasse), Scaridae (Parrotfish) and *C. trifascialis* (Chevron butterflyfish) subsequently recorded in high abundances (EPUE= 0.49 ± 3.15 individuals per survey minute, EPUE= 0.29 ± 3.71 individuals per survey minute, and EPUE= 0.21 ± 2.51 individuals per survey minute, respectively) (Table 2).

Considering each section, a total of 141 individuals were recorded whilst surveying the Bow section of the wreck, representing 69% of the 13 designated target fishes. The mid-section of the wreck exhibited lower total counts with 111 individuals recorded (62% of the 13 designated target fishes). Due to low sample size from each section ($n=1$), no means of abundance or mean EPUE could be derived.

Acanthuridae (Surgeonfish) were recorded in their greatest abundance within the mid-section of the wreck, represented by an

EPUE value of 1.40 individuals per survey minute. Acanthuridae (Surgeonfish) were subsequently followed in abundance by Labridae (Wrasse) and Scaridae (Parrotfish) (EPUE= 0.67 individuals per survey minute and EPUE= 0.50 individuals per survey minute, respectively). EPUE values determined for the bow-section contrast with those presented for the mid-section. *C. trifascialis* (Chevron butterflyfish) were the most numerous target species recorded in the mid-section of the wreck (EPUE= 0.35 individuals per survey minute) followed by Labridae (Wrasse) (EPUE= 0.32 individuals per survey minute). Acanthuridae (Surgeonfish) and Epinephelinae (Grouper) were recorded in equal abundances with an EPUE of 0.28 individuals per survey minute.

Length Frequencies

Acanthuridae (Surgeonfish) were dominated by individuals within the size category of >10cm ($f=33$), followed by 11-20 cm ($f=22$) (Fig. 6), within the parameters of the mid-section of the surveyed wreck. Individuals recorded within the bow-section of the wreck were within the size categories of <10cm ($f=8$) and 11-20 ($f=7$) (Fig. 6). Labridae (Wrasse), within the mid-section, were also dominated by individuals below 10cm ($f=19$) with $f=7$ individuals recorded between 21-30cm (Fig. 7). Scaridae (Parrotfish) were recorded in greater abundance within the mid-section of the *Shinkoku Maru*, in comparison to the bow-section, and were larger in size, with the dominant size classes in the mid-section being 11-20cm and 21-30cm ($f=10$ and $f=7$, respectively) (Fig. 7).

Epinephelinae (Grouper) were recorded in greater abundance within the bow-section parameter, in contrast to the mid-section, and were found distributed amongst all size classes up to a maximum length of 40cm (Fig. 7).

Butterflyfishes (Chaetodontidae) were recorded in greater abundance and size within the bow-section parameters, specifically when concerning *C. trifascialis* (Chevron butterflyfish) with $f=14$ and $f=6$

Table 2. Exposure Per Minute of Effort (EPUE minute⁻¹) for each target fish and vertebrate recorded during roving diver protocols on the *Shinkoku Maru* wreck, Chuuk Lagoon, Federated States of Micronesia. Sample standard deviation ($\pm$ SD) is given considering 2-sample multiplicative factor ($t=12.71$).

Target	EPUE	$\pm$ SD
<i>Chaetodon baronessa</i>	0.13	0.18
<i>Chaetodon lunulatus</i>	0.10	0.46
<i>Chaetodon trifascialis</i>	0.21	2.51
Chaetodontidae (Other)	0.00	0.00
Acanthuridae	0.84	10.10
Labridae	0.49	3.15
Epinephelinae	0.20	1.45
Scaridae	0.29	3.71
Lutjanidae	0.19	0.35
Tetraodontidae	0.01	0.21
<i>Bolbometopon muricatum</i>	0.00	0.00
<i>Cheilinus undulatus</i>	0.00	0.00
Sharks*	0.12	0.34
Rajiformes	0.04	0.79
Chelonioidea	0.01	0.16

*Sharks composed of *Carcharhinidae*, *Hemiscylliidae* and *Sphyrnidae*

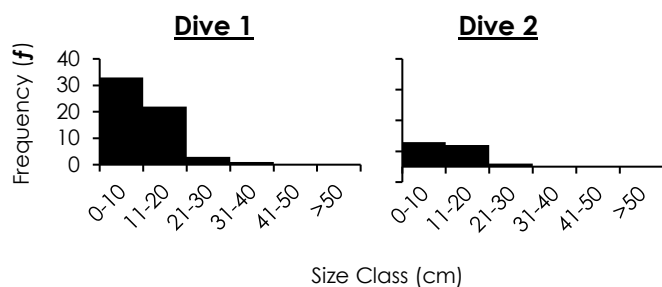


Figure 6. Size class (cm) frequency (f) histograms for Acanthuridae recorded over two roving diver surveys on the mid-section (Dive 1) and bow-section (Dive 2) of the Shinkoku Maru wreck, Truk Lagoon, Micronesia.

