UNIVERSITY OF THE PHILIPPINES LOS BAÑOS

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Alden Palacio Tagarino

SPATIO-TEMPORAL PATTERNS OF HAWKSBILL TURTLE NESTING AND MOVEMENTS IN AMERICAN SAMOA

Diomedes A. Racelis, Ph.D.
(Adviser)

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Alden P. Tagarino
(Student's Signature)

Diomedes A. Racelis
(Thesis Adviser's Signature)

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ALDEN PALACIO TAGARINO

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL,
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(Natural Resources Conservation)

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The thesis attached hereto, entitled "**SPATIO-TEMPORAL PATTERNS OF HAWKSBILL TURTLE NESTING AND MOVEMENTS IN AMERICAN SAMOA**" submitted by **ALDEN P. TAGARINO**, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (NATURAL RESOURCES CONSERVATION)** is hereby accepted:

JUANCHO B. BALATIBAT
Member, Guidance Committee
30 Oct 2015
Date Signed

JUAN CARLOS T. GONZALEZ
Member, Guidance Committee
30 Oct 2015
Date Signed

VICTOR S. TICZON
Member, Guidance Committee
30 Oct 2015
Date Signed

DIOMEDES A. RACELIS
Chair, Guidance Committee
5 NOV 2015
Date Signed

Accepted in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (NATURAL RESOURCES CONSERVATION).**

DIOMEDES A. RACELIS
Director, Institute of Renewable Natural Resources
5 NOV 2015
Date Signed

JOSE V. CAMACHO, Jr.
Dean, Graduate School,
University of the Philippines Los Baños
NOV 05 2015
Date Signed

BIOGRAPHICAL SKETCH

Author Alden Tagarino is currently residing in Nu'uuli village, American Samoa, he is the second of four siblings born to Rogelio Niedo Tagarino and Floria Palacio Tagarino. He obtained his primary and secondary education respectively from Maquiling School Inc. and the University of the Philippines (UP) Rural High School, both at UP Los Baños, College Laguna, and earned a degree on Bachelor of Science in Fisheries, major in Marine Fisheries from UP Visayas, Miag-ao Campus, Miag-ao, Iloilo, Philippines.

His interest in conservation was inspired by involvement in various volunteer works, beginning in 2001 with the coral reef assessment and fish diversity survey at Hinoba-an Negros Occidental with the Center for Environmental Concerns Philippines and 2004-2005 field seasons on the humpback whale research and conservation project of Kabang Kalikasan Pilipinas, World Wide Fund for Nature in Babuyan Islands, Philippines. In 2005, Mr. Tagarino worked with the Sri Lanka Ecotourism Foundation through the South-South Exchange Tsunami Special Program funded by Fredskorpset an organization based in Norway and thereafter, in 2006, he served as marine mammal observer of the marine mammal survey conducted by the Tropical Marine Research for Conservation for Conservation International Philippines. These work experiences motivated him to pursue a career in conservation.

Prior to his graduate studies, the author served as Wildlife Biologist with the Wildlife Division at the American Samoa Department of Marine and Wildlife Resources (DMWR) from June 2007 to June 2013, wherein among other duties, he acted as the principal investigator of the sea turtle, marine mammal and coconut crab projects of DMWR.

He is married to Kelley Lynn Anderson Tagarino.

ALDEN PALACIO TAGARINO

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ABSTRACT

TAGARINO, ALDEN P., University of the Philippines at Los Baños, December 2015. Spatio-Temporal Patterns of Hawksbill Turtle Nesting and Movements in American Samoa

Major Professor: Dr. Diomedes A. Racelis

The critically endangered status of the hawksbill turtle (IUCN Redlist 2013) elucidates the importance of making recent data available for conservation managers. This thesis studied the patterns of nesting occurrence and migratory behavior of hawksbill turtle populations of Tutuila, Ofu and Olosega Islands in the South Pacific Archipelago of American Samoa. Nesting beaches monitored from December 2009 to June 2013 suggest year round nesting season and peaking in January to February. Only 33 hawksbill nests were documented. Hawksbill turtles also exhibited both short and long distance migration. In total, one adult male, three juveniles and one post nesting turtle exhibited short distance migrations, however one juvenile (Curved Carapace Length, CCL: 51.5cm), travelled 1612.52 km to the Cook Islands area. Three post nesting turtles showed three distinct movements, a limited east-west movement within the Territory and Samoa, and southwest to Tonga. A post nesting turtle satellite tagged on Ofu Island travelled a total distance of 4907.19 km (straight line distance: 4047.8 km) with the last transmission located near the Gambier Islands in French Polynesia. The results reinforce the findings that hawksbills are indeed migratory and capable of traveling long distances. Such migratory behavior highlights the need for regional cooperation in management and conservation.

INTRODUCTION

Geographic Setting

American Samoa is the only inhabited United States Pacific Territory south of the equator and is composed of five islands and two atolls in the South Pacific Ocean. It has a total land area of 197km^2 and waters of approximately 400,000 km^2 up to its exclusive economic zone (EEZ) (Figure 1). As of 2010, the total population of American Samoa was 55,519 (U.S. Census 2010). Pago Pago, its capital is located (14.27°S 170.70°W) in Tutuila - the main island of approximately 142 km^2, where most of the population resides (Figure 2). The remainder of the population resides in Aunu'u, a small island south of the eastern end of Tutuila and the Manu'a Island group, located approximately 100km east of Tutuila and is composed of Ofu, Olosega and Ta'u islands (Figure 2).

The two uninhabited atolls are Rose Atoll, locally called Muliava or Motu o Manu (island of birds), and is located about 140km east of Ta'u and Swains Atoll or Swains Island is about 350km north of Tutuila. Rose Atoll was declared a National Marine Monument in 2009 and commercial fishing is prohibited within a 50nm zone around the atoll. The waters around Swains were recently declared part of the National Marine Sanctuary of American Samoa (Figure 2). All land within Rose Atoll is protected as a National Wildlife Refuge.

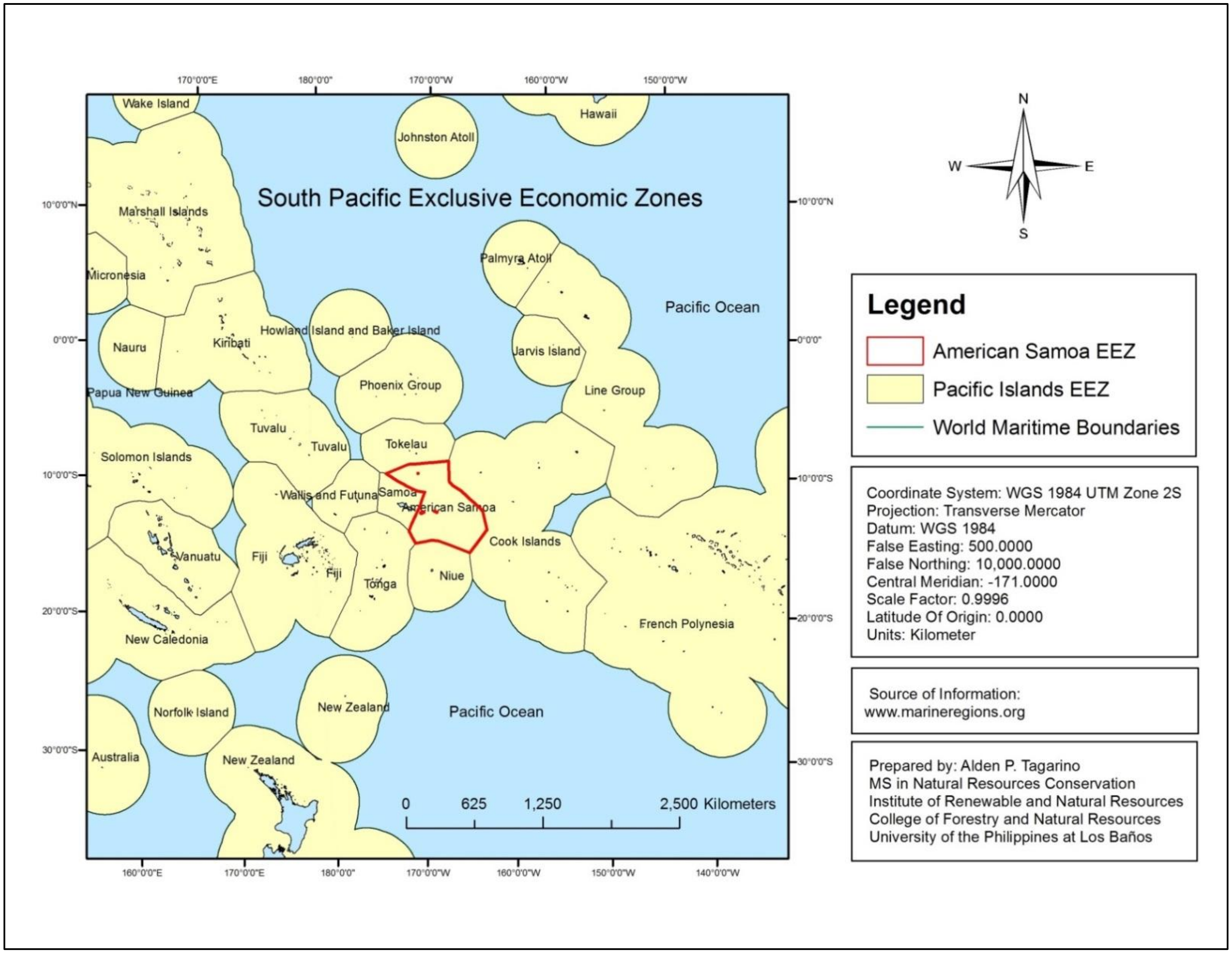

Figure 1. South Pacific Islands Exclusive Economic Zones.

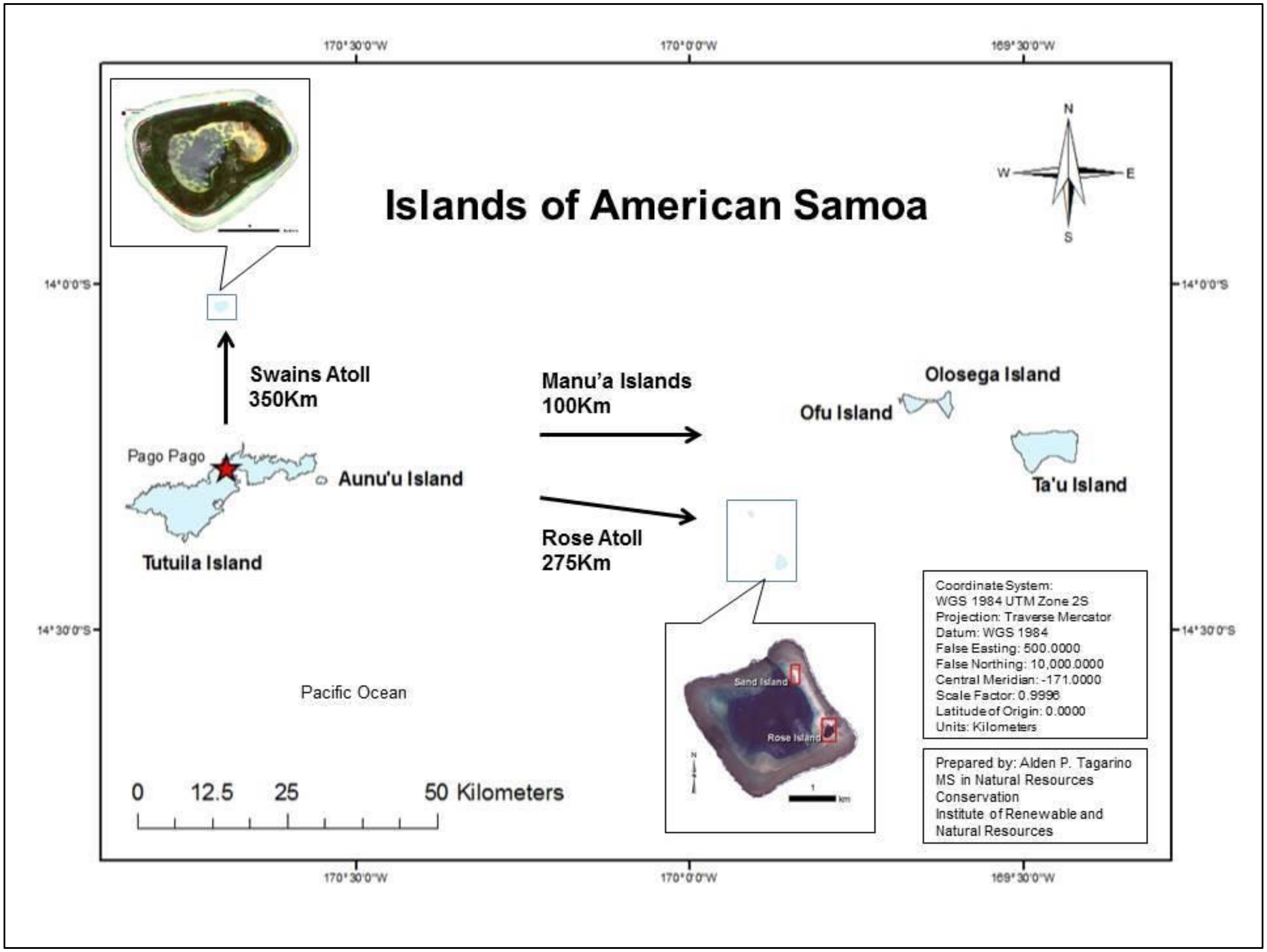

Figure 2. Islands of American Samoa.

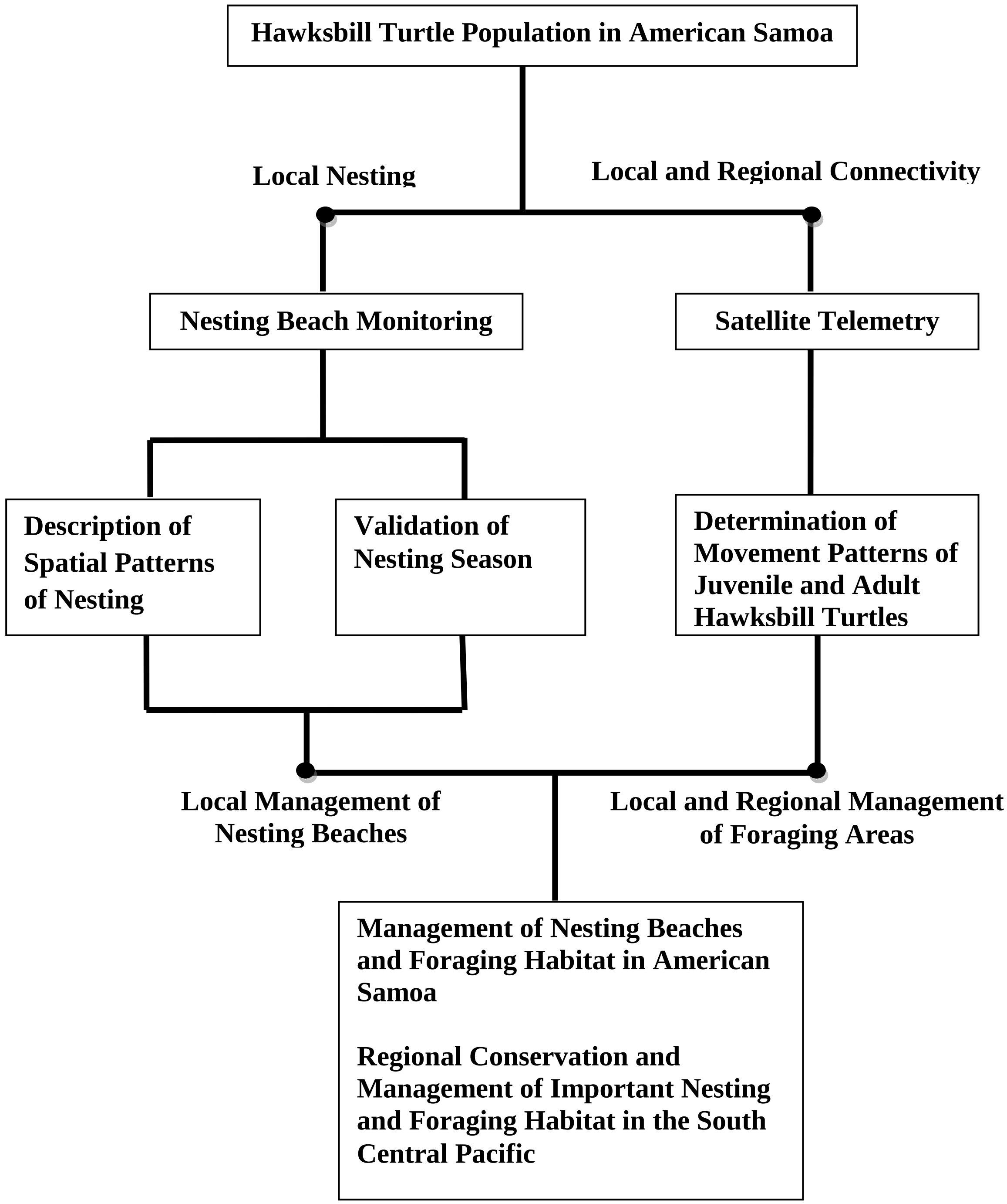

Figure 3. Research Framework

Background and Rationale of the Study

Studies on marine turtles have been conducted in American Samoa since the 1970's largely on an opportunistic basis (Utzurrum 2002). From 1980 to 1993, recorded studies on turtles have included satellite tagging, flipper tagging, residents survey, sighting and stranding reports. Overall, green turtles were satellite tagged at Rose Atoll (Balazs 1996), and between 1990 to 1996, a survey of residents and flipper tagging were conducted by Department of Marine and Wildlife Resources (DMWR) on Tutuila and Manu'a Islands (Tuato'o-Bartley et.al., 1993 and Grant et.al. 1997). Although no official sea turtle program existed in the Territory until 2004, data on flipper tagging, reported nesting and hatchling emergences as well as information on strandings were opportunistically collected. In 2004, with funds from the National Oceanographic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS), the Wildlife Division of the American Samoa Government's DMWR began to build a marine turtle conservation program in the Territory. The program was established with the philosophy that robust scientific information would lead to informed and sound conservation and management practices. It would also strengthen the Department's effectiveness in dealing with the public on marine turtle issues in collaborative stewardship of the shared migratory species with regional partners.

The DMWR Sea Turtle Project (2007-2013) was managed by the author of this thesis and included the following activities: flipper tagging, satellite tagging and tracking, tissue sampling for genetic studies, in-water surveys, nesting-beach remediation, community outreach, necropsies of dead turtles and policy implementation in collaboration with the DMWR Enforcement Division and NOAA Office of Law Enforcement. The Project also created and implemented a 24/7 sea turtle stranding response hotline, and the nesting beach monitoring activities in the Manu'a Islands, as well as the implementation of threats assessment of sea turtles in Swains Island from 2010 until 2012. All of the data generated were electronically recorded and stored. These were included in the Project's regular reports submitted to the grantors and are public information.

Currently, available sea turtle data for American Samoa have yet to be synthesized and analyzed for management and conservation purposes. The rules, regulations and guidelines for the enforcement of local policies need to be updated to identify important habitat for conservation strategies. A sound conservation plan for the species and its habitat is also yet to be formulated, so it is essential that the basic biological information of sea turtles be made available. In addition, there is an urgent need for these data to be synthesized into useful products for managers due to current and anticipated climate change impacts such as sea level rise. Concern over sea level rise has led to more of the territory's coastline being armored with sea walls, and currently there are plans to construct sea walls on the southern side of the east end of Tutuila island. Sea turtles play a vital biological role in maintaining biodiversity and productivity in the coastal ecosystem. Hawksbill turtles in particular are known to perform regulatory functions on the coral reefs (Leon and Bjorndal 2002) and are transporters of nutrients to nesting beaches (Bouchard and Bjorndal 2000). The nearshore benthic habitat of the Territory may perform an important role for the survival of hawksbill turtles as flipper tagging studies suggested that American Samoa waters are foraging grounds for juvenile hawksbill turtles (Grant et.al. 1997). Hawksbills have been documented to migrate short and long distances, and knowledge of their migratory behavior is necessary for an effective conservation plan in the Territory and the Pacific Region. Hawksbill turtles are the most commonly occurring species in Tutuila and Manu'a Islands and may have potential as an ecotourism attraction. However, little is known about the ecology and natural history of hawksbill sea turtles in American Samoa. This thesis aims to address these data gaps by presenting biological information on nesting and migration of hawksbill turtles in American Samoa.

Significance of the study

Of the seven (7) species of sea turtles in the world, four (4) species of turtles have been found in American Samoa. These are hawksbill (*Eretmochelys imbricata*), green (*Chelonia mydas*), olive ridley (*Lepidochelys olivacea*) and leatherback (*Dermochelys coriacea*) sea turtles. Hawksbill and green sea turtles occur regularly in American Samoa with hawksbills far outnumbering greens in around Tutuila (Utzurrum 2002). The majority of documented occurrences have been from the islands of Rose and Tutuila. Hawksbills have been documented to be nesting on Tutuila (Tuatoo-Bartley 1993, Utzurrum 2001), Ofu, Olosega, Ta'u and Swains Island (Craig pers. comm. 2007, NOAA Grant Report# NA08NMF4540506 and NA09NMF4540267).