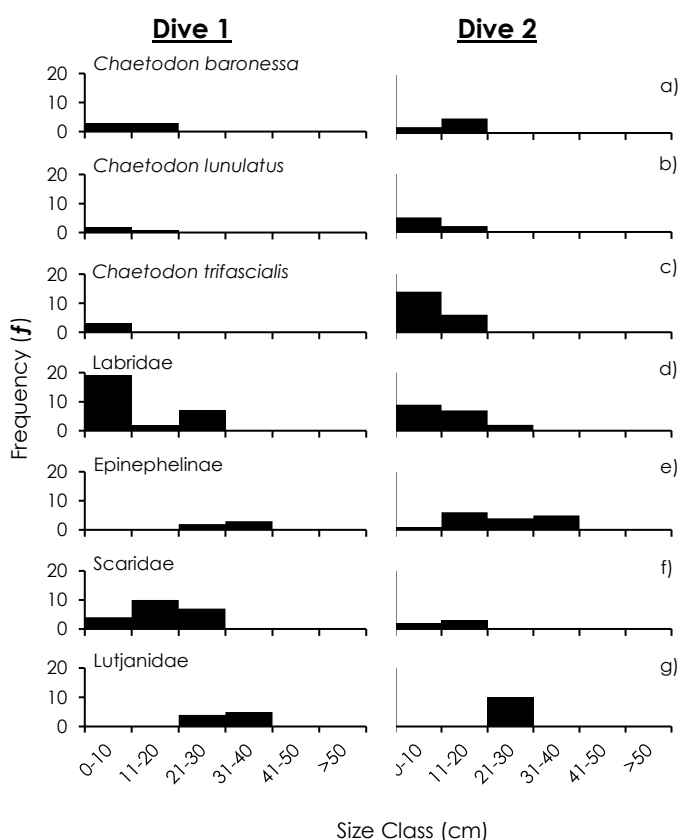


Figure 7. Size class (cm) frequency (f) histograms for target fishes (a-g) recorded over two roving diver surveys on the mid-section (Dive 1) and bow-section (Dive 2) of the Shinkoku Maru wreck, Truk Lagoon, Micronesia. Other Butterflyfish (Chaetodontidae), *Cheilinus undulatus*, *Bolbometopon muricatum*, and Tetradontidae were excluded due to low/none abundances. Acanthuridae were presented independently.

individuals recorded in comparison to $f = 3$ and $f = 0$ recorded in the mid-section of the wreck, in both size classes, 0-10cm and 11-20cm, respectively (Fig. 7).

Biomass Estimates

For target fishes where biomass (kg) calculations were undertaken, a total of 19.32kg of standing biomass was reported. Concerning the two sampled sections of the wreck, 10.42kg of biomass was recorded from the mid-section and 8.90kg from the bow. Due to minimal sample sizes, analysis of variances between sections was not undertaken.

Individual biomass estimates were calculated for available target fishes regarding each survey section of the Shinkoku Maru wreck (Table 3). Individual Lutjanidae (Snapper) were larger in the mid-section parameters (Med= 0.74kg individual⁻¹) in-comparison to bow-section parameters (Med= 0.27kg individual⁻¹) (Mann-Whitney $U = 20$, $Z = -2.37$, $p = <0.05$) (Table 3). No differences in individual biomass were exhibited between each surveyed section and other target fishes (Table 3).

No *Bolbometopon muricatum* (Bumphead Parrotfish), *Cheilinus undulatus* (Humphead Wrasse) or fishes within the 'Other Butterflyfish' category were recorded throughout the survey area. 1 Tetradontidae (Pufferfish) individual was recorded throughout the survey period.

Rare Organisms

Throughout the survey period, within both surveyed sections under Roving Diver Protocols, a total of $N = 12$ sharks were recorded (evenly recorded on both sections of the wreck), anecdotally identified post-survey as Whitetip Reef Sharks (*Triaenodon obesus*). Additionally, $N = 5$ rays (Rajiformes) and $N = 1$ Turtles (Chelonioidae) were recorded, however these were not identified.

General Substrate Composition

A total of $n = 39$ quadrats were sampled across the entire survey area ($n = 15$ Bow, $n = 9$ Mid, and $n = 15$ Stern), surveying an area of 21.94m².

Across the entire surveyed area, the composition of particular substrates was deemed to significantly differ

Table 3. Mean ($\bar{x}$) individual biomass (kg) estimates, with sample standard deviation ($\pm$ SD), and sample median (Med), calculated for available target fishes regarding each survey section of the Shinkoku Wreck, Chuuk Lagoon, Federated States of Micronesia.

Target Fish	Bow-section			Mid-section		
	$\bar{x}$	($\pm$) SD	Med	$\bar{x}$	($\pm$) SD	Med
<i>Chaetodon baronessa</i>	0.07	0.04	0.09	0.05	0.05	0.05
<i>Chaetodon lunulatus</i>	0.02	0.02	0.00	0.03	0.05	0.00
<i>Chaetodon trifascialis</i>	0.02	0.03	0.00	0.00	0.00	0.00
Epinephelinae	0.33	0.29	0.26	0.53	0.24	0.70
Scaridae	0.04	0.03	0.06	0.13	0.12	0.06
Lutjanidae	0.27	0.00	0.27 *	0.53	0.25	0.74 *

* indicates where divergence in medians were found to be significant through Mann-Whitney-U analysis with Benjamini-Hochberg correction.

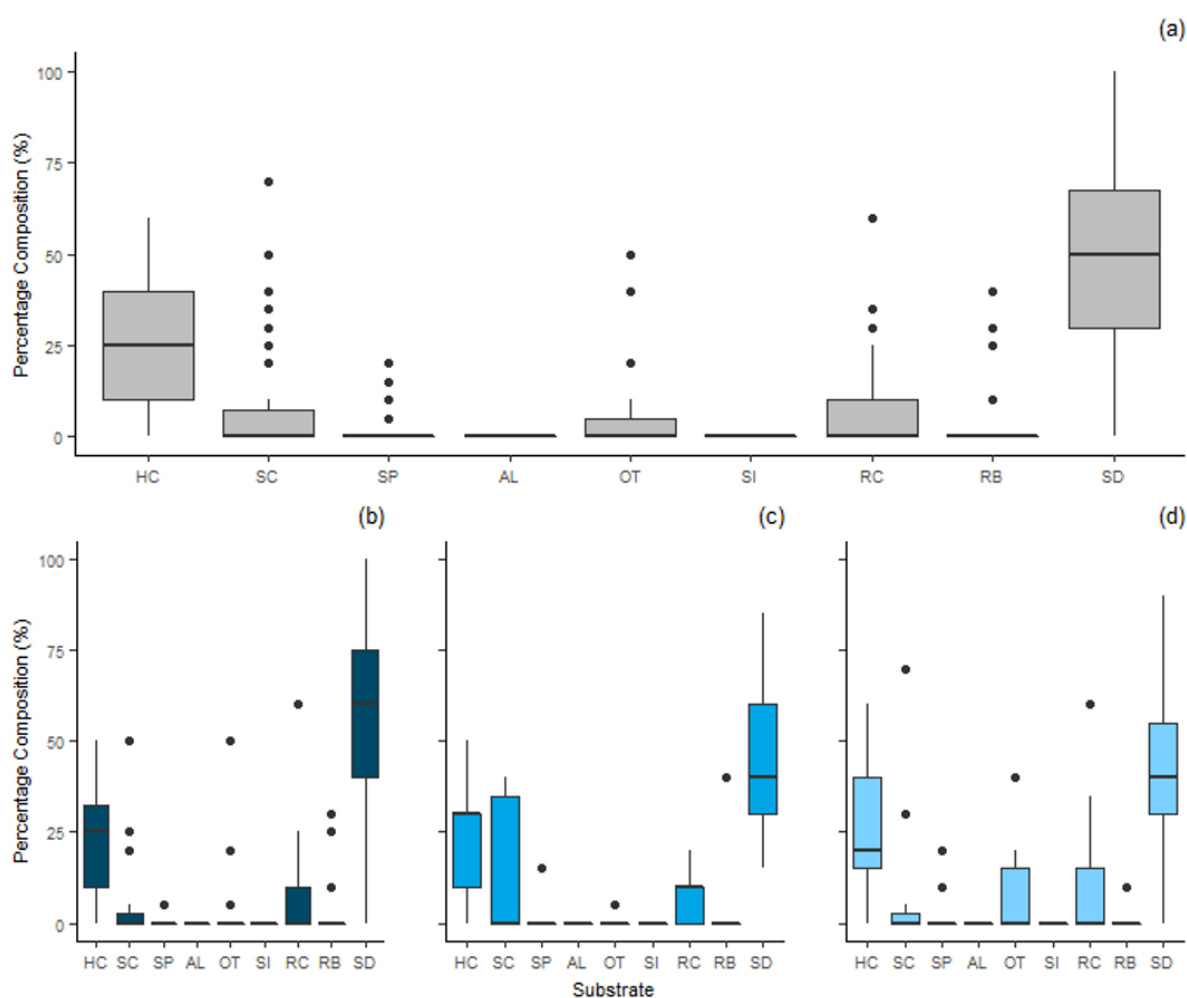


Figure 8. Boxplots presenting substrate composition (%) over the entire survey area (a) of the Shinkoku Wreck, Truk Lagoon, Federated States of Micronesia area. The wreck was subsequently surveyed in three independent areas; the Bow (b), the Mid-section (c) and the Stern (d). Substrates are represented by unique codes; HC (Scleractinian Hard Coral), SC (Soft Coral), SP (Sponge), AL (Nutrient Indicator Algae), OT (Other), SI (Silt), RC (Rock), RB (Rubble) and SD (Sand).