Sea turtle population levels around the world are a concern, with the primary threats caused by human impacts (Lutcavage et.al. in Lutz and Musick 1997). The

International Union for the Conservation of Nature (IUCN) classifies the olive ridley and leatherback sea turtles as vulnerable, the green sea turtle endangered, and the hawksbill turtle as critically endangered. The US Endangered Species Act (ESA) classified the olive ridley turtle as threatened and the remaining three (3) species as endangered. In American Samoa, the hawksbill population is listed as endangered by the US ESA, while the green sea turtles are listed as threatened and currently proposed for up-listing to endangered status (www.federalregister.gov).

The importance of this study for the conservation of the critically endangered hawksbill turtles in American Samoa cannot be understated. Results of this study will provide baseline information on nesting and movements of hawksbill turtles in the Territory. These will aid and guide managers for implementing appropriate conservation practices and activities, especially at essential habitats of the species in the Territory and the Central Pacific Region. In addition, the information generated from this study will direct future research on hawksbill turtles in American Samoa.

The sea turtles in the American Samoa Territory are protected by local policies – the American Samoa Administrative Code (Chapter 09 Fishing Title 24 Ecosystem Protection and Development 24.0959 Sea Turtles) and Executive Order 005-2003; and the Federal Law – U.S. Endangered Species Act of 1973.

Objectives of the Study

The general objective of this study is to determine the spatial and temporal patterns of hawksbill turtle nesting and movements in American Samoa for the formulation and/or strengthening of public policy for effective management of the resource. Specifically, the study aims to:

- Determine and describe the nesting patterns and validate the nesting season of hawksbill turtles on Ofu and Olosega Islands in American Samoa.
- Assess the local and regional movements of juvenile and adult hawksbill sea turtles of American Samoa.
- Analyze and synthesize nesting and movement information of hawksbill turtles in American Samoa for policy and management implications.

REVIEW OF LITERATURE

Sea turtles have complex life cycles and are highly migratory (Lohmann et.al. 1997, Musick and Limpus 1997, Meylan 1999), resulting in large data gaps in turtle biology and ecology continuing. Protection of sea turtle nesting habitat, developmental areas, foraging grounds, and migratory routes is imperative for conservation (Crouse et.al. 1987, Mazaris et.al. 2006, Pendoley et.al. 2014, Pilcher et.al. 2014, Schofield et.al. 2013a). It is necessary to determine the biological information of the species to effectively manage and conserve the population in the Territory. Little is known about the ecology and natural history of hawksbill sea turtles in American Samoa; this literature review attempts to synthesize all known information on this topic in a format accessible to both managers and policy makers. The rationale behind this review is to address the current lack of awareness of the life history traits of the American Samoan hawksbill turtle population, which hinder local conservation efforts. By synthesizing all known information on this stock's pertinent life history the paper establishes the foundation for improved conservation practices. This synthesis also highlights the gaps in our knowledge in order to guide future research efforts.

Within American Samoa the earliest written accounts of hawksbill turtles can be traced to Rose Atoll. A historical summary of turtle observations on Rose Atoll from 1839 to 1993 primarily consisted of green turtles; of the 47 sources of information, only five entries mentioned hawksbill turtles (Balazs 1996). During the months of August to September, nesting on Rose Atoll consisted primarily of green turtles, with hawksbills seldom coming to nest (Graffe 1873). Hawksbills nest primarily from May-July on Rose

Atoll (ASG 1979, unpub.). One hawksbill was reported in the channel at Rose Atoll on October 29, 1978 and one juvenile (43cm) was tagged from the lagoon (Ludwig et.al. 1981). Lastly, on June 18, 1992, a 60-70 cm hawksbill was observed at a pinnacle near the channel in Rose Atoll (Flint 1992, FWS unpub. Report). This is the extent of the written historical accounts of hawksbill turtles on Rose Atoll.

To date there are only three peer reviewed publications on sea turtles in American Samoa (Tuato'o-Bartley et.al. 1993; Grant et.al. 1997; and Craig et.al. 2004) and one in independent Samoa (Witzell and Banner 1980). However, there are also unpublished reports available, including the survey of nesting beaches on Tutuila and Aunu'u (Saili 2006) as well as reports from the Ministry of Natural Resources and Environment in Western Samoa (Bell et.al. 2004, Momoemausu et.al. 2006, Ward and Asotasi 2008), and a head-starting project in 1974 by Witzell.

Based on surveys of turtle tracks in independent Samoa, hawksbill turtles nest from September to July with the peak season between January and February (Witzell and Banner 1980). According to Bell et.al. 2004, Momoemausu et.al. 2006, and Ward and Asotasi 2008, there has been a steep decline in the hawksbill nesting activities on some nesting beaches in Samoa, and a general declining trend in nesting activity from the early 1990's to 2008. Sea turtle population declines are primarily due to human activities and coastal degradation of the nesting beaches (Lutcavage et.al. in Lutz and Musick 1997; Mortimer and Donnelly 2007). Over 100 nests were recorded on average during nesting seasons in the 1990's, however by the 2007-2008 season there were less than ten nests found in the monitored beaches (Ward and Asotasi 2008). These studies recommended satellite tagging to address the paucity of data regarding migration of hawksbill turtles in

Samoa (Ward and Asotasi 2008). To date there is only one documented hawksbill migration in the Central Pacific, migrating from Samoa to Fiji (SPREP 2007).

Based on standardized interviews with 155 residents of 58 villages, a rough estimate of 120 green and hawksbill turtles combined, nest throughout American Samoa per year (Tuato'o-Bartley et.al. 1993). According to Tuato'o-Bartley et.al. 1993, the population of nesting females in the Manu'a Islands was estimated at 30 and 50 for Tutuila Island while Swain's Island had very limited nesting activity, approximately 1-5 nesters, with the remainder nesting at Rose Atoll. A year round occurrence of nesting on Tutuila is suggested, however, there are no defined nesting periods and none of the nesting beaches were identified by the study (Tuato'o-Bartley et.al. 1993). According to Utzurrum 2002, the villages of Tula, Alao, Onenoa, Sailele and Masefau (all located at the eastern tip of Tutuila) were identified as having consistent records of hatchlings and adult female hawksbills from 1995-2002. A more seasonal nesting period is suggested based on the appearance of hatchlings from January to May (Utzurrum 2002).

Flipper tagging activities have been conducted in the territory since the 1970's. In the early 1990's, the turtle sightings around Tutuila consisted primarily of hawksbills and green turtles. (Tuato'o-Bartley et.al. 1993). According to Grant et al. 1997, juvenile hawksbill and green turtles exhibited short distance movements and high growth rates, based on their recapture locations, however, the tag return rates in the study were low. Both species of juvenile turtles observed in the coastal waters are likely foraging, however little in-water observational data has been published and thus their activities are poorly known and are in need of further study (Grant et.al. 1997).

Distribution of hawksbill turtles is centered around coral reef areas (Witzell 1983). Juvenile hawksbill turtle habitat have been known to be closely associated with the nearshore areas such as coral reefs, hard-bottom areas, estuarine areas (Musick and Limpus 1997) and even seagrass beds that may serve as peripheral habitats (Bjorndal and Bolten 2009). They recruit to developmental areas from 20 to 25cm SCL in the Caribbean to >35cm in the Indo-Pacific (van Dam and Diez 1998, Limpus 2008) foraging in the coral reef areas and feeding primarily on sponges (Meylan 1988, Blumenthal et.al. 2009). Flipper tagging recaptures studies conducted in the Territory on juvenile hawksbills (CCL 35.5 to 57.2 cm) exhibited high growth rates of about 4.5cm/year (Grant et.al. 1997) indicating importance of the nearshore benthic habitat in American Samoa, Juvenile hawksbill turtles have been observed resting in sandy bottom areas, foraging and feeding on sponges and in the coral reef areas around Tutuila, Ofu and Olosega islands (personal observation, and DMWR Unpublished Data). According to Meylan 1988, in the Caribbean, spongivory of hawksbills may influence succession and diversity of the reefs. In the Florida Keys, hakwsbills have been documented to feed on demosponges and a corallimorphian, and have a positive indirect effect on corals and overall reef benthic diversity (Leon and Bjorndal 2002).

According to Craig et al., 2003, the previous satellite tracking of green turtles from Rose Atoll and flipper tagging data from the region demonstrate potential for shared populations among American Samoa, Fiji, and other South Pacific countries. Furthermore, Craig et al., 2003, found that six of the seven turtles remotely monitored via satellite migrated westward to Fiji while one travelled east to French Polynesia. All the turtles stayed in the vicinity of Rose for about two months before migrating, and on average the turtles migrated about 1600kms at a speed of 1.8km/hr and spent 40 days in transit (Craig et.al. 2003). Juvenile hawksbill turtles are known to exhibit localized movement or short-range migrations (Maylen 1999 and Parker et.al. 2009). According to Parker et.al. in 2009, there were only few studies on post-nesting hawksbill migrations using satellite telemetry before 1995, and since then the usage of satellite telemetry increased. In 1999 Maylen presented flipper tagging evidence that adult post-nesting hawksbill have been documented to migrate long distances of up to 2000kms in the Caribbean Region. However, post nesting hawksbills in the eastern Pacific have been documented migrating only over a short distance to their foraging ground in mangrove estuaries (Gaos et.al. 2011). Migration of post nesting hawksbill turtles occurring in the Territory is unknown, as well as the foraging grounds and the movement of male hawksbills. Very limited information is available regarding male hawksbill migration. According to a mark-recapture study by Nietschmann 1981, male hawksbills are highly migratory. However, in a study by van Dam et.al. 2008 in Puerto Rico, male hawksbills exhibited short distance movements and one travelling up to 476 kilometers.

Documentation of large-scale movements and information on phylogeographic relationships among populations are essential for the conservation and management of migratory species such as sea turtles. The transboundary and geopolitical issues inherent in the protection and management of sea turtles require knowledge of connectivity among seemingly geographically separated populations. Ensuring turtles' ability to move across different geographic landscapes or seascapes is critical for maintaining short-term regional populations, and to allow for the future shifts in habitat use throughout their life cycles due to climate change impacts to these environments.

MATERIALS AND METHODS

Research Data

This study will make use of primary data/information on the hawksbill sea turtles in the American Samoa Territory (Appendix 1). The data and information were generated by the various research and sea turtle monitoring projects led by the author of this study under the Department of Marine and Wildlife Resources of the American Samoa Government, funded by the NOAA/NMFS Unallied Management Grant Program, NOAA/NMFS Unallied Management Grant: Award No. NA04NMF4540126, NA06NMF4540217, NA09NMF4540267 and NA10NMF4540387 through the NOAA Pacific Islands Regional Office. All sea turtle research activities were conducted under United States Fish and Wildlife Service (USFWS) Permit Numbers TE-094808-0 and TE-094808-1. The period covered, locations and the procedures on how the available data/information was generated are discussed in the following paragraphs:

Hawksbill Nesting Beach Monitoring

Four nesting beaches were identified through initial data collection before December 2009 from village workshops, key informant interviews and anecdotal accounts of nesting. These nesting beaches included the southern end of Olosega beach across from the dumpsite, Asaga beach, Vaoto beach and Toaga beach. Preliminary surveys at Mafafa and Agaputuputu beach on the northern side of Ofu island, were conducted in January 2011 and February 2012. After thorough checking of all the tracks leading up Agaputuputu beach and digging located turtle pits, we found that the beach is unsuitable for nesting due to the shallow sand on top of rocks. Mafafa beach on the other hand was confirmed to be a nesting beach and included in the monitoring activities beginning in August 2012.

Morning beach walks covered a consistent distance for the survey, start and end locations are detailed in Table 1. The five nesting beaches covered a total of approximately 3,635 meters of coastline. Regular surveys were conducted by only one nesting beach monitor responsible for covering all the nesting beaches; this man power constraint is the main limitation of the nesting beach data set. However, the survey design was adjusted to compensate for limited personnel by having the beach monitor conduct weekly surveys until the first crawl of the nesting season began before switching to daily beach walks. This survey design adjustment accounts for the low number of survey days compared to a daily monitored beach throughout the year. A total of 1,626.78 kilometers of coastline was covered by the survey, the summary of the nesting beach monitoring effort are described in Table 2.

Table 1. Beach monitoring start and end locations.

BEACH	START		END	
Olosega	14.183973°S	169.619026°W	14.185316°S	169.617948°W
Asaga	14.168407°S	169.632562°W	14.167372°S	169.633898°W
Vaoto	14.183230°S	169.674120°W	14.184084°S	169.633898°W
Toaga	14.179458°S	169.655727°W	14.170204°S	169.640096°W
Mafafa	14.167475°S	169.641704°W	14.167806°S	169.643976°W

Table 2. Summary of nesting beach monitoring effort.

CATEGORY	NESTING BEACH				
	Olosega	Asaga	Vaoto	Toaga	Mafafa
Length of beach (Kilometers)	0.200	0.185	1.00	2.00	0.25
Number of survey days	307	348	408	527	156
Total distance covered (Kilometers)	61.4	64.38	408	1054	39

From December 2009 to June 2013, regular monitoring of identified nesting beaches in Ofu and Olosega Islands were conducted on a weekly basis. Weekly early morning beach walks throughout the year were made until the first crawl of the season was sighted. Subsequently, walks were conducted daily through the season until fourteen days after the last sighted crawl. After this, weekly early morning walks resumed. Walks served to both quantify nesting activity by documenting nesting and non-nesting emergences as well as hatchling emergence and inform schedules of night time follow-up surveys. Specific day time activities recorded included: crawl species identification (ID); nesting or non-nesting emergence, and location of nest as determined using a Gamin 75CSX or 60CSX GPS. Toaga, Vaoto and Asaga beaches on Ofu Island were all monitored from December 2009 to June 2013, Olosega beach was monitored from December 2009 until August 2012 only, due to the erosion of the whole nesting beach caused by high surges. Before and after photos of the nesting beach were taken (Appendix Figures 1 & 2).

Nesting beach habitat mapping using a Trimble Geoexplorer 3 GPS receiver was conducted on May 18 – 19, 2010 and March 16 – 17, 2012. Street light locations were also collected via Trimble Geoexplorer 3 to document effects of light near the nesting beaches. Active nests during morning surveys were monitored opportunistically at night to characterize nesting females (by collecting morphometrics) and select post-nesting candidates for satellite tag attachment. Clutch inventory was done four days after the hatching date to determine hatching and emergence success.

Satellite Tagging and Tracking via ARGOS

Twelve healthy juvenile and post nesting sea turtles were satellite tagged from 2006 to 2011. They were either hand captured in-water, collected by enforcement officers or post nesting sea turtles caught on the beach during overnight monitoring activities in Tutuila, and Manu’a Islands.

We deployed Telonics A100 and A1010 satellite tags with six:twelve hour on:off duty cycle transmission via ARGOS satellite system. The Argos location measurements use the Doppler Shift on deployed transmitter signals which are used to calculate the locations of transmitters, following methodology of the CLS America, Inc. website http://www.argos-sytem.org/. The following satellite attachment method was adapted from Balazs et.al. 1996. Previously labeled transmitters were prepared by removing the magnet and placing masking tape over the screw heads (saltwater switch). The carapace was thoroughly cleaned at the placement site of the satellite tag and fiberglass cloth. The carapace was cleaned using scrub brush and fresh water and dried thoroughly with a towel. Working area on the carapace was sanded with coarse sandpaper, wiped again with freshwater and air dried. The elastomer was prepared by adding the catalyst and mixing. Then the elastomer was poured onto the bottom of satellite tag and placed on the second vertebral scute. After the elastomer was cured, the excess was cut away. A towel was placed over the turtle's head to protect its eyes during the next step. Wearing latex gloves, the resin and catalyst were mixed for 60 seconds. The resin was brushed onto the transmitter and carapace, pre-cut fiberglass cloths were placed onto the transmitter, and the cloths soaked with more resin using a paintbrush, allowing it to dry until only slightly tacky. The process of mixing of resin and the placing of more pre-cut fiberglass cloth was repeated for two additional layers. The tape covering the saltwater switch contact heads were then removed using a small knife. The turtles' carapace was labeled by lightly sanding a code and painting them with white appliance paint. After about an hour the sea turtles were released at their original capture site. Positions/locations of the turtles were mapped using ARCGIS 10.

Methods of Analysis

Spatial patterns of nesting were analyzed and mapped using ARCGIS 10 to better visualize and understand clustering patterns. The Average Nearest Neighbor tool of the Spatial Statistical Toolset of ARCGIS 10 was used to calculate the nearest neighbor index based on the average distance of each nest to the neighboring nest. This identified beaches where significant clustering or significantly dispersed nests occured. Five results were given by the average nearest neighbor analysis namely: observed mean distance, expected mean distance, nearest neighbor index, z-score and p-value.

The Point Density tool of the Spatial Analyst Toolset or extension was used to examine the hawksbill turtle nest locations. Density analyses determine where the locations of the nesting activity and nests are concentrated or clustered based on the clutch size.

Temporal analysis was conducted with the NCSS 10 statistical software. Circular statistics was used to determine the mean direction and the test of uniformity conducted by using the Rayleigh Test to validate and determine nesting seasonality. Month of the year data are represented by integers using the relationship; 1 = January, 2 = February, and so on. The integers are then converted to degrees and the Rayleigh Test of uniformity conducted with the null hypothesis that the circular distribution is uniform. The Rayleigh Test is the score test and the likelihood test for uniformity.

ARCGIS 10 was used to describe the frequency and spatial distribution of nests on the nesting beaches on Ofu and Olosega Islands, including the movements of the satellite tagged hawksbill turtles in its migration routes. Possible foraging and feeding areas can be identified from the juvenile and adult hawksbill turtle movements. Point Density Tool was also used to analyze the migration of the hawksbill turtle with the longest migration to determine foraging and feeding areas along the migration route.

Nest inventories were conducted to determine the hatching and emergence success. Clutch is the number of eggs laid into the nest excluding the yolkless eggs or eggs smaller than half the diameter of normal eggs (Miller, 1999). Clutch size was calculated using, Clutch = E + L + D + UD + UH + UHT + P, assuming all hatchlings were intercepted. If not all hatchlings were intercepted, E was estimated by using E = (S -

(L + D)). The categories and definitions of nest contents used as defined by Miller, 1999, are detailed in Table 3.

Table 3. Categories and definitions of nest contents (Miller, 1999).

CATEGORY	DEFINITION
E = Emerged	Hatchlings leaving or departed from nest
S = Shells	Number of empty shells counted (>50% complete)
L = Live in nest	Live hatchlings left among shells (not those in neck of nest)
D = Dead in nest	Dead hatchlings that have left their shells
UD = Undeveloped	Unhatched eggs with no obvious embryo
UH = Unhatched	Unhatched eggs with obvious embryo (excluding UHT)
UHT = Unhatched Term	Unhatched apparently full term embryo in egg shell or pipped (with a small amount of external yolk material)
P = Depredated	Open, nearly complete shells containing egg residue

Hatching success, emergence success and annual averages were calculated. Hatching success and emergence success was determined using the nest categories in Table 1 and the following formula by Miller, 1999:

Hatching Success (%) = $$\frac{\#Shells}{\#Shells+\#UD+\#UH+\#UHT+\#P}\ x\ 100$$

Emergence Success (%) = $$\frac{\#Shells-(\#L+\#D)}{\#Shells+\#UD+\#UH+\#UHT+\#P}\ x\ 100$$

Analysis of variance (ANOVA) and T-Test were used to analyze the effects of the location of nests across the beach, nest habitat location, predation, and inundation by water on the hatching and emergence success.

RESULTS

Ofu and Olosega Islands Nesting Patterns

A total of 36 nests were documented from December, 2009 to June, 2013 from the five nesting beaches on Ofu and Olosega Islands, 33 were from hawksbill turtles and three were from green turtles. Two of the green turtles nests were located on Vaoto beach and one on Toaga beach. Of the 64 non-nesting emergences, 59 were tracks of hawksbill turtles and five were of green turtles. Percent of crawls that led to successful nesting, including the four hatchling emergences from undetected nests, is 39% for hawksbills and 37.5% for green turtles. Toaga beach had the highest number of nests, a total of 17, and one nest in Asaga beach, which was the least number of nests found of the beaches monitored (Figure 4). Four hatchling emergences were recorded from undetected nests, hatchlings from these nests were found under street lights (Table 4, Figures 5 - 7).

Fifty percent of crawls led to successful nesting at the monitored beach in the eastern section of Olosega beach, excluding the nest and non-nesting emergences on the beach across the village. Including the two hatchling emergence events (Table 4), Asaga beach exhibited 30% nesting emergence success. Toaga beach had 36% including the hatchling emergence event (Table 4), and Mafafa beach had the highest successful nesting emergence at 52.4%.