in comparison to other substrates (Kruskal Wallis, chi-squared = 172.12, df = 8, $p < 0.05$). Further *post-hoc* analysis (Dunn Test with Benjamini-Hochberg (bh) correction) indicated that (Sand (SD) ($\bar{x} = 47.05 \pm 27.90$ %, Med = 50%) and Scleractinian Hard Corals (HC) ($\bar{x} = 24.62 \pm 17.34$ %, Med = 25%) were the dominant substrates throughout the survey area, with both demonstrating greater compositions than other respective substrates (Dunn Test with bh correction, $p < 0.05$) (Fig. 8). Furthermore, Rock (RC) ($\bar{x} = 9.23 \pm 15.11$ %, Med = 0%) was recorded in greater compositions than both Sponge (SP) ($\bar{x} = 1.41 \pm 4.28$ %, Med = 0%) and Rubble (RB) ($\bar{x} = 2.95 \pm 8.64$ %, Med = 0%)

(Dunn Test with bh correction, $p < 0.05$, respectively). Nutrient Indicator Algae (AL) and Silt (SI) were poorly represented throughout ($\bar{x} = 0$ %, Med = 0%, respectively) (Fig. 8).

Regarding localised survey areas (bow, mid and stern), SD and HC substrates continued to dominate (Dunn Test with bh correction, $p < 0.05$) however, this did not demonstrate dominance over Soft Coral (SC) or Rock (RC) within the mid-section of the wreck ($\bar{x} = 13.88 \pm 18.67$ %, Med = 0% and $\bar{x} = 7.22 \pm 6.66$ %, Med = 10%, respectively) (Fig. 9 b, c and d).