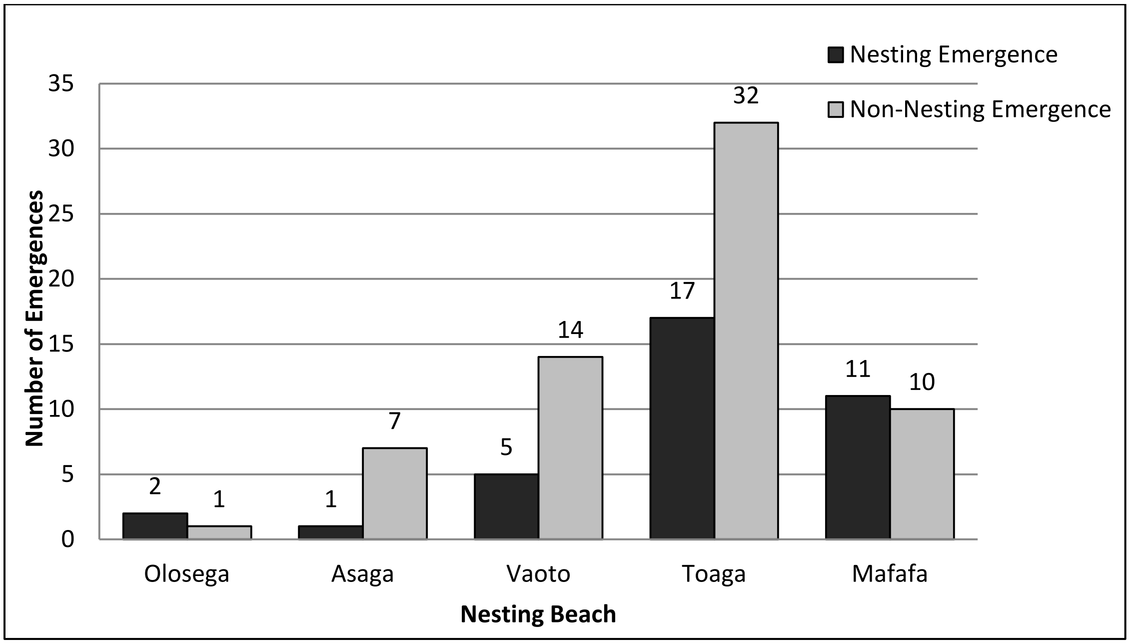

Figure 4. Nesting and non-nesting emergence at Ofu and Olosega islands, American Samoa from December, 2009 to June, 2013.

Table 4. Hawksbill turtle hatchling emergence (HE) found under street lights.

FIELD ID	DATE OBSERVED	BEACH	LOCATIONS		NO. OF HATCHLINGS
HE	20-Feb-10	Toaga	14.169869°S	169.641737°W	40
HE	8-Apr-11	Vaoto	14.183868°S	169.671907°W	4
HE	2/28/2013	Asaga	14.167972°S	169.633499°W	no estimate
HE	3/15/2013	Asaga	14.167959°S	169.633268°W	30-40

Data indicate that if each documented hatchling emergence event on Tutuila Island from October 2007 to March 2013 originated from a single nest (Appendix Table 1). The number of hatchling emergences is equal to 15 nests from six nesting beaches,which is less than half the documented nesting on five beaches in Ofu and Olosega Islands.

Spatial Patterns of Nesting

Olosega Beach Nesting

The nesting beach monitored in Olosega island is located at the south western end of the island, towards the end of the road across the Olosega landfill (Figure 5), and is 200 meters in length (Table 2) bound by rocky shores on both ends. The southern half of the beach is composed of 95% sand and 5% coral rubble while the northern half is composed of 60% sand and 40% coral rubble (Figure 5). The beach vegetation above the high tide line is composed mainly of grass, beach pea and other creeping vegetation. Only one hawksbill nest located in the vegetation was recorded on the monitored section of this beach (Figure 5 and Appendix Table 2). There were signs of depredation on the day the nest was laid. The eggs in the nest were exposed and small pieces of egg shells were found on top of the sand around the clutch. On its second day of incubating, the nest was disturbed again, this time leaving a thin layer of sand on top of the clutch and dog tracks were observed around the nest. The nest was also inundated by water due to the high surge a day before it was dug up for inventory.

One non-nesting emergence and a second nest was documented on the northern section of Olosega beach right across the Village (Figure 5), when the fresh tracks were reported by residents on April 25, 2011. The hawksbill nest was located above the high tide line, beside a coconut tree and under its crown. It was inundated by water during high surges from June 15-18, 2011. This beach across the Village of Olosega was not identified as nesting beach and there were no anecdotal accounts of nesting reported during preliminary data gathering.

A non-nesting emergence occurred on January 10, 2011, when a set of green turtle tracks that led to a body pit in grassy vegetation under the canopy of coconuts was reported by the villagers (Appendix Table 3). However after a thorough check of the body pit and surrounding area, the nesting beach monitor did not find any nest and determined the tracks was a non-nesting emergence.

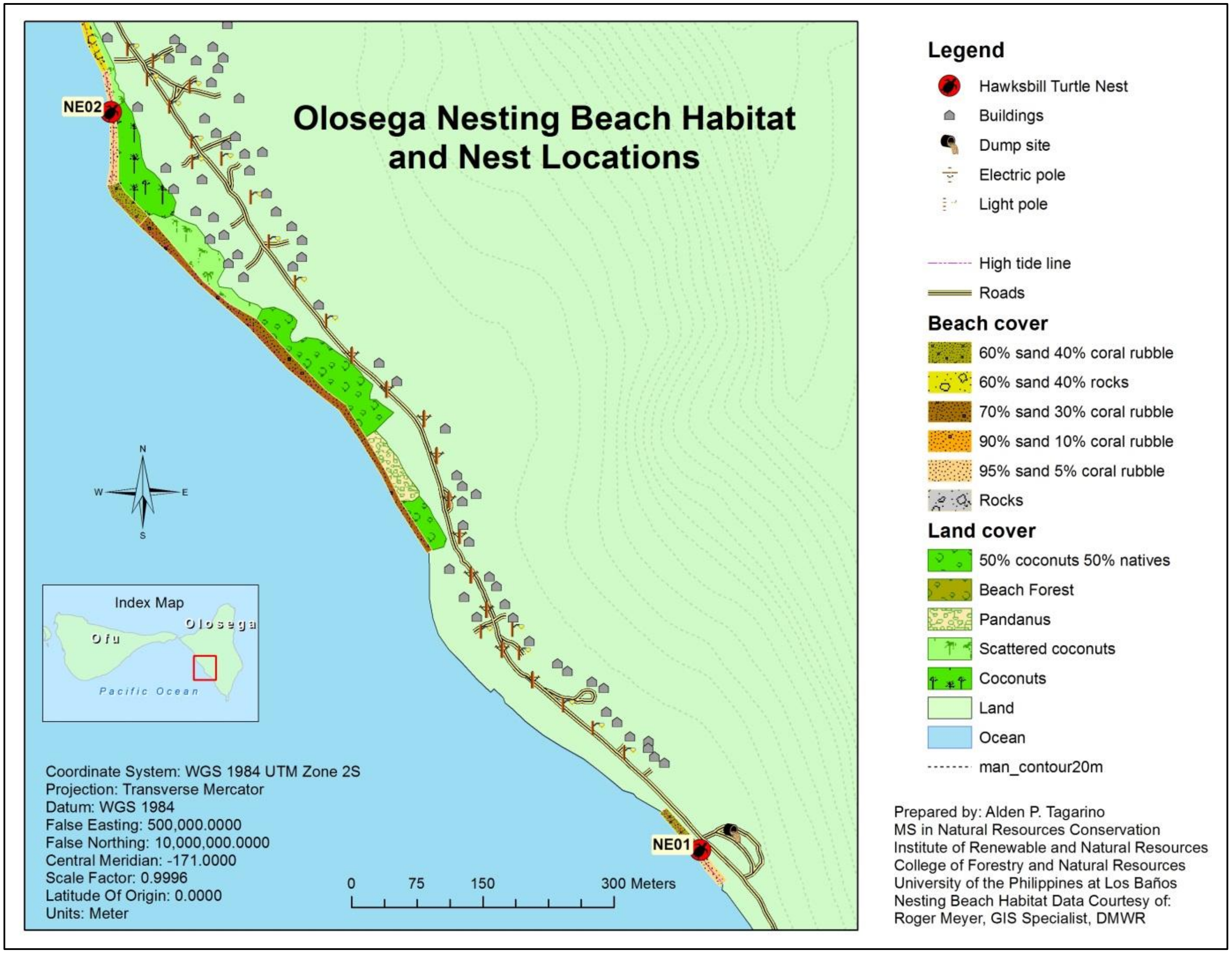

Figure 5. Olosega nesting beach habitat and nest locations.

Asaga Beach Nesting

One nest (NE01) and two hatchling emergence events (HE01 and HE02) from undetected nests were documented on Asaga beach on Ofu Island (Figure 6), as well as seven unsuccessful attempts to lay eggs by hawksbill nesters (non-nesting emergences) (Appendix Table 3). Hatchlings were observed in the yard of Asaga Inn and emerging from the nest on April 14, 2011 (HE01), and the only nesting activity previously recorded in this area were hawksbill tracks and empty egg chambers recorded on February 21, 2011(HE02) several meters away from the nest. Hatchling emergence events were documented on February 28, 2013 and March 15, 2013. The hatchlings were from the second and third nests of the season in this nesting area, however, neither of the nests were located. On both occasions, hatchlings were found under the street light across the road from the beach (Figure 5). Asaga beach is about 70% sand and 30% coral rubble (Figure 6). The only nest located (NE01) was in an open area without vegetation about one meter from the doorstep of one of the rooms at Asaga Inn across the street from the beach (Figure 6).

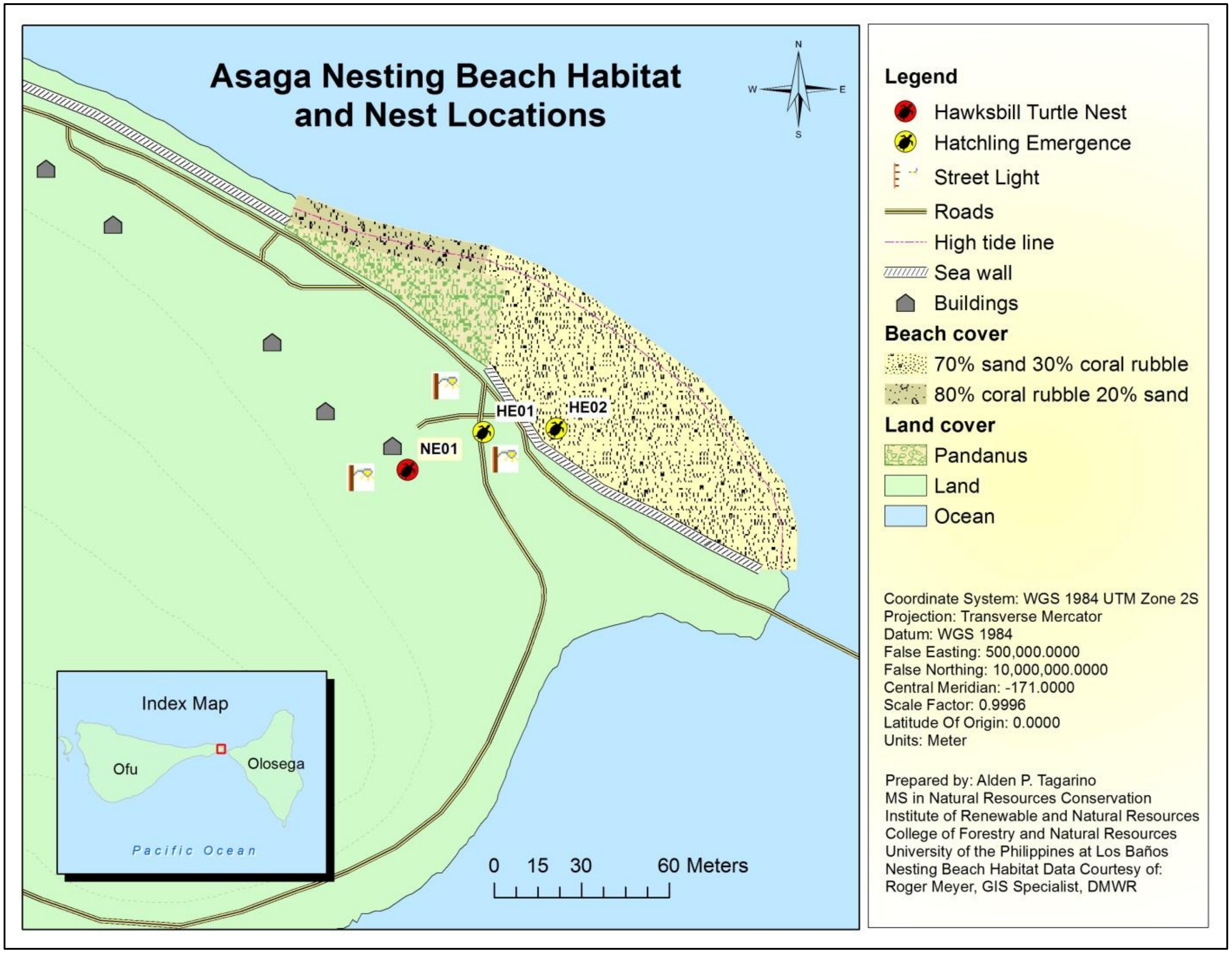

Figure 6. Asaga nesting beach habitat, nest and hatchling emergence locations.

Vaoto Beach Nesting

Vaoto beach is composed of 95% sand 5% coral rubble, and is located at the southernmost point of Ofu Island, to the north of which is the airport (Figure 7). Three hawksbill and two green turtle nests including one hatchling emergence found under a street light were documented on this beach during the study (Figure 7 and Appendix Table 2). The three hawksbill turtle nests, NE01, NE02, NE04, were located above the high tide line, one at the top section of the beach slope while two were behind the beach slope. Both nests above the beach slope were located in vegetation, one in grass and creeping vegetation, and the other in the beach forest vegetation of mostly *Scaevola* sp. and grass. The nest on the beach slope was located in grass and creeping vegetation. Green turtle nest locations, NE03 and NE05, are both above the high tide line and beach slope, one was in vegetation of grass and vines while the second nest is located under vegetation of the beach forest. The second green turtle nest was inundated by water for about 10 days in June 2011 due to high surge. Four hawksbill hatchlings were found under the street light across the western end of the runway on April 8, 2011 (Table 4 and Figure 7).

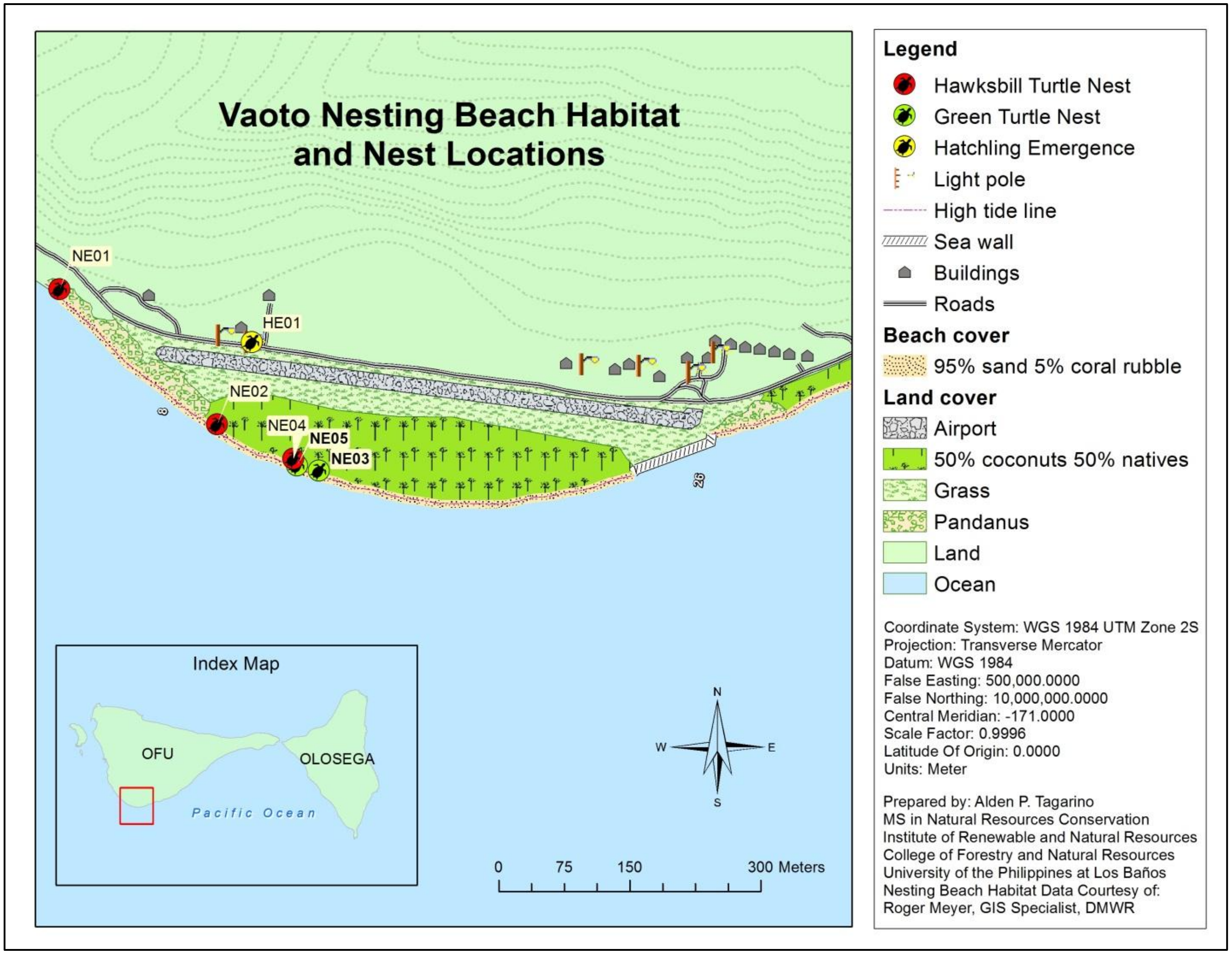

Figure 7. Vaoto nesting beach habitat, nest (NE) and hawksbill hatchling emergence (HE) locations.

Toaga Beach Nesting

Toaga beach is the longest of the five nesting beaches monitored at two kilometers (Table 3), and is located at the south eastern section of Ofu Island (Figure 8). A total of 17 nests were documented on this beach, 16 hawksbills and one green turtle nest, NE12. One nest was a previously undetected nest, NE17 (Table 4, Appendix Table 2). Hatchling emergence from an undetected nest was recorded on February 20, 2010 (Table 3). The hatchlings were found under the active light post by the house at the eastern end of the nesting beach (Figure 8). Approximately 40 hatchlings were released back to the ocean by the residents who found them under lights. The nest locations across the beach and nest location habitat are described in Table 4 and locations along the beach in Figure 8. About 70% of nests were laid under native vegetation, primarily *Scaevola sp, Hibiscus tiliaceus, Terminalia sp. and Pandanus sp.*, with the remainder comprised of 12% in grass and vines, 6% under coconut trees and the remaining12% without any vegetation cover. Four nests were inundated by water due to high surge, NE10 on September 2010, while NE11 and NE12 were inundated on November 2010, and lastly NE13 was inundated on June 2011.

Table 5. Toaga beach nest distribution by location across the beach and nest habitat.