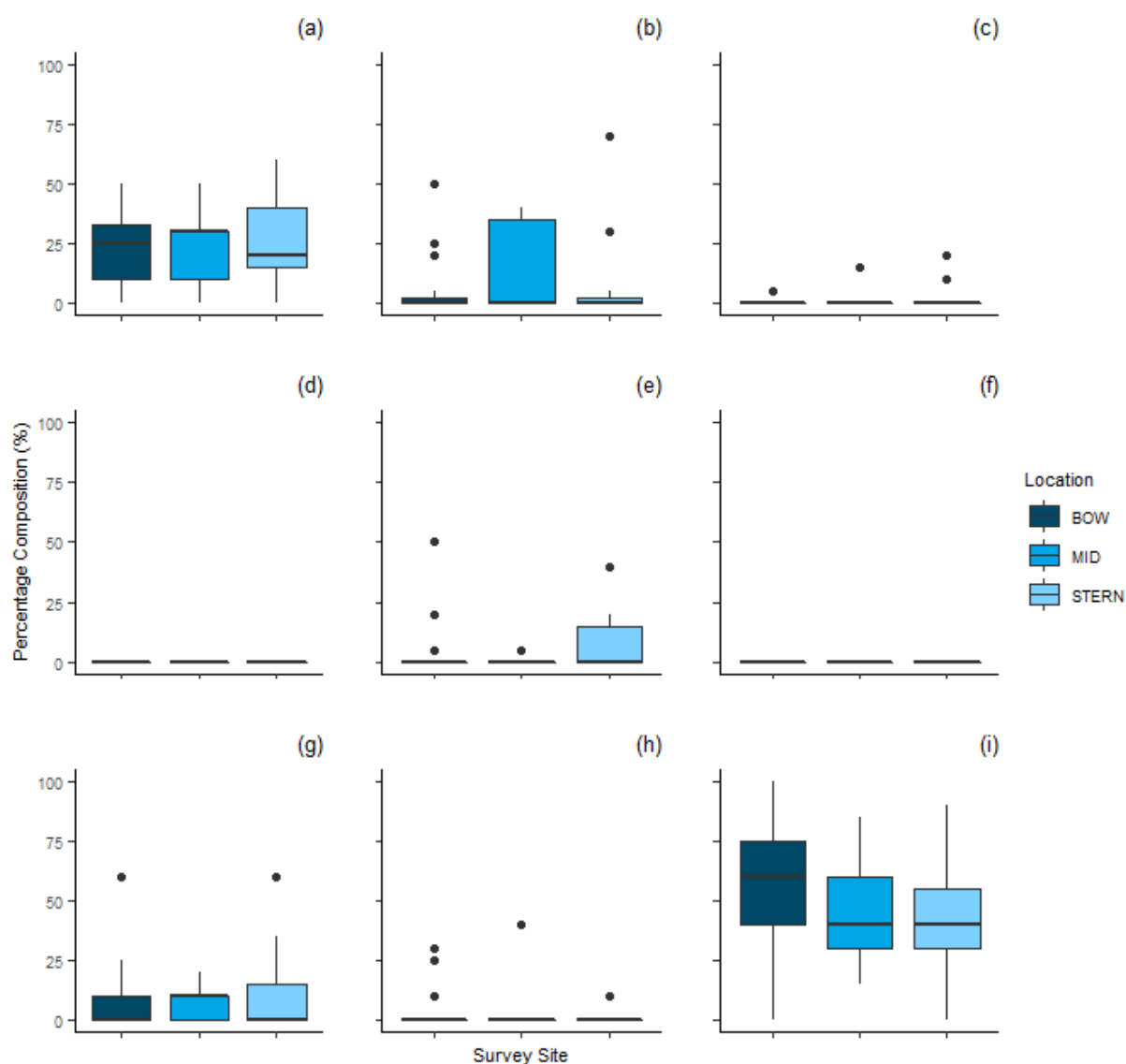


Figure 9. Boxplots presenting substrate composition (%) over three independent survey areas of the Shinkoku Wreck, Truk Lagoon, Federated States of Micronesia; the Bow (D. blue), the Mid-section (blue) and the Stern (L. blue). Each substrate is presented within the matrix; a (HC (Scleractinian Hard Coral)), b (SC (Soft Coral)), c (SP (Sponge)), d (AL (Nutrient Indicator Algae)), e (OT (Other)), f (SI (Silt)), g (RC (Rock)), h (RB (Rubble)) and i (SD (Sand)).

Hard Coral Lifeform Composition

As HC was identified as a dominating substrate on the *Shinkoku Maru* wreck, it is important to understand the structural complexity and diversity of the colonies surveyed. However, although non-Acropora Branching ($\bar{x} = 17.50 \pm 5.00$ %, Med = 10%) and Non-Acropora Encrusting ($\bar{x} = 23.33 \pm 14.14$ %, Med = 20%) corals were recorded in seemingly high abundance throughout the entire survey site, no differentiation between each lifeform was found ($p = >0.05$). Furthermore, when grouped into Acropora and Non-Acropora, no difference was identified ($p = >0.05$).

The composition of Non-Acropora Encrusting coral was found to significantly differ between the three survey parameters of the wreck (Kruskal Wallis, chi-squared = 6.92, df = 2, $p = <0.05$). Further post-hoc analysis indicated that the Non-Acropora Encrusting corals were in greater composition within the Stern survey parameters ($\bar{x} = 10.66 \pm 15.80$ %, Med = 15%) than the composition recorded within the Bow parameters ($\bar{x} = 2.00 \pm 7.75$ %, Med = 0%, Dunn Test with bh correction $p = <0.05$). No differences were recorded between the other surveyed areas.

Other HC lifeforms did not differ in composition between surveyed areas of the *Shinkoku Maru* wreck. Nor did they differ when grouped into two distinct groups; Acropora and Non-Acropora.

There were no distinct substrate community structures found within each surveyed section of the wreck (DCA analysis) (Fig. 10). Furthermore, no survey location could be defined by distinct hard coral lifeforms through DCA analysis (Fig. 11).

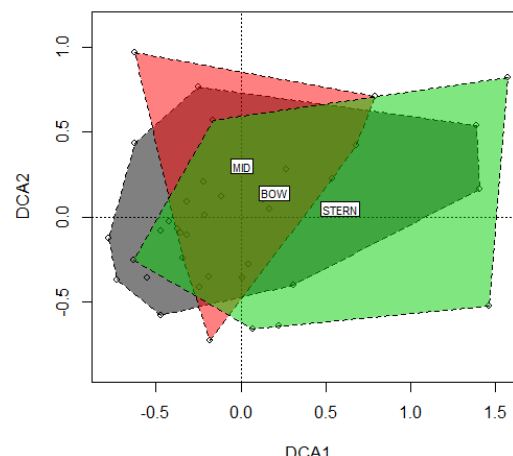


Figure 10. DCA plot, with hull clustering, demonstrating substrate community structure for the three survey locations of the *Shinkoku Maru* wreck; bow (grey), stern (green) and mid (red).