NEST #	NEST LOCATION ACROSS BEACH		NEST LOCATION HABITAT		PREDATED	INUNDATED BY WATER
	High Tide Line	Slope	Vegetation Cover	Vegetation		
NE01	Above	On	None	NA	No	No
NE02	Above	Behind	Under Vegetation	*Scaevola sp.*	No	No
NE03	Above	On	Under Vegetation	*Scaevola sp.*	No	No
NE04	Above	On	None	NA	No	No
NE05	Above	On	Under Vegetation	*Cocos nucifera*	No	No
NE06	Above	On	Under Vegetation	*Scaevola sp.*	No	No
NE07	Above	On	Under Vegetation	*Scaevola sp. and Hibiscus tiliaceus*	No	No
NE08	Above	Behind	Under Vegetation	*Scaevola sp. and Hibiscus tiliaceus*	No	No
NE09	Above	Behind	Under Vegetation	*Scaevola sp. and Hibiscus tiliaceus*	No	No
NE10	Above	On	Under Vegetation	*Scaevola sp.*	No	Yes
NE11	Above	On	In Vegetation	Grass and vines	No	Yes
NE12	Above	On	Under Vegetation	*Scaevola sp. and Cocos nucifera*	No	Yes
NE13	Above	Behind	Under Vegetation	*Scaevola sp.*	No	Yes
NE14	Above	On	In Vegetation	Grass and vines	No	No
NE15	Above	Behind	Under Vegetation	*Scaevola sp. and Pandanus sp.*	No	No
NE16	Above	On	Under Vegetation	*Terminalia sp.*	No	No
NE17-UN	Above	On	Under Vegetation	*Terminalia sp.*	No	No

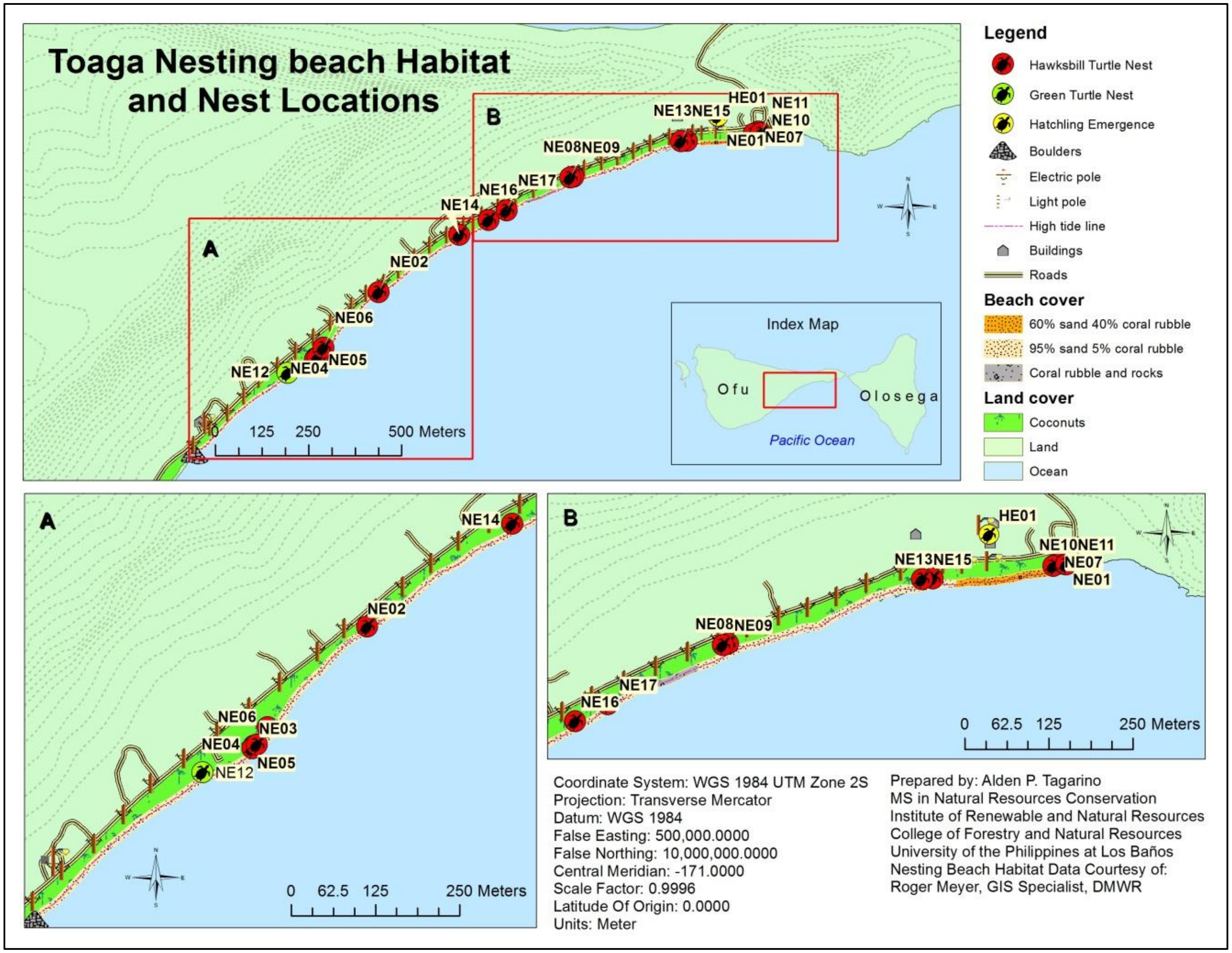

Figure 8. Toaga nesting beach habitat and nest location

Mafafa Beach Nesting

Mafafa nesting beach is 250 meters long (Table 3), composed of 75% sand and 25% coral rubble, and is located on the northern section of Ofu Island (Figure 9). On January 12, 2011 during a beach mapping survey, two non-nesting emergences and four nests were opportunistically documented on this beach, which confirmed it as a nesting beach for hawksbill turtles (Appendix Table 4). February 8, 2012, six nests and one non-nesting emergence were documented on this beach, and in August of 2012 Mafafa beach was included in the nesting beach monitoring survey, replacing Olosega beach. The nest locations across the beach and nest location habitat are described in Table 5 and locations along the beach in Figure 9. 45.4% of the nests were laid under the native *Scaevola* sp. and *Hibiscus tiliaceus*, with 27.3% in grass and creeping vegetation, and 27.3% under coconut trees. One nest was completely depredated, NE06, 100% of the eggs were lost to predators like crabs as evidenced by the crab holes found directly on top of the clutch while it was developing. One nest on this beach, NE07, was also inundated by water on March 2013.

Table 6. Mafafa beach nest distribution by location across the beach and nest habitat.

NEST #	NEST LOCATION ACROSS BEACH		NEST LOCATION HABITAT		PREDATED	INUNDATED BY WATER
	High Tide Line	Slope	Vegetation Cover	Vegetation		
NE01	Above	Behind	Under Vegetation	*Scaevola sp.*	No	No
NE02	Above	Behind	In Vegetation	Grass and vines	No	No
NE03	Above	Behind	In Vegetation	Grass and vines	No	No
NE04	Above	Behind	Under Vegetation	*Cocos nucifera*	Yes	No
NE05	Above	Behind	Under Vegetation	*Scaevola sp.*	No	No
NE06	Above	Behind	Under Vegetation	*Scaevola sp.*	Yes	No
NE07	Above	Behind	Under Vegetation	*Cocos nucifera*	Yes	Yes
NE08	Above	Behind	Under Vegetation	*Cocos nucifera* and vines	No	No
NE09	Above	Behind	Under Vegetation	*Hibiscus tiliaceus*	No	No
NE10-UN	Above	Behind	In Vegetation	Grass and vines	No	No
NE11	Above	Behind	Under Vegetation	*Scaevola sp.*	No	No

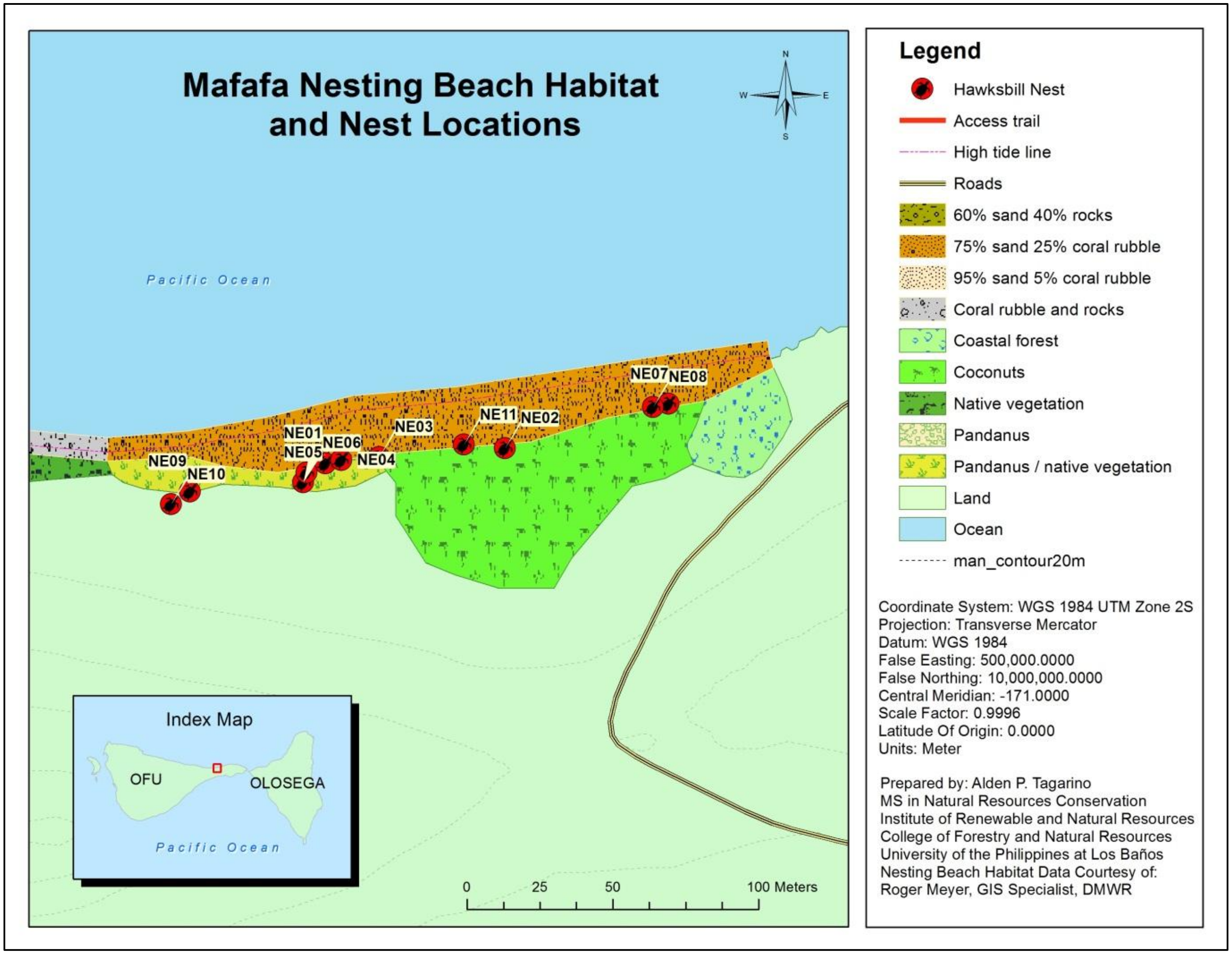

Figure 9. Mafafa nesting beach habitat and nest location.

Nest Density Analysis

Analysis of the density of nests indicates high density of nests towards the eastern end of Toaga beach. The western most nests were found at the widest area of the beach from the road about midway as shown in Figure 10, inset A. Density analysis on Mafafa beach shows high density in the native vegetation area on the western section of the beach (Figure 11). Visual inspection of the maps generated from nest locations and nesting beach habitat of Toaga and Mafafa beach clearly shows the areas of the beach with high nest densities. Nest density analysis conducted with ARCGIS 10 (Figure 10 and 11) provides a better visualization of densities of nests on the nesting beaches. Due to the low number of nests on Olosega (n=2), Asaga (n=1), and Vaoto (n=3) beaches, nest density analysis was only conducted on Toaga beach (n=17) and Mafafa beach (n=11).

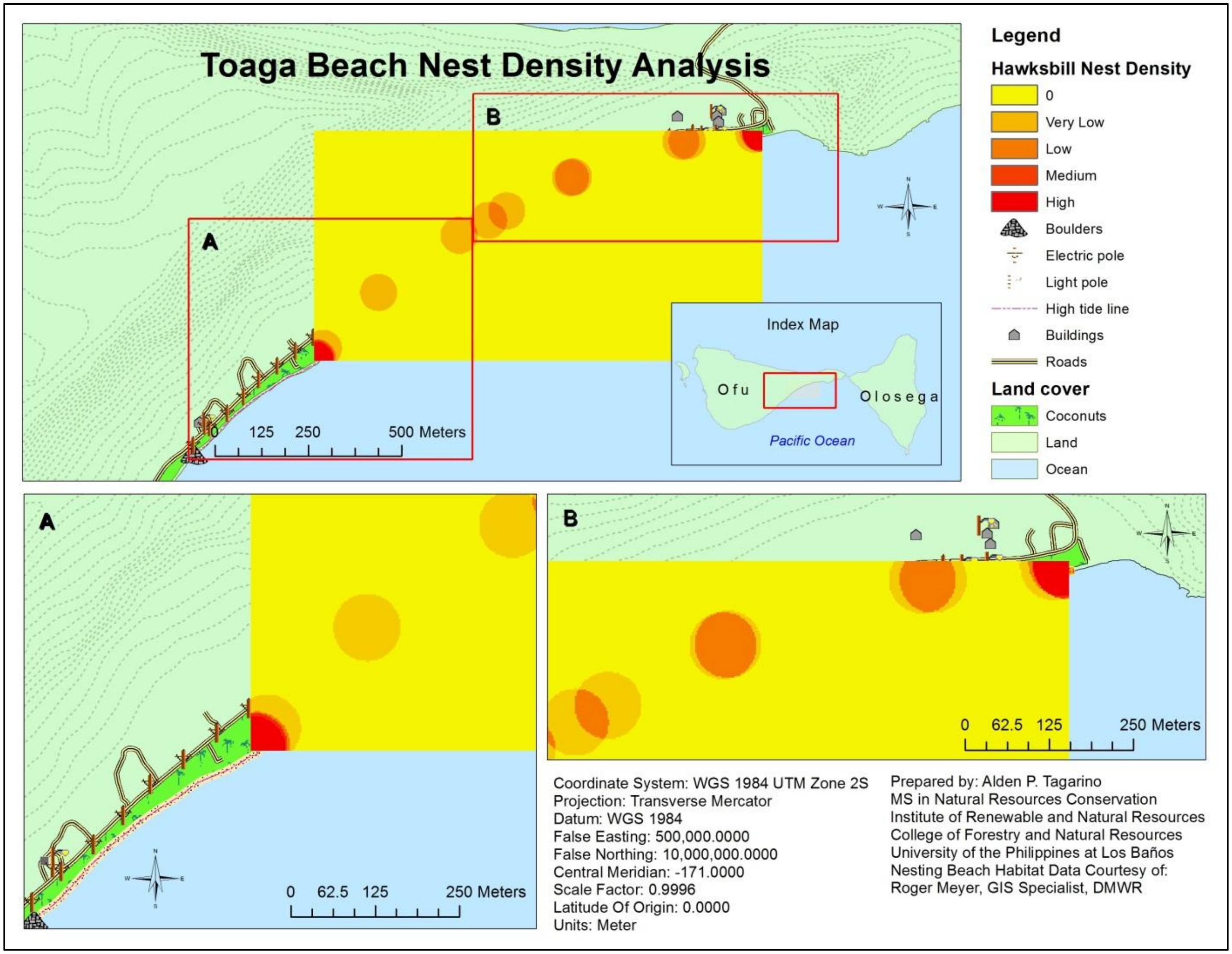

Figure 10. Point density analysis of nests at Toaga beach in Ofu.

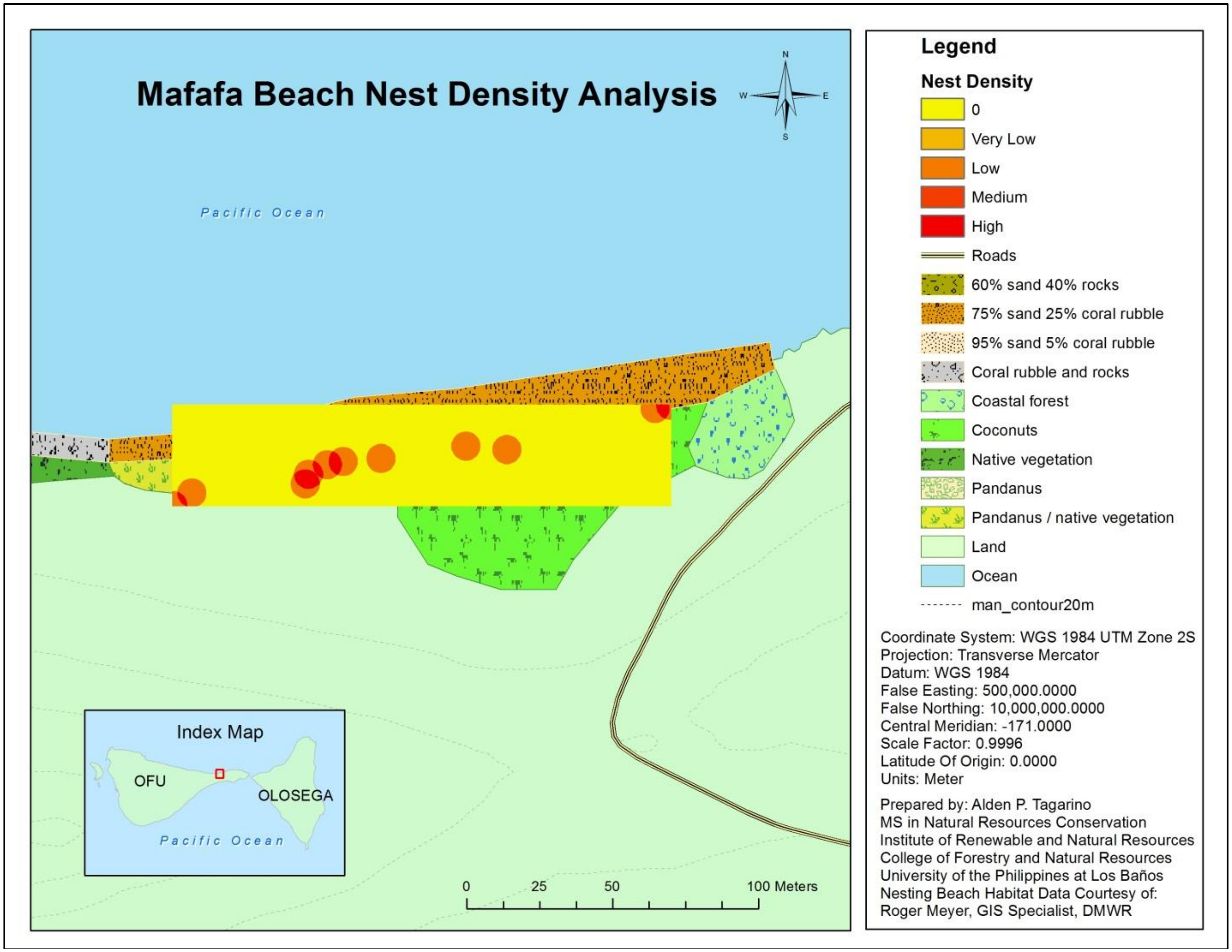

Figure 11. Point density analysis of nests at Mafafa beach in Ofu.

Average Nearest Neighbor Analysis

Toaga Beach Average Nearest Neighbor Summary Results

Results from an Average Nearest Neighbor analysis for Toaga beach nests yielded a p-value of 0.005807, which is significant at a 99% confidence level (Table 7 and Appendix Figure 3). This result shows the nesting pattern to not be random, but rather clustered. Given the z-score of -2.76, there is a less than 1% likelihood that this clustered pattern could be the result of random chance. On the other hand, results for all emergences (Nesting + Non-Nesting Emergences) yielded a p-value of 0.000000, which is significant at a 99% confidence level (Table 7 and Appendix Figure 4). This result shows the nesting pattern to not be random, but rather dispersed. Given the z-score of 95.4658, there is a less than 1% likelihood that this clustered pattern could be the result of random chance.

Mafafa Beach Average Nearest Neighbor Summary Results.

Results from an Average Nearest Neighbor analysis for Mafafa beach nests yielded a p-value of 0.000015, which is significant at a 99% confidence level (Table 7 and Appendix Figure 5). This result shows the nesting pattern to not be random, but rather dispersed. Given the z-score of 4.32, there is a less than 1% likelihood that this dispersed pattern could be the result of random chance. Conversely the results for all emergences (Nesting + Non-Nesting Emergences) yielded a p-value of 0.357798, which is not significant at a 99% confidence level (Table 7 and Appendix Figure 6). This result shows the nesting pattern to not be dispersed, but rather random. Given the z-score of 0.919569, the pattern does not appear to be significantly different than random.

Table 7. Average nearest neighbor analysis summary results for nesting emergence (NE) and all emergences (NE+NNE), 99% confidence level.

BEACH	CATEGORY	P-VALUE	Z-SCORE
Toaga	All emergences (NE+NNE)	0.000000	95.4658
Toaga	Nests (NE)	0.005807	-2.7585
Mafafa	All emergences (NE+NNE)	0.357798	0.9196
Mafafa	Nests (NE)	0.000015	4.3229

Temporal Patterns of Nesting

The temporal pattern of nesting activity, nesting and non-nesting emergence, by month from December 2009 to June 2013 are illustrated and described below in Figures 12 & 13.

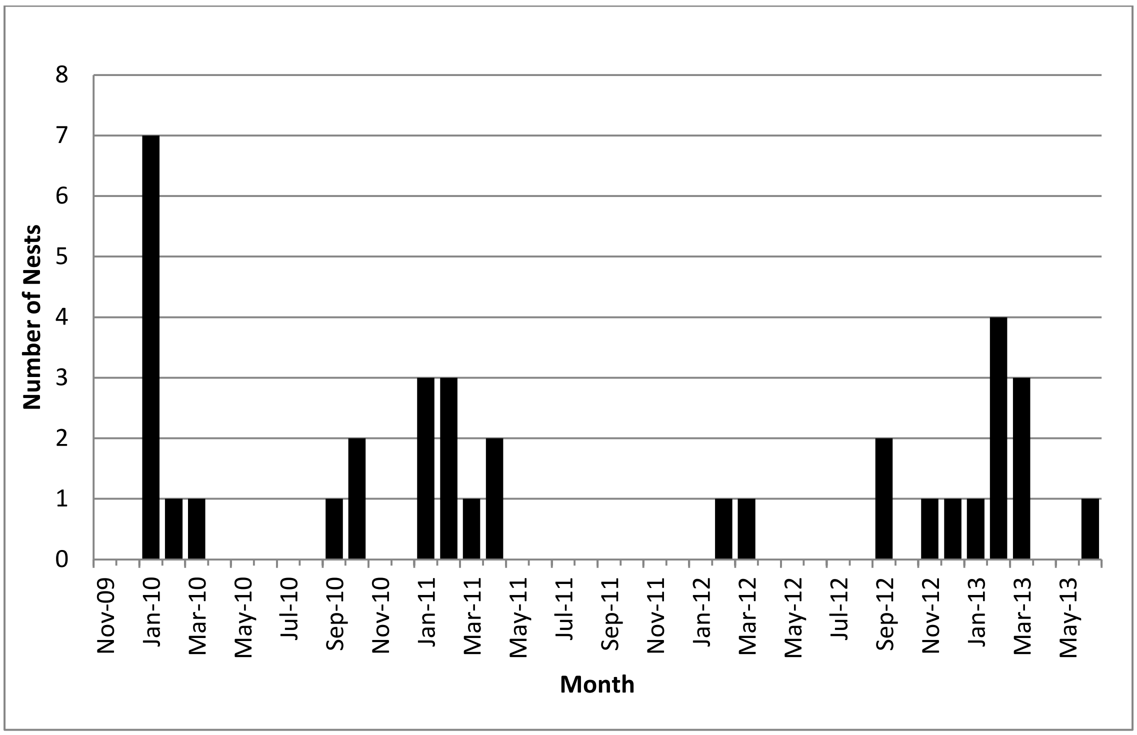

Figure 12. Ofu and Olosega islands recorded nests from December 2009 to June 2013.

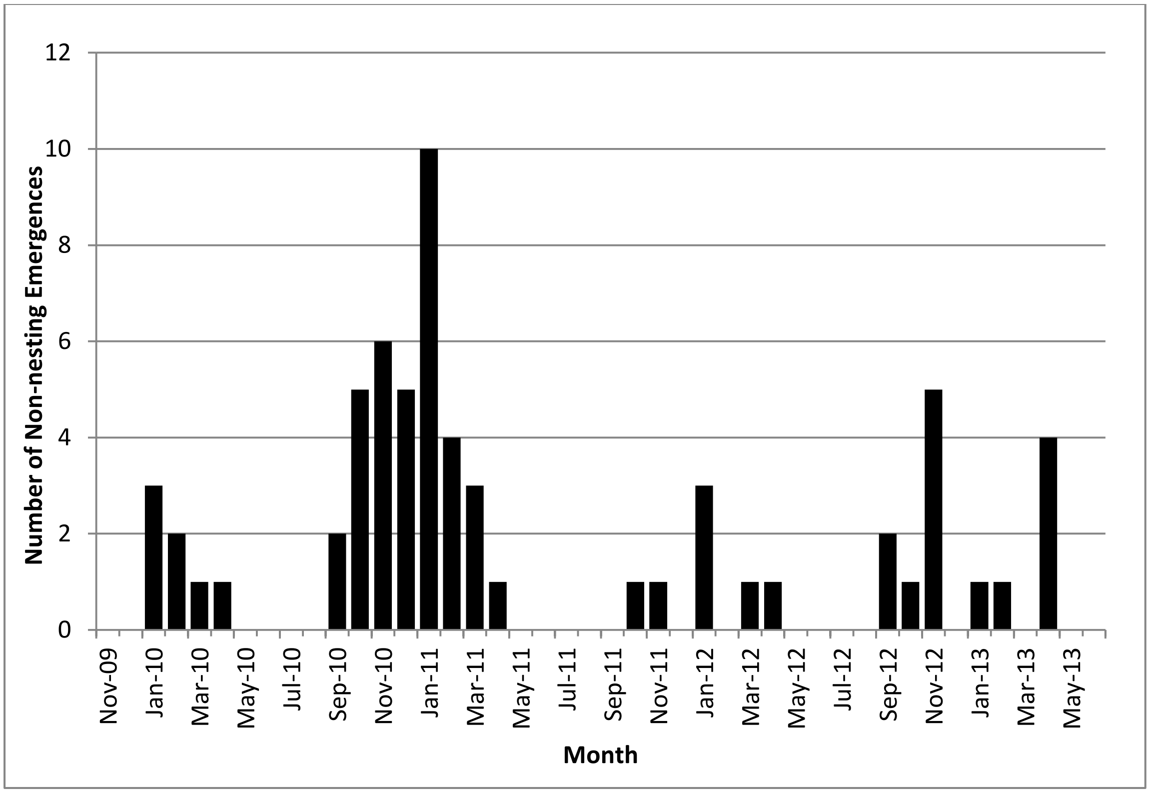

Figure 13. Ofu and Olosega islands non-nesting emergence December 2009 to June 2013.

Data indicate year round nesting with the peak season in the month of January and February (Figure 14). This follows the seasonality of nesting in Samoa as documented by Witzel in 1980, specifically the peak months of nesting. In this study, daily monitoring for the nesting season ended 14 days after the emergence of the last active nest; using this delineation of active nesting these data show, nesting activity occurs year round. Although no nests were laid during the months of May and July, these months were defined as part of nesting season due to active (incubating) nests that were laid during the months of March and April. Hatchling emergence from these nests occurred from May through July and can extend up to August, as in the case of NE11 on Mafafa beach laid in June 4, 2013 (Figure 12 and Appendix Table 2).

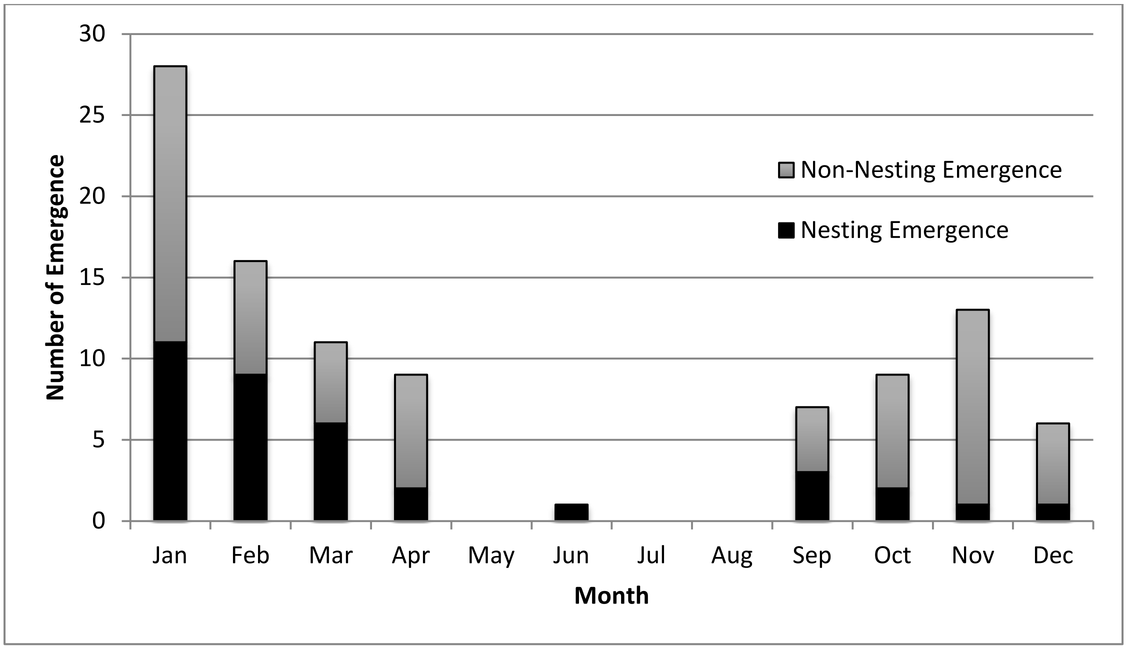

Figure 14. Ofu and Olosega islands hawksbill nesting season.

Year round nesting season of Ofu and Olosega Islands is similar to Tutuila Island based on the nesting activity (nesting and hatchling emergences) recorded from February 2006 to March 2013 (Appendix Table 1 and Appendix Figure 7). A total of 22 nesting events were documented on Tutuila, seven nesting emergences and 15 hatchling emergences, recorded on nine sites or villages (Appendix Table 1 and Appendix Figure 8). Out of the 22 nesting events, all were hawksbill turtles except for a single nesting emergence by a green turtle on November 16, 2008 that was found in the middle of the road at the boundary of Alao Village and Tula Village. The nesting green turtle was found with a crushed carapace consistent with trauma caused a vehicle that ran over the turtle (personal observation).

To better characterize the nesting season Rayleigh's Test was conducted on all nesting and non-nesting emergences recorded. The results confirmed that the mean time of nesting during of the nesting season is in January, with the lower limit of the 95% confidence interval at the beginning of January (1.0265) and the upper limit at the beginning of February (2.1908) as seen in Table 8. For Non-Nesting Emergences the mean month of these emergences was also January (0.5449) with the lower limit of the 95% confidence interval at the end of November (11.8574) and the upper limit at the beginning of January (1.2323) as seen in Table 8.

Table 8. Mean direction and uniform distribution goodness-of-fit test (Rayleigh's Test).

CATEGORY	NESTING EMERGENCE	NON-NESTING EMERGENCE
Variable	Month	Month
Sample Size (N)	33	59
Mean Direction (Theta)	1.6087	0.5449
Lower 95% Confidence Limit of Theta	1.0265	11.8574
Upper 95% Confidence Limit of Theta	2.1908	1.2323
Standard Error of Mean Direction	0.2924	0.3432
Rayleigh's Test Statistic (S*)	27.0095	34.3106
Rayleigh's Test Prob Level (P-value)	0.0000	0.0000

Nest Inventories

Overall (all nests combined) nest clutch sizes held an average of 114 eggs for hawksbills and 69 eggs for greens (Table 9). Hatching success for hawksbills was an average of 78%, with greens having an average of 54% (Table 9). Emergence success for hawksbills was at an average of 75%, with greens having an average of 54% (Table 9). Standard deviations for each average are provided in Table 9.

Table 9. Mean and standard deviation of clutch size, hatching success and emergence success.

SPECIES	SAMPLE SIZE	CLUTCH SIZE	HATCHING SUCCESS	EMERGENCE SUCCESS
Eretmochelys imbricata	*33*	114.16 ± 42.68 S.D.	78.36 ± 28.55 S.D.	75.44 ± 29.36 S.D.
Chelonia mydas	*3*	69.33 ± 27.21 S.D.	54.11 ± 33.72 S.D.	53.72 ± 33.82 S.D.

For Olosega beach nests, the clutch had an average of 154 eggs, the only nest in Asaga had 150 eggs, Vaoto beach nests had an average of 81 eggs, Toaga beach nests had an average of 131 eggs, and Mafafa beach nests had an average of 87 eggs (Table 10). Hatching success for Olosega beach nests averaged 39%, Asaga's nest was 94%, Vaoto averaged 85%, Toaga 81%, and Mafafa 78% (Table 10). Emergence success for Olosega beach nests averaged 39%, Asaga's nest was 94%, Vaoto averaged 85%, Toaga 81%, and Mafafa 69% (Table 10).

Table 10. Mean and standard deviation of clutch size, hatching success and emergence success by beach.

BEACH	SAMPLE SIZE	CLUTCH SIZE (NUMBER OF EGGS)	HATCHING SUCCESS (%)	EMERGENCE SUCCESS (%)
Olosega	2	153.50 ± 21.92 S.D.	38.59 ± 11.53 S.D.	38.59 ± 11.53 S.D.
Asaga	1	150.00	94.00	94.00
Vaoto	3	81.33 ± 21.03 S.D.	85.08 ± 21.15 S.D.	85.08 ± 21.15 S.D.
Toaga	16	130.50 ± 43.30 S.D.	81.36 ± 20.52 S.D.	81.26 ± 20.54 S.D.
Mafafa	11	86.40 ± 28.62 S.D.	77.98 ± 38.79 S.D.	69.36 ± 39.93 S.D.

Two nests were completely (100%) depredated - NE06 and NE07 on Mafafa Beach and one nest was almost 75% depredated - NE04 (Appendix Table 5). Excluding these nests, hawksbill hatching success is 94.73% ± 4.68 S.D. and emergence success of 92.02% ± 7.63 S.D. Mean clutch size excluding the three depredated nest is 87.38 ± 23.58 S.D. eggs.

Mean days of incubation for hawksbill nests surveyed was 63.1, n = 22, while green turtle nest incubation periods were 74.5, n = 2 (Appendix Table 5). Exact dates of emergence from six nests (Toaga NE16 and NE17, Mafafa NE03, NE05, NE07 and NE09) were not determined however the date of inventory was used to calculate the number of incubation days (Appendix Table 5). If these six nests were excluded, mean incubating days is 61.75.

Based on six documented nests on Tutuila Island (Appendix Table 1) the mean clutch size of hawksbill turtles nest is 175.5 ± 15.62 S.D. eggs. Hatching success and emergence success are the same at 93.44% ± 5.19 S.D. (Appendix Table 6).

Nest Location and Nest Habitat Factors Affecting Hatching and Emergence Success

Factors affecting hatching and emergence success may include nest location and nest habitat (Zare et.al. 2012, Cuevas et.al. 2010, Mortimer 1990). Results of analyzing the statistical significance of nest locations across the beach and nest habitat data collected (Table 5 & 6), shows that there is a significant difference between the hatching success of nests inundated by water and nests that were not, given the p-value of 0.011889 (Table 11 and Appendix Table 7). On the other hand, there is no significant difference between hatching success of nests located on the slope and behind the slope as well as nests that were depredated and no predation, both p-values are higher than $\alpha = 0.05$ (Table 11 and Appendix Tables 8 & 9). There is no significant difference between hatching success of nest location habitat, vegetation cover and vegetation type, given the p-values higher than $\alpha = 0.05$ (Table 11 and Appendix Tables 10 & 11).

Table 11. Effects of nest location and nest habitat on hatching success, 95% confidence level.

FACTORS COMPARED	TEST	P-VALUE
Slope (on slope/behind slope)	T-test	0.447707
Vegetation Cover (no veg/under-veg/ in-veg)	ANOVA	0.900163
Vegetation Type (no veg/native veg/non-native veg)	ANOVA	0.441894
Predation (no predation/depredated)	T-test	0.328226
Inundation by water (no inundation/inundated)	T-test	0.011889

Results indicate that emergence success was only affected by predation and inundation by water based on the p-values of 0.009823 and 0.036603 respectively (Table 12 and Appendix Tables 12 & 13). There are no significance differences between emergence success of nests located on slope or behind slope, no vegetation cover, under vegetation and in-vegetation including vegetation type (no vegetation, native vegetation and non-native vegetation), given the P-values higher than α = 0.05 (Table 12 and Appendix Tables 14, 15 and 16). Effects of location relative to high tide were no longer included in the analysis as all nests are located above high tide.

Table 12. Effects of nest location and nest habitat on emergence success, 95% confidence level.

FACTORS COMPARED	TEST	P-VALUE
Slope (on slope/behind slope)	T-test	0.219534
Vegetation (no veg/under-veg/ in-veg)	ANOVA	0.508608
Vegetation Type (no veg/native veg/non-native veg)	ANOVA	0.238276
Predation (no predation/depredated)	T-test	0.009823
Inundation by water (no inundation/inundated)	T-test	0.036603

Satellite Telemetry of Hawksbill Turtles of American Samoa

Argos location classes (accuracy codes) 3, 2, 1, and 0 were accepted for mapping including location classes A and B (Table 13). Locations on land and location class Z were rejected, and the speed traveled between two locations that are over 5km/hr, as well as locations that made a turn greater than 90 degrees in less than a 24hr period (Parker et. al. 2009). Determining acceptable location classes were subjective and based on the previously stated criteria. Details of the 12 satellite tags deployed on juvenile and post nesting turtles are summarized in Table 14, while distances traveled, straight line distance, and average swimming speeds were calculated in ARCGIS 10 (Table 15). All mapped locations are illustrated in Figures 14 to 19. Juvenile and post nesting turtle movements are described in the next two sections.

Table 13. ARGOS Location Classes (Argos User's Manual 2007-2015 CLS).

LOCATION CLASS (ACCURACY CODE)	ESTIMATED ERROR
3	<250 m
2	250< <500 m
1	500< <1000m
0	>1500m
A	No accuracy estimation
B	No accuracy estimation
Z	Invalid location

Table 14. Satellite Tags deployed in Tutuila and Ofu Islands, American Samoa

DATE DEPLOYED	LAST TRANSMISSION DATE	RELEASE SITE	DAYS TRANSMITTING	PTT ID - NAME	CURVED CARAPACE LENGTH (CM)	SPECIES
2006 Feb 28	2007 Jan 3	Malota	310	60060 - Ms Malota	81	*E. imbricata*
2006 Apr 27	2007 Feb 16	Amouli	296	60067 - Nimo	49	*E. imbricata*
2006 Jun 2	2006 Aug 24	Pago Harbor	84	60068 - Bob	46	*C. mydas*
2006 Jun 2	2008 Apr 6	Fagaitua	673	60069 - Fabelowe	51.5	*E. imbricata*
2006 Jun 16	2010 Mar 4	Fagaalu	989	60070 - Galuaselaina	43	*E. imbricata*
2008 Feb 1	2008 Jul 30	Amalau	181	60061 - Ms Amalau	81	*E. imbricata*
2008 Jul 23	2009 Nov 19	Amalau	120	60063 - Ms Teuila	86.5	*E. imbricata*
2008 Aug 28	2009 Jul 6	Tula	313	60062- Ms Tula	84	*E. imbricata*
2009 Dec 11	2010 Jul 25	Amalau	227	60071 - Ms SarahAmalau	87.1	*E. imbricata*
2010 Jan 19	2011 Jan 7	Toaga	354	60065 - Ms Toaga	92.9	*E. imbricata*
2010 Aug 11	2011 Sep 17	Aua	402	60064 - Mr Aua	68.2	*E. imbricata*
2011 Jan 11	2011 Apr 22	Toaga	101	60066 - Ms Muliulu	74.6	*E. imbricata*

Table 15. Distance traveled, straight-line distance and average swimming speeds of satellite tagged turtles in Tutuila and Ofu Islands, American Samoa.

DATE DEPLOYED	PTT ID - NAME	SPECIES	DISTANCE TRAVELED (KM)	STRAIGHT LINE DISTANCE (KM)	AVERAGE SWIMMING SPEED (KM/HR^{-1})
2006 Feb 28	60060 - Ms Malota	*Eretmochelys imbricata*	1257.47	202.43	0.1690
2006 Apr 27	60067 - Nimo	*Eretmochelys imbricata*	NA	NA	NA
2006 Jun 2	60068 - Bob	*Chelonia mydas*	NA	NA	NA
2006 Jun 2	60069 - Fabelowe	*Eretmochelys imbricata*	3038.82	1612.52	0.1881
2006 Jun 16	60070 - Galuaselaina	*Eretmochelys imbricata*	NA	NA	NA
2008 Feb 1	60061 - Ms Amalau	*Eretmochelys imbricata*	2668.98	1493.75	0.6144
2008 Jul 23	60063 - Ms Teuila	*Eretmochelys imbricata*	NA	NA	NA
2008 Aug 28	60062- Ms Tula	*Eretmochelys imbricata*	28.15	6.27	0.0037
2009 Dec 11	60071 - Ms SarahAmalau	*Eretmochelys imbricata*	895.51	810.92	0.1644
2010 Jan 19	60065 - Ms Toaga	*Eretmochelys imbricata*	4907.19	4047.8	0.5776
2010 Aug 11	60064 - Mr Aua	*Eretmochelys imbricata*	NA	NA	NA
2011 Jan 11	60066 - Ms Muliulu	*Eretmochelys imbricata*	576.11	147.96	0.2377

Juvenile Turtle Movements

Mapping of the locations transmitted showed that the one green and three hawksbill turtles, all sub-adults (43-51cm Curved Carapace Length (CCL) stayed near shore and did not migrate away from Tutuila except the largest hawksbill (60069-Fabelowe) Fabelowe-60069 which stayed near-shore of Tutuila for 17 months (June 2006 to November 2007) before migrating to the Cook Islands area around Rarotonga island (Figure 15). Fabelowe-60069 traveled a total distance of 3,038.82 km, a straight line distance of 1,612.52 km. The Juvenile turtle tracking data strongly suggest high site fidelity to the near shore or coastal areas around the island of Tutuila, specifically the outer Pago Harbor area and Fagaitua Bay which is located east of Pago Harbor (Figure 15).