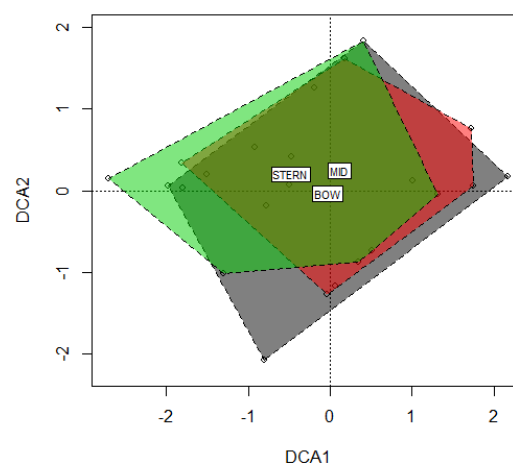


Figure 11. DCA plot, with hull clustering, demonstrating hard coral lifeform community structure for the three survey locations of the *Shinkoku Maru* wreck; bow (grey), stern (green) and mid (red).

DISCUSSION



The aim of this study, conducted by members of Depththerapy, aimed to 'map' the ecological communities of the *Shinkoku Maru* shipwreck and provide a greater understanding of the ecological community assemblages found within the area. In undertaking this study, Depththerapy have been able to provide clarity to support governing agencies to make informed management decisions to benefit the economy, societal values and ecosystems within the area.

Notably, Depththerapy have also demonstrated that personnel suffering from various physical and mental ailments hold the ability to undertake such studies; overcoming the barriers associated with the rigorous physical demands of undertaking scientific data collection protocols *in-situ*.

Acanthuridae (Surgeonfish) were recorded in greatest abundance, quantified through the rate of exposure to survey divers. Acanthuridae (Surgeonfish) and Scaridae (Parrotfish), as well as Labridae (Wrasse), have been demonstrated to inhabit shallower (<30m) systems within the FSM [44] supporting the abundances recorded in this study, as both fish surveys were undertaken with a maximum depth of 20m. Due to the low resolution of the data, the individuals within the survey area cannot be identified to species level, however, with the majority of individuals recorded below 20cm in length, the results are reflected by the general trend observed within Chuuk Lagoon from 2012 to 2016 [13]. From 2012, a substantial increase in small-bodied fishes, specifically surgeon and parrotfishes, was observed throughout the entire lagoon [13] which may explain the dominance of Acanthuridae (Surgeonfish) on the *Shinkoku Maru* wreck, whilst also supporting the presence of Scaridae.

Scaridae (Parrotfish) were recorded in relatively high rates of exposure during the survey period, however, the mean biomass (kg) per individual and the greatest recorded abundance of individuals between 11-20cm, indicates a dominance of smaller, possibly sexually immature fishes

within the Scaridae community assemblage. This is further supported by Houk *et al*'s study, in 2016, that evidenced an increasing abundance of roving herbivorous fishes [13]. However, this result is also surprising as the same report identifies survey sites in proximity to the *Shinkoku Maru* wreck being mostly composed of heavy-bodied fishes – which were observed in minimal abundance during this study (excluding the presence of *T. obesus*). Jeffery (2012) [19] presents a summary of findings by an Earthwatch funded field expedition that aimed to quantify the coral reef communities residing on the wrecks in Chuuk Lagoon. Despite the Earthwatch results focusing on the *Kensho Maru* (7° 22' 48" N, 151° 50' 60" E) and *Fujikawa Maru* (7° 20' 60" N, 151° 53' 24" E), their results also supported the small abundance of larger, heavy-bodied fishes from surveys.

It must be noted, however, that the referenced studies [11] [13] [44] surveyed the fish assemblages of natural reefs within Chuuk Lagoon and the surrounding region, and did not include shipwrecks within focus survey areas. Shipwrecks have often been purposely, or accidentally, deployed as artificial reefs to mitigate the degradation of natural reefs [24] and their influence has been well documented, with the reported benefits for replicating natural reef fish assemblages varying (e.g. [24] [25]). Therefore, dissimilarities between the fish assemblages recorded on the *Shinkoku Maru* wreck and from the Chuuk Lagoon region can be postulated to be due to the wreck supporting a distinct ecological assemblage that diverges from natural regional trends.