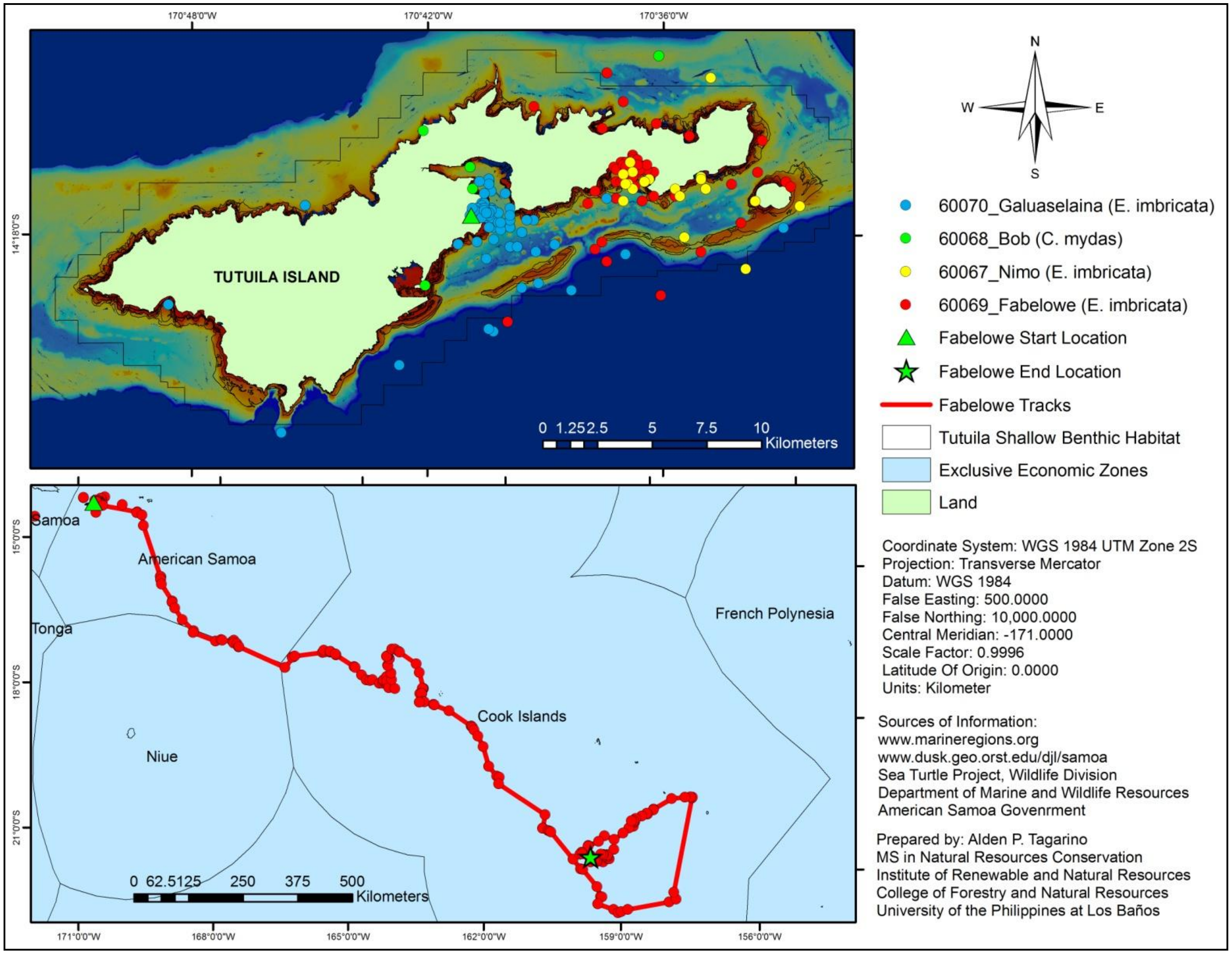

Figure 15. Movements of one green and three hawksbill juvenile sea turtles in American Samoa.

Post Nesting Turtle Movements

Adult post-nesting hawksbill females, (CCL (cm) Mean - S.D. of 83.87 ± 5.79), showed large-scale movements. One turtle Ms Teuila (60063) transmitted only seven locations, and within a span of two days, the remaining active days of the satellite tag did not give locations indicating a damaged satellite tag. Out of the seven transmissions only two were useable (Figure 16) based on the criteria for accepting Argos locations for mapping as described in the methods. Ms Tula (60062) transmitted 42 times in the span of 10 months and exhibited movement on the northern side of Tutuila Island (Figure 16). Ms Tula-60062 travelled a total distance of 28.15 km, a straight line distance of 6.27 km. indicating that the turtle did not migrate to a feeding ground located farther from Tutuila. Short distance movements of post nesting hawksbills have been documented before (Maylan 1991, Miller 1998, and Parker et.al. 2009), as well as records of short distance movement to estuarine and mangrove habitats in the eastern Pacific off Central America (Gaos 2011).

Interestingly, directions of the movements of three tagged post-nesting hawksbills, Ms Malota (60060), Ms Muliulu (60066) and Ms Sarrah Amalau (60071) (Figure 17) showed three distinct migration patterns. First, a generally southern pattern with a more limited East-West range within the Samoan waters as exhibited by Ms Malota (60060) travelling a total of 1,257.47 km., a straight line distance of 202.43 km. (Table 15 and Figure 17). Second, a southern direction of Ms Muliulu (60066) after which making a loop back to Tutuila Island, west of where the turtle was tagged and released, Toaga beach on Ofu Island. Ms Muliulu-60066 travelled a total distance of 576.11 km, a straight line distance of 147.96 km (Table 15). Third, a south-westerly movement towards Tonga (Figure 17) by Ms Sarrah Amalau (60071), which ended with last transmitted locations about 2 kilometers near Fonoifua island. Ms Sarrah Amalau-60071 travelled a total distance of 895.51 km, a straight line distance of 810.92 km (Table 15). All three movements differ from the northwest then south movement ending in Fiji shown by a post-nesting hawksbill tagged and released from Samoa (Appendix Figure 9).

Ms. Toaga followed the south-southeast direction of Ms Amalau (60061) that travelled 2,668.98 km. a straight line distance of 1,493.75 km (Table 15 and Figure 18). However she passed the Cook Islands and travelled a straight line distance of 4047.8 km and a total distance travelled of 4,907.19 km (Table 15 and Figure 18), to the Gambier Islands in French Polynesia. This represents the longest known migration of a post-nesting hawksbill tracked by satellite telemetry (Figure 18). Point density analysis conducted on the migration route of Ms. Toaga suggests that French Polynesia, is a foraging and feeding ground of post nesting hawksbill turtles from American Samoa based on the high density of points (Figure 19).

Adult Male Hawksbill Turtle Movements

The only adult male hawksbill turtle (Mr. Aua) satellite tagged in American Samoa, stayed close to shore or within Territorial waters (Figure 20) for 402 days (Table 13). Mr Aua was recovered dead on July 9, 2012 on the northwest side of Pago Pago Harbor near the tuna canneries. The satellite tag was already damaged and lost its antenna.

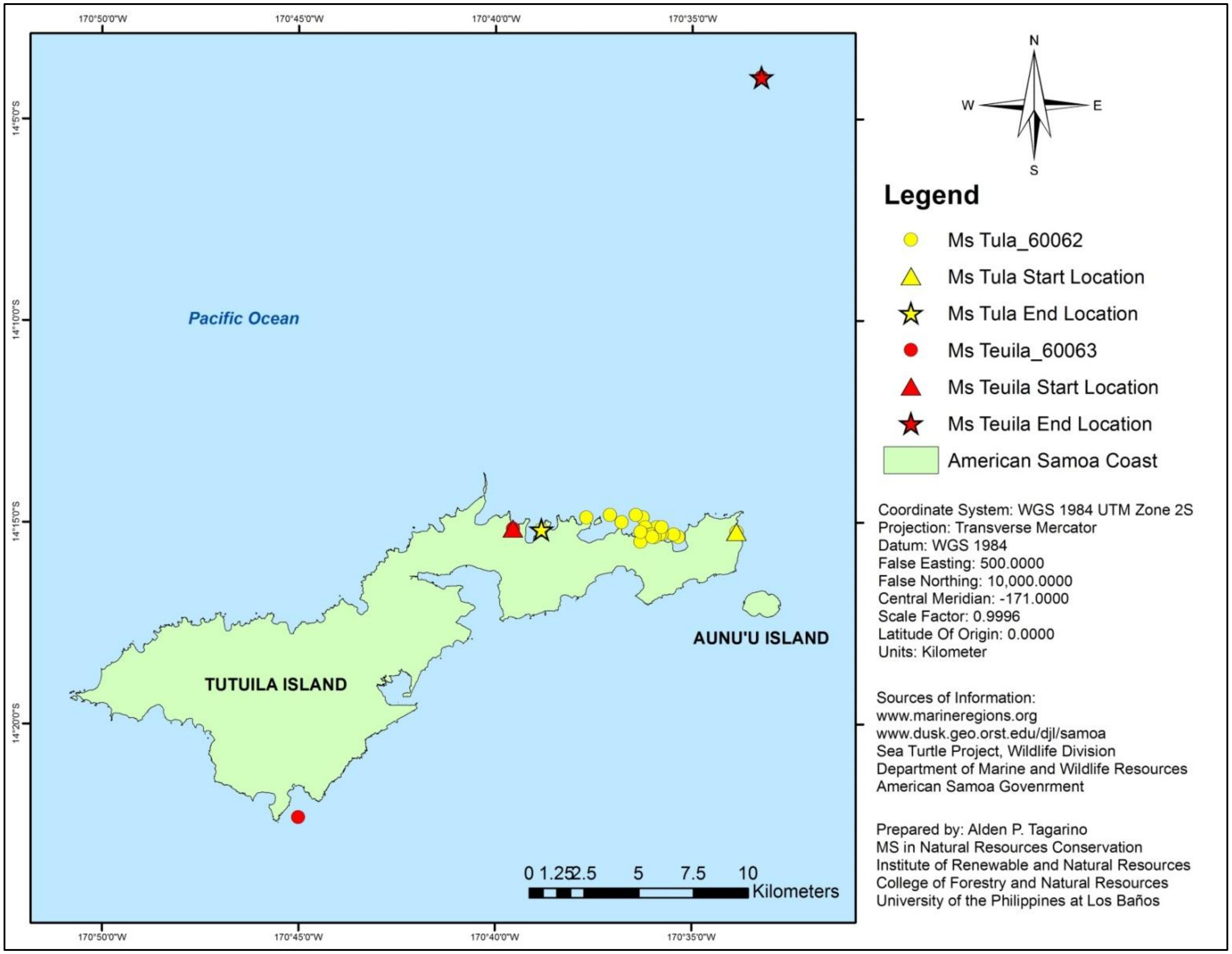

Figure 16. Movements of post nesting hawksbill turtles (*E. imbricata*), Ms Tula and Ms Teuila.

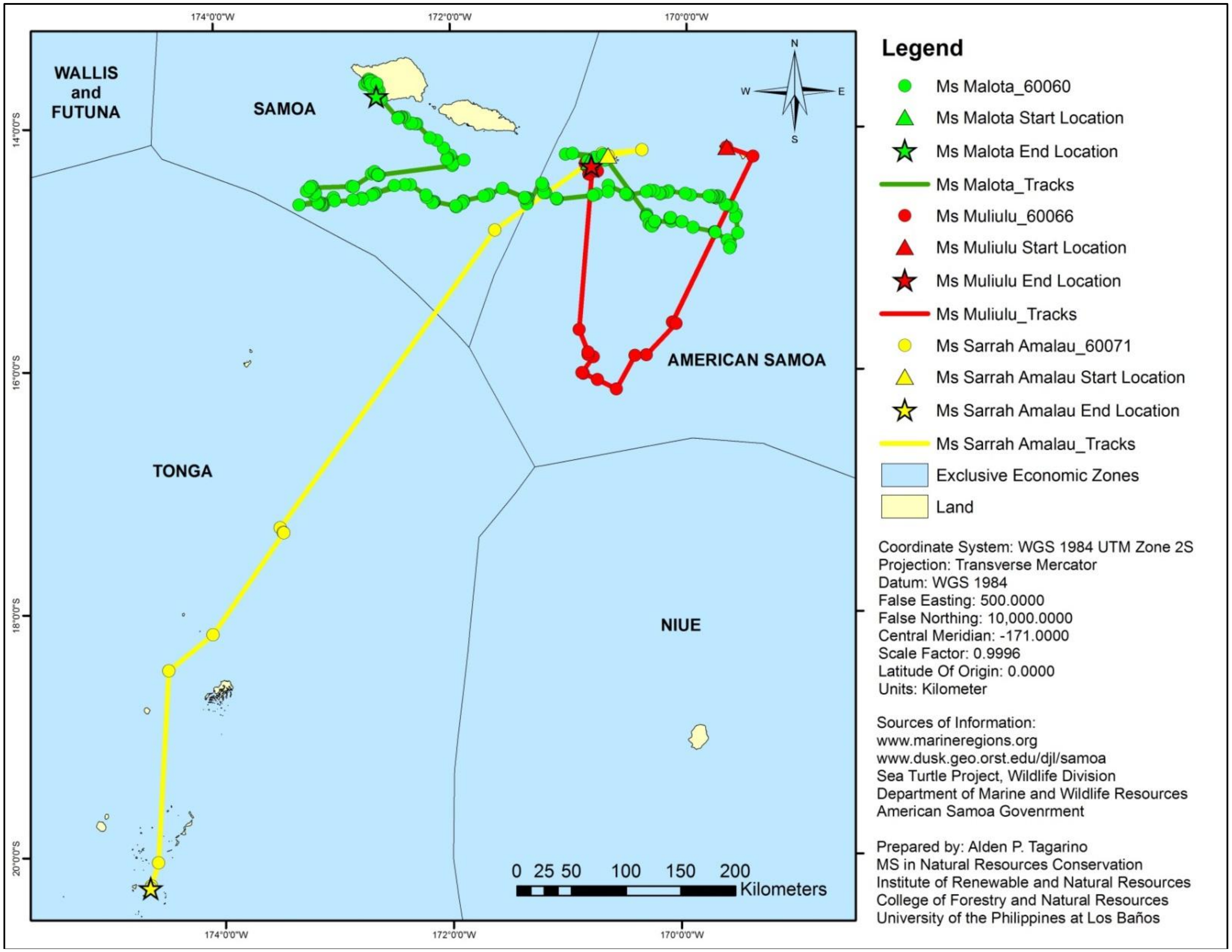

Figure 17. Movements of post nesting hawksbill turtle (*E. imbricata*) Ms Malota, Ms Muliulu and Ms Sarrah Amalau.

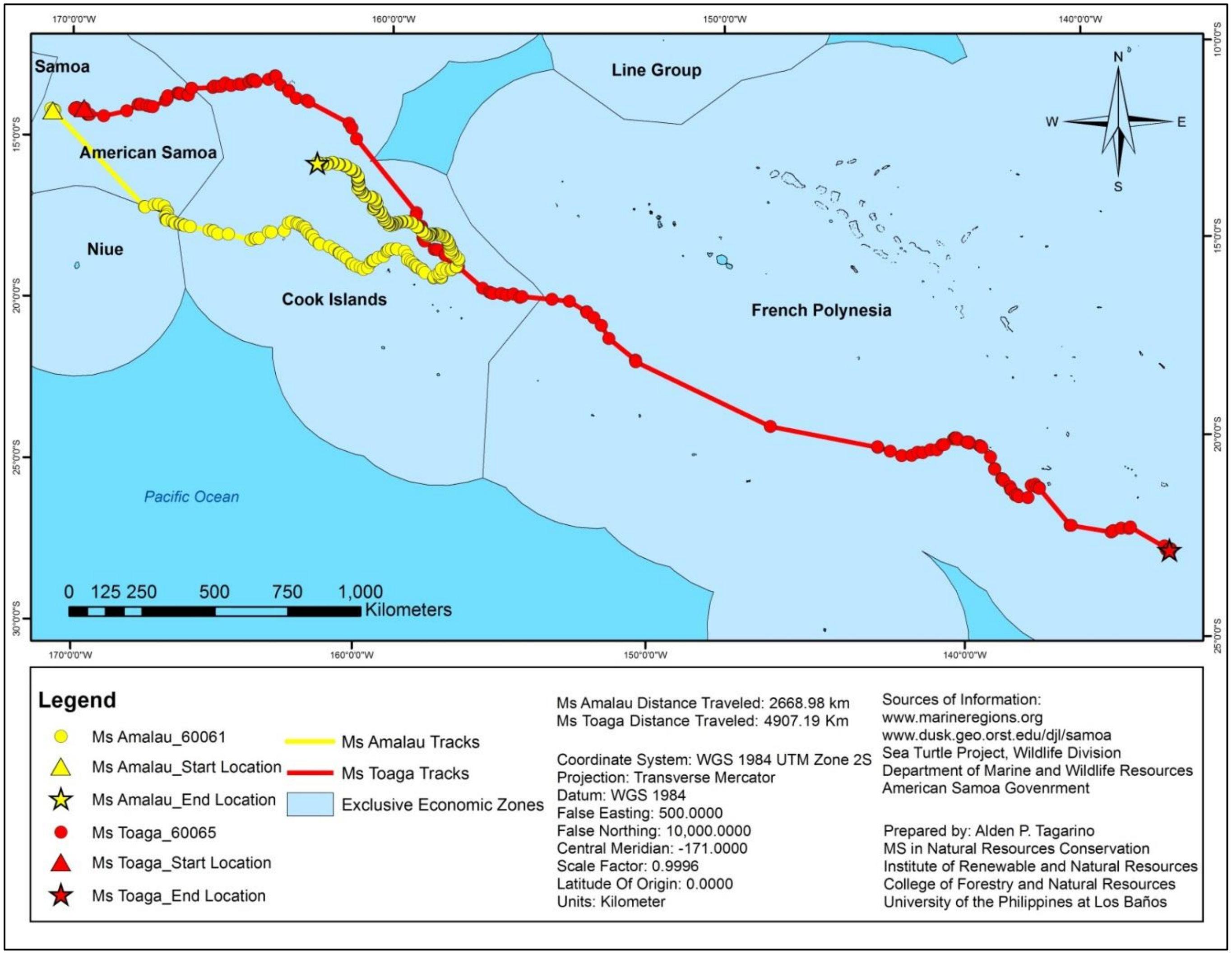

Figure 18. Movements of post nesting hawksbill turtle (*E. imbricata*) Ms Amalau and Ms Toaga.

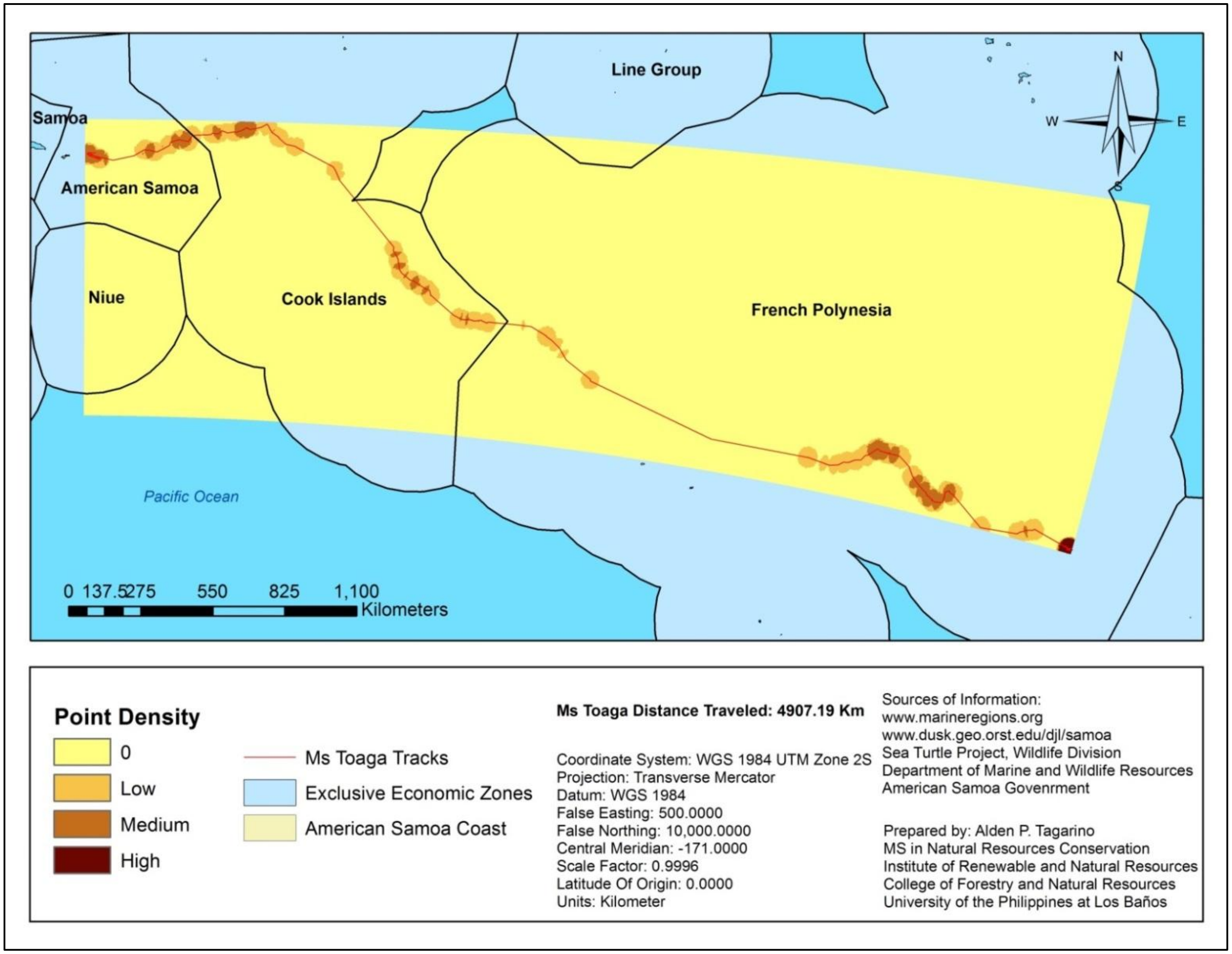

Figure 19. Ms Toaga (*E. imbricata*) migration route point density analysis.

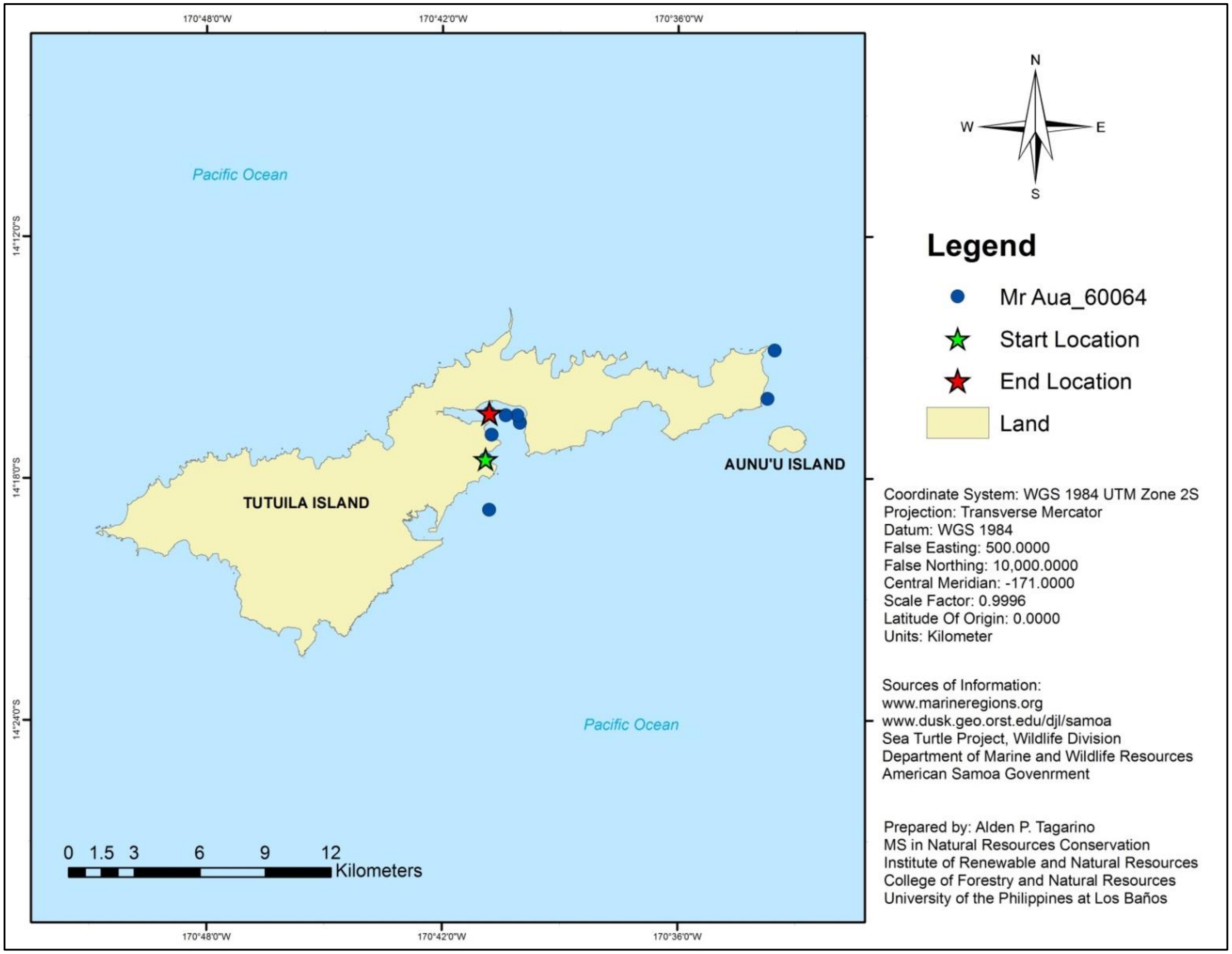

Figure 20. Movements of an adult male hawksbill turtle (*E. imbricata*).

DISCUSSION

Ofu and Olosega Islands Spatial Patterns of Nesting

This thesis presents the first systematically collected data on turtle nesting in American Samoa. The significance of publishing updated survey numbers for endangered marine turtles and endangered species in general cannot be overstated (Kamel and Delcroix 2009). Results from collecting anecdotal accounts of nesting in Ofu and Olosega islands as well as workshops conducted in the villages identified seven nesting beaches. However, only five nesting beaches were included in this study and were consequently confirmed as active hawksbill turtle nesting beaches, namely: the southeastern end of Olosega Beach, Asaga beach, Vaoto beach, Toaga beach and Mafafa beach, the beach on the north eastern side of Ofu island and the beach on the east side of Olosega were not included in the study due to logistical limitations. This study also confirmed the nesting of green turtles in Vaoto beach (n = 2) and Toaga beach (n = 1) on Ofu Island.

Locations of nests across the beach relative to slope (on the slope and behind the slope) and high tide line, and vegetation cover can provide insightful implications on sea turtle hatching sex ratios (Wibbels in Lutz and Musick 2003). Gender determination of hawksbill turtles is temperature dependent, since higher beach sand temperatures produce a higher female ratio while lower temperatures than the pivotal temperature produces a higher ratio of males (Horrocks and Scott 1991, and Wibbels in Lutz and Musick 2003). Pivotal temperatures for hawksbill turtles reported in other studies are 29.2°C in Antigua and 29.6°C in Brazil (Wibbels in Lutz and Musick 2003). Spatial patterns of nesting can have profound effects on the population structure of hawksbill turtles in American Samoa as well as the management and conservation actions for the species. Results of this thesis however, determined that locations of nests relative to slope, high tide line, and vegetation do not have a significant effect on the clutch size, hatching success and emergence success. This can be attributed to the low density of nesting occurring on the beaches in Ofu and Olosega. Nesting density is further discussed in the hatching and emergence success section of the discussion.

Spatial patterns of nesting, specifically, clustering of nests was determined and analyzed. Point density analysis and average nearest neighbor analysis were conducted only on beaches with the highest number of nests, Toaga and Mafafa nesting beaches. Olosega, Asaga and Vaoto beaches have a low number of nests ($n \leq 3$). Point density analysis illustrates the density of nests relative to the clutch size and provides a better visualization. Conversely, the average nearest neighbor analysis conducted on the nests on Toaga beach indicates that clustering of the nests are significant while nests on Mafafa beach are significantly dispersed (Table 7). It is also important to note that Toaga beach on the south side of Ofu island is almost 5 times longer than Mafafa beach on the north side a steeper slope compared to the latter.

Proximity of the nesting beaches to active lights has been documented to disorient and adversely affect the movement of hatchlings after emergence (Witherington and Martin 1996). This thesis documented four events of disoriented hatchlings congregating under streetlights instead of moving directly towards the sea.

Hawksbill nesting beaches in the Manu'a Island Group, specifically Ofu and Olosega Islands represents a significant area for nesting in American Samoa. If the population of about 30 nesting females per year in Manu'a Islands estimated from interviews in 1990 – 1991(Tuato'o-Bartley et.al. 1993) were realistic, there is a steep decline of nesting activity in Manu'a Islands. The 33 recorded hawksbill nests from 2009 – 2013 can translate to 11 nesting females if each turtle laid three clutches, a single hawksbill nester can deposit up to five clutches in a season (Miller 1997). The decline in nesting population in American Samoa is comparable to the decline in Samoa (Bell et.al 2004; Momoemausu et. al. 2006; Ward and Asotasi 2008). Current nesting emergence of Ofu and Olosega Islands is 55% higher than documented hatchling emergence on Tutuila Island. The information from the nesting emergences establishes the importance of the nesting beaches of Ofu and Olosega Islands for the whole Territory of American Samoa.

American Samoa Hawksbill Turtle Nesting Season

Nesting periodicity such as inter-nesting intervals and remigration are principal for determining the minimum population size of nesters required for recovery, management and conservation of sea turtles (Alvarado and Richardson in Eckert et.al. 1999). Establishing the seasonality of hawksbill nesting in American Samoa and identifying the peak of the nesting season will have management implications on allocating limited resources for nesting monitoring effort. To efficiently gather the most data on nesting turtles from the field, effort should be focused on the peak months of nesting to enable characterization of the nesting population.

The most recent information on sea turtle nesting activity in the Territory suggested a seasonal nesting period based on the appearance of hawksbill turtle hatchlings from January to May (Utzurrum 2002). An earlier study based on interviews describe a year round nesting on Tutuila Island, however, seasonality was not defined and nesting beaches were not identified; an additional confounding factor in this study was that the respondents were not able to differentiate between the species (Tuato'o-Bartley et.al. 1993). Results of this thesis show that in general, turtle nesting season is year round with a peak between the month of January and February for Ofu and Olosega Islands. Despite the low levels of nesting activity, data collected show a significant seasonality when analyzed using the Rayleigh test (Table 7).

Findings coincide with the nesting and hatchling events on Tutuila Island from nine nesting beaches between February 2006 and March 2013. Results follow the peak nesting season in Samoa as documented by Witzell and Banner in 1980, year round nesting and the peak in the months of January and February. However it must be noted that this thesis is limited to the first three years of nesting beach monitoring in American Samoa. Overlap in the nesting seasons for these islands, which are all within the Samoan archipelago, is not surprising given the trend towards synchrony in nesters within a region (Witzell 1980). In data deficient areas it can be difficult to determine these types of basic information, highlighting the importance of making sea turtle research information available for managers (Camel and Delcroix 2009 and Mortimer 2011).

Validation of the nesting season increases the ability of managers to employ appropriate activities in mitigating threats to nesting like shielding/covering of lights facing the beach, setting “lights out” curfews near nesting beaches or use of turtle friendly street lights. Increasing awareness of this information can improve community participation and cooperation to increase conservation efforts such as turning off of lights outside residences that illuminate the nesting beaches during the nesting season.

Clutch Size, Hatching Success and Emergence Success

Determining hatching success and emergence success provides vital basic information for conservation and management of sea turtles (Miller in Eckert et.al. 1999). Data on clutch size, hatching success, and emergence success is necessary for understanding the suitability of the beach for incubation and reproductive effort of hawksbills in American Samoa as well as the overall status of the nesting population. Physical factors such as sand temperatures, sand particle size and pH, as well as location of nests including slope and vegetation cover directly influence hatching success and emergence success (Zare et.al. 2012, Cuevas et.al. 2010, Mortimer 1990). In this thesis I focused on the effects of location of the nests, vegetation cover and type, predation and inundation by water on hatching success and emergence success.

Prior data on clutch size, hatching success and emergence success in the Territory is virtually non-existent. Results of this thesis on clutch size and hatching success provides the baseline data for American Samoa and are comparable to findings in Samoa by Witzell in 1980 of translocated nests in a hatchery. Mean clutch size of hawksbills in Ofu-Olosega Islands American Samoa (114.16 ± 42.68 S.D.) is comparable to 127.0 ± 30 S.D. eggs in Barbados, West Indies (Horrocks and Scott 1991); Shadivar Island in Iran, 124 ± 28 eggs S.D. (Zare et.al. 2012), and Guadaloupe, French West Indies in 2002, 137 ± 26 eggs and in 2004, 159 ± 29eggs S.D., but lower than the largest clutch of a hawksbill recorded at 276 eggs (Kamel and Delcroix 2009). However, based on six nests on three nesting beaches on Tutuila Island the mean clutch size is higher at 175.5 ± 15.62

S.D. eggs. Conversely, Toaga beach has a higher clutch size n=16 (130.50 ± 43.30 S.D.) compared to Mafafa beach n=11 (86.40 ± 28.62 S.D.).

Hatching success 78.36 ± 28.55 S.D. and emergence success 75.44 ± 29.36 S.D. of nests in Ofu-Olosega Islands are almost similar to Barbados, West Indies with a hatching success of 84.5 ± 19.8 S.D. and emergence success of 75.5 ± 29.0 S.D. (Horrocks and Scott 1991). Hatching success and emergence success of the Territory is also comparable with the values from Iran's Shadivar Island eastern beach hatching success at 73.3 ± 11.1 S.D. and emergence success of 70.5 ± 26.8 S.D., and the northern beach hatching success 84.3 ± 22.1 S.D. and emergence success of 78.7 ± 30.3 S.D. (Zare et.al. 2012).

Predation and inundation by water significantly affected the hatching and emergence success of hawksbill nests on Ofu and Olosega Islands while beach vegetation and locations of nests did not. Management leading to a reduction of predation on sea turtle nests has resulted in increased hatching and emergence success (Engeman et.al. 2009, Dutton et.al. 2004). Sea level rise and climate change implications may have profound effects on the nests in Ofu and Olosega islands given the already significant effect in of water inundation on the nests caused by high water surges.

Local and Regional Movements of Hawksbill Sea Turtles

Hawksbill turtle movements have been studied through flipper tagging and recapture (Meylan 1999), satellite telemetry (Parker 2009, Miller 1998, Balazs 1996 and 1994), and genetic studies (Maylan 1999, Mortimer et.al. 2007, Troeng 2005). Movements exhibiting habitat use of juvenile and adult hawksbill provide key information for management and conservation of the species (Mortimer 2007, Limpus and Miller 2008, Parker et.al. 2009, and Gaos 2011). However, research and information on habitat utilization and behavior of juvenile hawksbills remains sparse (Musick and Limpus 1997), while information on adult hawksbill migration in the Central Pacific is limited to one post nesting hawksbill satellite tagged in Samoa (SPREP 2007).

Juvenile hawksbill turtles have been known to inhabit nearshore coral reef areas, estuarine areas (Musick and Limpus 1997) and even seagrass beds that may serve as peripheral habitats (Bjorndal and Bolten 2009). They recruit to developmental areas from 20 to 25cm SCL in the Caribbean to >35cm in the Indo-Pacific (van Dam and Diez 1998, Limpus 2008). Previous flipper tagging recaptures studies conducted in the Territory on juvenile hawksbills (CCL 35.5 to 57.2 cm) exhibited short distance movements and high growth rates of about 4.5cm/year (Grant et.al. 1997), suggesting that the near shore waters of American Samoa is a developmental habitat of juvenile hawksbill turtles.

Results of this thesis show that juvenile hawksbill turtle movement in American Samoa exhibited site fidelity to the nearshore waters of Tutuila Island, specifically the outer Pago Pago harbor and Fagaitua Bay. This indicates that the coastal area of

American Samoa is a developmental habitat of hawksbill turtles, similar to findings from studies on the movements of juvenile hawksbills in the Caribbean, Central American and Australia (Meylan 1999, van Dam and Diez 1998, Musick and Limpus 1997), which all exhibited a short range of movement.

Movement of one juvenile from Tutuila island to the waters around Rarotonga island in the Cook Islands suggests a movement from the developmental feeding area to an adult feeding ground. The waters around Rarotonga island can be established as an adult feeding area of hawksbill from the Territory as well as shown by the migration of a post nesting hawksbill to the Cook Islands. While there is limited studies on juvenile hawksbills movement to adult foraging grounds (Whiting and Koch 2006), overlap of developmental habitat of juvenile and adult foraging habitat of hawksbill turtles have been well established in other areas (Musick and Limpus 1997).

Adult hawksbills have been documented to migrate short and long distances up to thousands of kilometers (Gaos 2011, Mortimer 2007, Limpus and Miller 2008, Meylan 1999 and Miller 1998). Green turtles satellite tagged in the Territory migrated mainly to Fiji and one to Tahiti (Craig et.al 2004). Hawksbills have been documented to migrate up to 2425km between nesting and foraging grounds traveling through different political boundaries (Miller 1998). This thesis demonstrates that post nesting hawksbill movement from American Samoa are wide-ranging; from one turtle that did not migrate but remained around Tutuila Island, to one that migrated to a feeding ground in Mangareva/Gambier group of islands at French Polynesia with a straight line distance of 4047kms. Point density analysis of the migration route also displayed high density at the Gambier or Mangareva group of islands in French Polynesia. Long-range migration of hawksbill from American Samoa is comparable to migrations of green turtles (Craig et.al. 2004, Plotkin in Lutz et.al. 2003 and Luschi et.al. 1998). These data confirm that migration routes of post nesting hawksbills connect Samoa, Tonga, Cook Islands, and French Polynesia to American Samoa, reinforcing the importance of regional cooperation for effective management of the species.

Very little is known about adult male movement in hawksbill turtles (Plotkin in Lutz et.al. 2003) based on one mark recapture study of an adult male hawksbill the findings suggested movements to be highly migratory (Nietschmann 1981). Although, as documented in Puerto Rico by van Dam et.al. in 2008, male hawksbills may exhibit short distance migrations. Based on the results of this thesis, adult male hawksbill turtles in American Samoa may be limited to the nearshore of the Territory similar to the short-ranged movements in Puerto Rico. However further studies on male hawksbill movements are needed to verify these findings.

While more data are needed, the outcomes of this study add important findings to our knowledge base on the local and regional movements of hawksbill turtles. In order to effectively conserve hawksbills in American Samoa and the South Pacific region we need to consider the wide-ranging movements of hawksbill turtles in the Territory to advance conservation of the species. Strategies for conservation must consider the relationships and correlation of coral reefs and hawksbill turtle foraging and feeding grounds as revealed by the migrations that cross geopolitical boundaries in the region.

Summary of Management and Policy Implications

Sea turtles in the Territory of American Samoa are protected by local policies – the American Samoa Administrative Code (Chapter 09 Fishing Title 24 Ecosystem Protection and Development 24.0959 Sea Turtles), Executive Order 005-2003, and the Federal Law – U.S. Endangered Species Act of 1973. Results of this thesis underscore management and policy implications on hawksbill turtles in the Territory, particularly the nesting beach habitat, foraging habitat and migration routes. Specifically, this thesis finds there is a need for protection of the nesting habitat, by maintaining or improving beach vegetation using native species, and mitigation of threats causing disorientation of hatchlings by light, predation, and nest inundation. Ambient light on the nesting beaches caused by street lights can be addressed by shading/covering the light facing the beach or turning off of lights during the peak of nesting and hatchling emergence. Nest protection on the other hand such as cages, wire or bamboo mesh placed on top of the nest can be used to mitigate predation. Translocation of nests that are prone to inundation must be considered, as well as other climate change mitigation practices pertaining to sea level rise

Continued monitoring is imperative for effective management and conservation of sea turtles and their nesting and foraging habitats in the Territory and the Central South Pacific. Cooperation and collaboration with the landowners, village council and National Park of American Samoa through effective outreach and education is essential for the efficient monitoring of all nesting beaches on Ofu and Olosega Islands. Intensified monitoring is necessary during peak seasons to characterize the females and general health of the nesting population. Volunteer or ecotourism programs can be partnered with academic institutions where research projects are driven by faculty, local management agencies or communities and data collection is carried out by students or tourists/volunteers. Data collection goals may include nesting beach monitoring, inventory of nests and near shore in-water surveys.

Based on the results of the movement patterns of hawksbill turtles in this study, regional collaboration and cooperation are necessary for the protection, effective management and conservation of foraging and feeding habitats as well as migration routes in American Samoa, Samoa, Tonga, Cook Islands and French Polynesia. This study may serve as a starting point for discussions in the Central South Pacific Region regarding the conservation of the species and its habitats.

CONCLUSION AND RECOMMENDATIONS

In conclusion, this thesis demonstrated that hawksbill turtle nesting in American Samoa are spatially variable across beaches. Nests in Toaga beach are clustered on the eastern and western sections of the nesting beach that are the widest sections of the beach while nests laid on Mafafa beach are spatially dispersed. It must be noted that hawksbill nesting levels are very low on the islands of Ofu and Olosega. However, it is important to note that this study is based on only 43 months of monitoring. Additionally this study confirmed presence of green turtle nesting on Toaga beach and Vaoto beach on Ofu island.

Hawksbill turtles nesting season was confirmed to occur year round with a peak season in January and February. This study also suggests there are multiple beaches on Ofu and Olosega used by nesting turtles, a nesting female may not necessarily nest on only one beach. Loss of nesting area such as the southeastern section of Olosega due to erosion of sand is a noteworthy implication of climate change on nesting beaches in the Territory. On the other hand, new nesting beaches developing like Agaputuputu beach is equally important for further investigation.

Coral reefs and the nearshore benthic habitat around Tutuila Island is an important foraging and feeding grounds for immature hawksbill turtles. Post nesting females migration patterns from American Samoa are highly varied from short-range movements to record-setting long distance, as seen with Ms.Toaga who traveled 4047km (straight-line distance). Waters off American Samoa, Samoa, Tonga, Cook Islands and French

Polynesia are feeding or foraging grounds of hawksbill turtles. Adult male hawksbill movement may be confined to the nearshore of the Territory.

To further the understanding of nesting biology of hawksbill turtles in American Samoa, the following are recommended: continue the day time monitoring of the nesting beaches and increase night time monitoring to characterize nesting turtles and determine the multi-beach use of nesters. The use of temperature data loggers to collect sand temperature data of the nests and beach as information on sand temperatures can have profound implications on the sex ratio of the hatchlings. Explore the potential use of nest protection to deter predators and decrease predation of nests, and lastly study the feeding habitats of juvenile hawksbills around Tutuila, Ofu and Olosega Islands. Additionally, at a Regional scale to inform conservation managers and decision makers, investigate and study potential foraging and feeding habitats in Samoa, Fonoifua island in Tonga, Cook Islands and Magareva islands of French Polynesia.

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APPENDIX TABLES

Appendix Table 1. Nesting events on Tutuila island American Samoa from 2006 to 2013 (Satellite Tagging and 24Hour Sea Turtle Stranding Response Data).