Shipwrecks undergo slow-paced structural changes over time, in both biotic and abiotic aspects [24] [28]. Rugosity and relief are often higher on shipwrecks in comparison to natural reefs [24] due to the structure (such as hatchways and hold openings) and external ironware being corroded and crushed with time [19] providing refugia to, and influencing the presence of, various species of fishes (and invertebrates) [25] [45] [46]. This highly complex

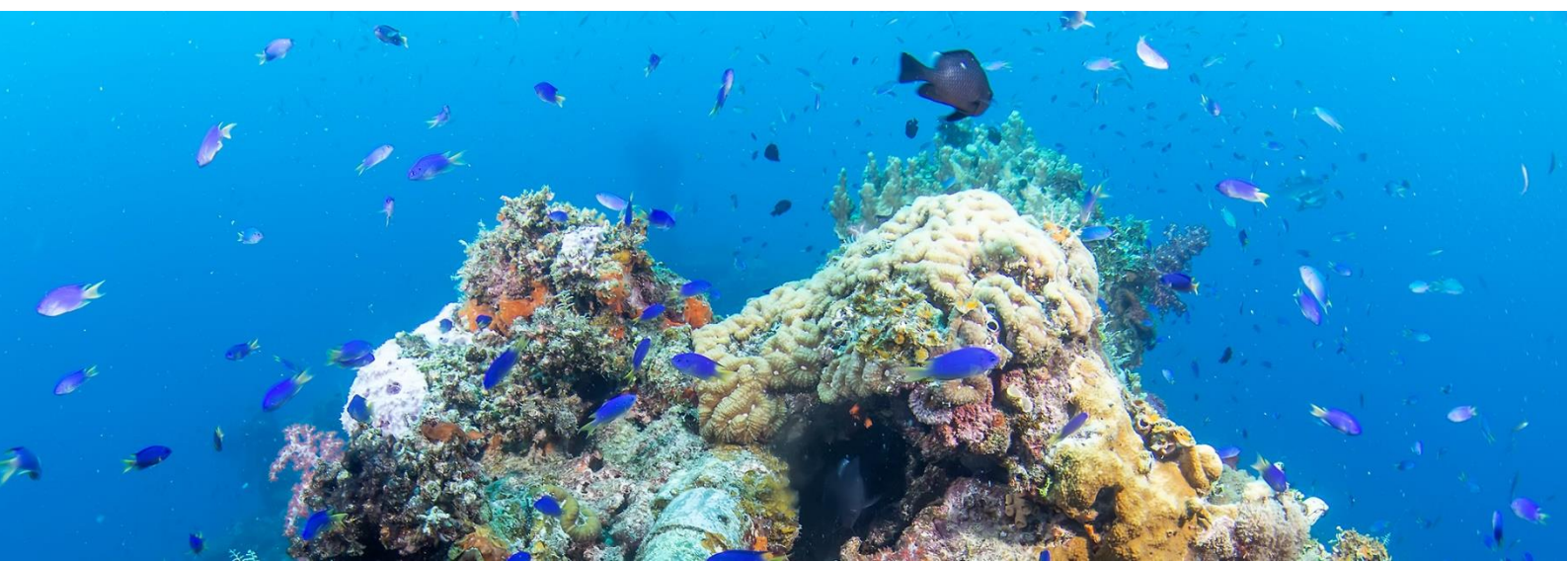
environment, coupled with the composition of Scleractinian corals (supported an approximate 25% regional cover in 2016 [11]), offers support to the observed community fish assemblages on the *Shinkoku Maru* wreck by Depththerapy survey teams.

Further contributing to the economic value of the lagoon, and the *Shinkoku Maru* wreck, to the tourism industry, is the presence of 'Rare Organisms', or charismatic fauna, during the survey period. *T. obesus* (Whitetip reef shark) were recorded throughout both surveys, with further sightings recorded during substrate survey efforts within the Stern-section of the wreck. Sharks hold high trophic guilds within reef-associated assemblages and represent top predators within such systems. Their presence on the *Shinkoku Maru* is highly positive and indicates that there is an abundance of smaller-bodied, lower trophic level prey to support their presence, within the lagoon [13]. Sharks are also highly sensitive to fishing practices, with their presence contrasting reports and other evidence indicating high levels of fishing activities. Additionally, the presence of *T. obesus* further contradicts results from Hauk *et al.* (2016) [13] where reef sharks were totally absent from natural reefs within proximity to, and the surrounding neighbouring islands of, the *Shinkoku Maru* wreck.

Sharks, including *T. obesus*, are highly valued throughout the tourist industry with high economic values for shark-related tourism (namely encounters through diving) reported throughout numerous coastal

nations; US\$ 4.4 million per annum in South Africa [47]; US\$ 8.9 million per annum in the Maldives [48] [49]; US\$ 78 million in the Bahamas [50]. This is further emphasised by Vianna *et al.* (2012) [51] where it was reported that, in Palau, shark diving generated US\$18 million per annum (8% of Palau's GDP). Vianna *et al.* (2012) [51] further quantified that the same population of sharks generating 8% of Palau's GDP, would be worth, at the most, US\$ 10,800 to capture fisheries (namely to supply the shark fin trade). This usage comparison between live and dead sharks creates a stark dichotomy and provides evidence for the ecological, social and economic importance of the natural and anthropogenic systems within Chuuk Lagoon.

The results of this study highlight that the substrate community composition found to inhabit the *Shinkoku Maru* wreck is dominated by Scleractinian corals and sand and did not differ in composition between each area surveyed, suggesting a dominated benthic system present on the wreck. The survey findings also indicate that the diversity of lifeforms amongst Scleractinian corals is relatively even, supported by the lack of dominant coral lifeforms throughout the wreck. This indication of an even, high coral cover environment, contradicts the findings within adjacent areas of natural reefs, as reported by Houk *et al* in 2016 [13]. The natural reefs within proximity to the *Shinkoku Maru* wreck are dominated by *Porites* spp. colonies and have seen an increase since 2008 (to 2016) [13]. As no divergence in the composition of lifeforms, nor between the grouped





Acropora spp. and non-*Acropora* spp., was found on the *Shinkoku Maru*, it provides evidence that the wreck is providing protection to various Scleractinian colonies from the observed perturbations (COTS outbreaks and typhoon disturbances) on the adjacent natural reefs. Although not recorded within this study, various reports have stated that evidence of COTS can be found on certain wrecks [52] alongside evidence of dynamite fishing [33]. Reports of the use of dynamite fishing practices within Chuuk Lagoon lead to concern for the reef assemblages on shipwrecks, and natural reefs, throughout the lagoon due to the wholesale localised ecological and physical impacts. As no recorded or anecdotal evidence (large, localised physical damage to colonies and the shipwreck) was reported within this survey, the use of dynamite within the vicinity of the *Shinkoku Maru* cannot be concluded, however reports of the practice indicates a possible Malthusian fishery status within the lagoon, possibly contributing to the absence of heavy-bodied fish within the survey area, contradicting the presence of *T. obesus*.

The habitual refuge provided to coral colonies and fauna is further supported by evidence from Jeffery (2012) [19], through the Earthwatch field expedition, where colonies of *Acropora pichoni* were recorded that often colonise protected reef slopes [53]. The composition of Scleractinian corals is a positive indication that the *Shinkoku Maru* has been successfully colonised by coral recruits and holds the capacity to support a coral-reef associated community assemblage. This is further supported by the abundance of *C.*

trifascialis (Chevron butterflyfish) an obligate corallivore [54], commonly associated with, and holding a high preference for, *Acropora* spp. [55].

The abundance of a seemingly even distribution and diversity of Scleractinian corals on the *Shinkoku Maru* wreck, as well as the presence of specialised obligate corallivorous butterflyfish species and apex predators, such as *T. obesus*, indicates that the community associated with the *Shinkoku Maru* wreck is in good ecological status, proving positive for the ecological characteristics and services of the survey area as well as for tourism. It must, however, be noted, that the lack of heavy-bodied fishes, and evidence of dynamite fishing practices and COTS scars on other wrecks within the lagoon are of concern and provide further evidence for the necessity of protection of these sites for ecological, economic and aesthetic reasons.

Conclusion; Ben Lee

“Completing the study was a massive achievement for the Deptherapy team, not only because we had accomplished our set aims in Truk, but also proved to the world that we, as disabled veterans, missing limbs and having mental health issues, can conduct our own conservation-orientated studies and help in the protection of our Oceans; a pledge we have made through our Protecting Our Oceans Campaign.”

For me it was a challenging task to achieve, not only for the guys involved but for Tom Dallison at Coral Cay Conservation, having to

train and educate 7 injured veterans that had no knowledge of the marine biology world or any idea of how the coral reef ecosystem worked underwater. To then hand that knowledge down to more of our team and complete the task of mapping the life of the Shinkoku Maru wreck proved that we had the power to use the knowledge to educate others on Depththerapy programmes and we will continue to do so on our future courses.

The study we carried out helped the charity promote our new Protecting Our Oceans Campaign showing the SCUBA world that even with some of the worse physical and mental injuries, we, as one, can help educate the world about the damage we are causing to our Oceans and carry out data collection that is vital to presenting the problem to the required governing bodies."

- Ben Lee



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