LOCATION (VILLAGE)	DATE	SPECIES	EMERGENCE	CLUTCH SIZE
Malota	28-Feb-06	EI	Nester	NA
Amanave	28-Oct-07	EI	Hatchlings	192
Amanave	12-Nov-07	EI	Hatchlings	194
Amanave	28-Nov-07	EI	Hatchlings	174
Alao	19-Jun-08	EI	Nester	NA
Sailele	10-Jan-08	EI	Hatchlings	NA
Amalau	1-Feb-08	EI	Nester	NA
Tula	26-Aug-08	EI	Nester	NA
Afono	26-Sep-08	EI	Hatchling	NA
Alao-Tula Boundary	16-Nov-08	CM	Nester	NA
Sailele	16-Jan-09	EI	Hatchlings	NA
Sailele	9-Feb-09	EI	Hatchlings	NA
Amalau	18-Nov-09	EI	Nester	NA
Amalau	11-Dec-09	EI	Nester	NA
Alega	18-Feb-11	EI	Hatchlings	170
Alega	26-Feb-11	EI	Hatchlings	171
Nu’uuli (pala lagoon)	16-Mar-11	EI	Hatchlings	NA
Sailele	8-Apr-11	EI	Hatchlings	NA
Amalau	4-Dec-11	EI	Hatchlings	NA
Amalau	16-Jan-12	EI	Hatchlings	152
Tula	17-Jun-12	EI	Hatchlings	NA
Tula	19-Mar-13	EI	Hatchlings	NA

Appendix Table 2. Nest locations Ofu and Olosega islands American Samoa December 2009 to June 2013. (CM = *Chelonia mydas*, EI = *Eretmochelys imbricata*). (NE=Nest)

FIELD ID	SPECIES	DATE TRACKS OBSERVED	BEACH	NEST LOCATIONS	
NNE1	CM	10-Jan-11	Olosega	14.177584°S	169.624684°W
NE01	EI	22-Feb-11	Dumpsite	14.18420°S	169.61879°W
NE02	EI	25-Apr-11	Olosega	14.17661°S	169.62508°W
NE01-UN	EI	21-Feb-11	Asaga	14.16809°S	169.63374°W
NE01	EI	10-Jan-11	Vaoto	14.18333°S	169.67395°W
NE02	EI	10-Jan-11	Vaoto	14.18472°S	169.67227°W
NE03	CM	13-Jan-11	Vaoto	14.18519°S	169.67119°W
NE04	EI	24-Feb-11	Vaoto	14.18507°S	169.67146°W
NE05	CM	19-Mar-11	Vaoto	14.18514°S	169.67142°W
NE01	EI	15-Jan-10	Toaga	14.1702386°S	169.6407269°W
NE02	EI	18-Jan-10	Toaga	14.174188°S	169.6501442°W
NE03	EI	3-Jan-10	Toaga	14.1757967°S	169.6516931°W
NE04	EI	7-Jan-10	Toaga	14.1758342°S	169.6517162°W
NE05	EI	7-Jan-10	Toaga	14.1757838°S	169.6516553°W
NE06	EI	22-Jan-10	Toaga	14.1755480°S	169.6515067°W
NE07	EI	27-Jan-10	Toaga	14.17029°S	169.64084°W
NE08	EI	26-Feb-10	Toaga	14.17136°S	169.64532°W
NE09	EI	3-Mar-10	Toaga	14.17138°S	169.64539°W
NE10	EI	19-Sep-10	Toaga	14.17027°S	169.64067°W
NE11	EI	7-Oct-10	Toaga	14.17027°S	169.64066°W
NE12	CM	23-Oct-10	Toaga	14.17616°S	169.6524°W
NE13	EI	16-Apr-11	Toaga	14.17047°S	169.64250°W
NE14	EI	4-Feb-12	Toaga	14.17279°S	169.64815°W
NE15	EI	3/1/2012	Toaga	14.17048°S	169.64265°W
NE16	EI	9/25/2012	Toaga	14.17242°S	169.64742°W
NE17-UN	EI	9/27/2012	Toaga	14.17219°S	169.64697°W

Appendix Table 2. Continued...

FIELD ID	SPECIES	DATE TRACKS OBSERVED	BEACH	NEST LOCATIONS	
NE01	EI	11/17/2012	Mafafa	14.16781°S	169.64316°W
NE02	EI	12/10/2012	Mafafa	14.16776°S	169.64259°W
NE03	EI	2/2/2013	Mafafa	14.16779°S	169.64299°W
NE04	EI	2/15/2013	Mafafa	14.16780°S	169.64311°W
NE05	EI	2/19/2013	Mafafa	14.16787°S	169.64323°W
NE06	EI	2/28/2013	Mafafa	14.16784°S	169.64322°W
NE07	EI	3/1/2013	Mafafa	14.16762°S	169.64207°W
NE08	EI	3/7/2013	Mafafa	14.16763°S	169.64212°W
NE09	EI	3/15/2013	Mafafa	14.16790°S	169.64359°W
NE10-UN	EI	Undetected	Mafafa	14.16794°S	169.64365°W
NE11	EI	6/4/2013	Mafafa	14.16775°S	169.64272°W

Appendix Table 3. Ofu and Olosega Islands Non-Nesting Emergences (NNE).

FIELD ID	SPECIES	DATE TRACKS OBSERVED	BEACH	NON-NESTING EMERGENCE LOCATIONS	
NNE01	CM	10-Jan-11	Olosega	14.177584°S	169.624684°W
NNE01	EI	20-Jan-10	Asaga	14.1681052°S	169.6327865°W
NNE02	EI	5-Apr-10	Asaga	14.168419°S	169.632665°W
NNE03	EI	31-Jan-11	Asaga	14.167512°S	169.633360°W
NNE04	EI	21-Feb-11	Asaga	14.168076°S	169.633499°W
NNE05	EI	17-Oct-11	Asaga	14.168091°S	169.632808°W
NNE06	EI	17-Jan-12	Asaga	14.167949°S	169.632853°W
NNE07	EI	31-Jan-12	Asaga	14.167877°S	169.632911°W
NNE01	EI	18-Nov-10	Vaoto	14.183060°S	169.674342°W
NNE02	EI	27-Nov-10	Vaoto	14.184615°S	169.666471°W
NNE03	EI	29-Nov-10	Vaoto	14.185341°S	169.668457°W
NNE04	EI	10-Dec-10	Vaoto	14.184451°S	169.666018°W
NNE05	EI	11-Dec-10	Vaoto	14.184639°S	169.666535°W
NNE06	EI	10-Jan-11	Vaoto	14.18368°S	169.67368°W
NNE07	EI	12-Jan-11	Vaoto	14.18355°S	169.6738°W
NNE08	EI	13-Jan-11	Vaoto	14.18401°S	169.67339°W
NNE09	EI	13-Jan-11	Vaoto	14.18291°S	169.67451°W
NNE10	CM	5-Feb-11	Vaoto	14.183872°S	169.673456°W
NNE11	EI	12-Feb-11	Vaoto	14.184871°S	169.672114°W
NNE12	EI	12-Feb-11	Vaoto	14.184927°S	169.671994°W
NNE13	EI	5-Mar-11	Vaoto	14.18438°S	169.66576°W
NNE14	EI	11/16/2012	Vaoto	14.18515°S	169.67134°W
NNE01	EI	7-Jan-10	Toaga	14.170470°S	169.641602°W
NNE02	EI	29-Jan-10	Toaga	14.172508°S	169.647580°W
NNE03	EI	11-Feb-10	Toaga	14.172601°S	169.647561°W
NNE04	EI	11-Feb-10	Toaga	14.172793°S	169.647959°W
NNE05	EI	22-Mar-10	Toaga	14.171510°S	169.645385°W
NNE06	EI	21-Sep-10	Toaga	14.170401°S	169.641071°W
NNE07	EI	27-Sep-10	Toaga	14.170337°S	169.641421°W
NNE08	EI	5-Oct-10	Toaga	14.170440°S	169.641479°W
NNE09	EI	23-Oct-10	Toaga	14.175156°S	169.651136°W
NNE10	EI	23-Oct-10	Toaga	14.174423°S	169.650400°W

Appendix Table 3. Continued...

FIELD ID	SPECIES	DATE TRACKS OBSERVED	BEACH	NON-NESTING EMERGENCE LOCATIONS	
NNE11	EI	23-Oct-10	Toaga	14.170473°S	169.641679°W
NNE12	EI	23-Oct-10	Toaga	14.170408°S	169.641204°W
NNE13	EI	16-Nov-10	Toaga	14.175862°S	169.651756°W
NNE14	EI	18-Nov-10	Toaga	14.175230°S	169.651305°W
NNE15	EI	26-Nov-10	Toaga	14.174113°S	169.649969°W
NNE16	EI	6-Dec-10	Toaga	14.175593°S	169.651485°W
NNE17	EI	13-Dec-10	Toaga	14.170351°S	169.640875°W
NNE18	EI	16-Dec-10	Toaga	14.175872°S	169.651692°W
NNE19	EI	8-Jan-11	Toaga	14.17588°S	169.65175°W
NNE20	EI	8-Jan-11	Toaga	14.17042°S	169.64215°W
NNE21	EI	8-Jan-11	Toaga	14.17042°S	169.64195°W
NNE22	EI	8-Jan-11	Toaga	14.17190°S	169.64655°W
NNE23	EI	3-Mar-11	Toaga	14.170444°S	169.641884°W
NNE24	EI	19-Mar-11	Toaga	14.170381°S	169.641141°W
NNE25	EI	3-Apr-11	Toaga	14.170328°S	169.640673°W
NNE26	EI	15-Nov-11	Toaga	14.170318°S	169.640783°W
NNE27	EI	17-Jan-12	Toaga	14.17279°S	169.64751°W
NNE28	EI	3/20/2012	Toaga	14.170281°S	169.640496°W
NNE29	EI	4/19/2012	Toaga	14.17041°S	169.6410°W
NNE30	EI	9/10/2012	Toaga	14.17213°S	164.64697°W
NNE31	EI	9/21/2012	Toaga	14.17067°S	169.64153°W
NNE32	EI	10/6/2012	Toaga	14.17042°S	169.64133°W
NNE01	EI	11/16/2012	Mafafa	14.16782°S	169.64323°W
NNE02	EI	11/29/2012	Mafafa	14.16758°S	169.64218°W
NNE03	EI	11/29/2012	Mafafa	14.16763°S	169.64236°W
NNE04	EI	11/29/2012	Mafafa	14.16781°S	169.64372°W
NNE05	EI	1/26/2013	Mafafa	14.167920°S	169.643399°W
NNE06	EI	2/5/2013	Mafafa	14.16759°S	169.64197°W
NNE07	EI	4/10/2013	Mafafa	14.16758°S	169.64218°W
NNE08	EI	4/10/2013	Mafafa	14.16763°S	169.64236°W
NNE09	EI	4/10/2013	Mafafa	14.16789°S	169.64372°W
NNE10	EI	26-Apr-13	Mafafa	14.16779°S	169.64336°W

Appendix Table 4. Historical opportunistic data collected

FIELD ID	SPECIES	DATE TRACKS OBSERVED	BEACH	LOCATIONS	
NE	EI	8-Oct-08	Toaga	14.17249°S	169.64761°W
NE	EI	8-Oct-08	Toaga	14.17025°S	169.64066°W
NE	EI	2-Dec-08	Vaoto	14.18475°S	169.67216°W
NE	EI	2-Dec-08	Vaoto	14.18499°S	169.67165°W
NE	EI	2-Dec-08	Vaoto	14.18522°S	169.66820°W
NE	EI	2-Dec-08	Vaoto	14.18522°S	169.66818°W
NE	EI	2-Dec-08	Vaoto	14.18490°S	169.67187°W
NE	EI	2-Dec-08	Vaoto	14.18476°S	169.67236°W
NNE	EI	28-Jan-09	Vaoto	14.18418°S	169.66600°W
NNE	EI	28-Jan-09	Vaoto	14.18448°S	169.66609°W
NNE	EI	28-Jan-09	Vaoto	14.18525°S	169.67111°W
NEST	EI	12-Jan-11	Mafafa	14.1678°S	169.643383°W
NEST	EI	12-Jan-11	Mafafa	14.1678°S	169.643217°W
NEST	EI	12-Jan-11	Mafafa	14.1677°S	169.642767°W
NEST	EI	12-Jan-11	Mafafa	14.167617°S	169.64235°W
NNE	EI	12-Jan-11	Mafafa	14.16777°S	169.64397°W
NNE	EI	12-Jan-11	Mafafa	14.16777°S	169.6438°W
NNE	EI	12-Jan-11	Mafafa	14.16775°S	169.64369°W
NNE	EI	12-Jan-11	Mafafa	14.16775°S	169.64351°W
NNE	EI	12-Jan-11	Mafafa	14.16775°S	169.6432°W
NNE	EI	12-Jan-11	Mafafa	14.1676°S	169.64235°W
PIT-4	UNK	12-Jan-11	Mafafa	14.16781°S	169.64394°W
PIT-3	UNK	12-Jan-11	Mafafa	14.1678°S	169.64375°W
PIT-1	UNK	12-Jan-11	Mafafa	14.1678°S	169.64368°W
PIT-1	UNK	12-Jan-11	Mafafa	14.1678°S	169.64365°W
PIT-2	UNK	12-Jan-11	Mafafa	14.16781°S	169.64359°W
PIT-2	UNK	12-Jan-11	Mafafa	14.16781°S	169.64342°W
PIT-2	UNK	12-Jan-11	Mafafa	14.1678°S	169.6432°W
PIT-1	UNK	12-Jan-11	Mafafa	14.16781°S	169.64311°W
PIT-1	UNK	12-Jan-11	Mafafa	14.16778°S	169.64293°W
PIT-2	UNK	12-Jan-11	Mafafa	14.16774°S	169.6429°W
PIT-2	UNK	12-Jan-11	Mafafa	14.16769°S	169.6427°W
PIT-2	UNK	12-Jan-11	Mafafa	14.16769°S	169.64264°W
PIT-2	UNK	12-Jan-11	Mafafa	14.16772°S	169.64252°W

Appendix Table 4. Continued...

FIELD ID	SPECIES	DATE TRACKS OBSERVED	BEACH	LOCATIONS	FIELD ID
NE	EI	8-Feb-12	Mafafa	14.16783°S	169.64366°W
NE	EI	8-Feb-12	Mafafa	14.16795°S	169.64362°W
NNE	EI	8-Feb-12	Mafafa	14.16784°S	169.64343°W
NE	EI	8-Feb-12	Mafafa	14.16783°S	169.64336°W
NE	EI	8-Feb-12	Mafafa	14.16779°S	169.64311°W
NE	EI	8-Feb-12	Mafafa	14.16774°S	169.64294°W
NE	EI	8-Feb-12	Mafafa	14.16772°S	169.64285°W
NNE	EI	12-Jan-11	Agaputuputu	14.16759°S	169.64786°W
NNE	EI	12-Jan-11	Agaputuputu	14.16761°S	169.64761°W
PIT-1	UNK	12-Jan-11	Agaputuputu	14.16764°S	169.64799°W
PIT-2	UNK	12-Jan-11	Agaputuputu	14.16765°S	169.64792°W
PIT-2	UNK	12-Jan-11	Agaputuputu	14.16766°S	169.64787°W
PIT-3	UNK	12-Jan-11	Agaputuputu	14.16767°S	169.64783°W
PIT-5	UNK	12-Jan-11	Agaputuputu	14.16766°S	169.64763°W
PIT-1	UNK	12-Jan-11	Agaputuputu	14.16763°S	169.64752°W
PIT-3	UNK	12-Jan-11	Agaputuputu	14.16759°S	169.64743°W
PIT-2	UNK	12-Jan-11	Agaputuputu	14.16758°S	169.64737°W
PIT-4	UNK	12-Jan-11	Agaputuputu	14.16771°S	169.64658°W
PIT-2	UNK	12-Jan-11	Agaputuputu	14.16775°S	169.64636°W
PIT-1	UNK	8-Feb-12	Agaputuputu	14.167363°S	169.64769°W
PIT-1	UNK	8-Feb-12	Agaputuputu	14.16767°S	169.64767°W
PIT-1	UNK	8-Feb-12	Agaputuputu	14.16772°S	169.64757°W
PIT-1	UNK	8-Feb-12	Agaputuputu	14.16767°S	169.64757°W
PIT-1+EC	UNK	8-Feb-12	Agaputuputu	14.16771°S	169.64746°W
PIT-1	UNK	8-Feb-12	Agaputuputu	14.16765°S	169.64743°W

Appendix Table 5. Hatching success and emergence success

FIELD ID	BEACH	SPECIES	INVENTORY DATE	CLUTCH SIZE	HATCHING SUCCESS (%)	EMERGENCE SUCCESS (%)	NUMBER OF DAYS INCUBATING
NE01	Dumpsite	EI	22-Apr-11	138	30.43	30.43	53
NE02	Olosega	EI	15-Jul-11	169	46.75	46.75	NA
NE01-UN	Asaga	EI	22-Apr-11	150	94.00	94.00	52
NE01	Vaoto	EI	31-Mar-11	103	97.09	97.09	47
NE02	Vaoto	EI	26-Apr-11	61	60.66	60.66	71
NE03	Vaoto	CM	21-Sep-11	83	90.36	90.36	72
NE04	Vaoto	EI	5-May-11	80	97.50	97.50	NA
NE05	Vaoto	CM	9-Jun-11	38	23.68	23.68	NA
NE01	Toaga	EI	15-Jun-10	161	97.52	97.52	NA
NE02	Toaga	EI	27-Jun-10	91	91.21	91.21	NA
NE03	Toaga	EI	17-Mar-10	181	85.08	85.08	71
NE04	Toaga	EI	17-Mar-10	103	92.23	92.23	50
NE05	Toaga	EI	17-Mar-10	56	91.07	91.07	51
NE06	Toaga	EI	29-Jun-10	170	97.06	97.06	NA
NE07	Toaga	EI	17-Jun-10	126	96.83	96.83	NA
NE08	Toaga	EI	26-May-10	173	78.03	78.03	NA
NE09	Toaga	EI	26-May-10	156	80.13	80.13	61
NE10	Toaga	EI	8-Jan-11	74	90.54	90.54	NA
NE11	Toaga	EI	8-Jan-11	174	48.85	48.85	58
NE12	Toaga	CM	12-Jan-11	87	48.28	47.13	77
NE13	Toaga	EI	5-Jul-11	128	28.13	28.13	77
NE14	Toaga	EI	11-Apr-12	188	77.66	76.06	65
NE15	Toaga	EI	16-May-12	137	93.43	93.43	72

Appendix Table 5. Continued...

FIELD ID	BEACH	SPECIES	INVENTORY DATE	CLUTCH SIZE	HATCHING SUCCESS (%)	EMERGENCE SUCCESS (%)	NUMBER OF DAYS INCUBATING
NE16	Toaga	EI	30-Nov-12	94	100.00	100.00	<60
NE17-UN	Toaga	EI	4-Dec-12	76	53.95	53.95	<62
NE01	Mafafa	EI	28-Jan-13	122	97.54	97.54	69
NE02	Mafafa	EI	19-Feb-13	87	88.51	88.51	67
NE03	Mafafa	EI	9-Apr-13	106	89.62	89.62	<66
NE04	Mafafa	EI	15-Apr-13	41	100.00	26.83	59
NE05	Mafafa	EI	27-Apr-13	98	98.98	98.98	<67
NE06	Mafafa	EI	24-May-13	NA	0.00	0.00	NA
NE07	Mafafa	EI	23-May-13	124	0.00	0.00	<83
NE08	Mafafa	EI	13-May-13	68	100.00	100.00	65
NE09	Mafafa	EI	16-May-13	60	98.33	76.67	<62
NE10-UN	Mafafa	EI	17-Mar-13	101	90.10	90.10	NA
NE11	Mafafa	EI	15-Sep-13	57	94.74	94.74	NA
		EI		**114.16 ± 42.68 S.D**	**78.36 ± 28.55 S.D.**	**75.44 ± 29.36 S.D.**	**61.75 ± 9.22 S.D.**
		CM		**69.33 ± 27.21 S.D.**	**54.11 ± 33.72 S.D.**	**53.72 ± 33.82 S.D.**	**74.50 ± 3.54 S.D.**

Appendix Table 6. Mean, standard deviation and distribution of clutch size, hatching success and emergence success of hawksbill turtles from documented nests on Tutuila Island.

VILLAGE	DATE	SPECIES	CLUTCH SIZE	HATCHING SUCCESS	EMERGENCE SUCCESS
Amanave	28-Oct-07	EI	192	86.98	86.98
Amanave	12-Nov-07	EI	194	96.39	96.39
Amanave	28-Nov-07	EI	174	89.66	89.66
Alega	18-Feb-11	EI	170	90.00	90.00
Alega	26-Feb-11	EI	171	98.25	98.25
Amalau	16-Jan-12	EI	152	99.34	99.34
		Mean	**175.50**	**93.44**	**93.44**
		StDev	**15.62**	**5.19**	**5.19**

Appendix Table 7. Hatching success T-test, Inundation by water: Not inundated vs Inundated.

T-TEST: TWO-SAMPLE ASSUMING UNEQUAL VARIANCES	VARIABLE 1	VARIABLE 2
Mean	86.7132446	40.78274333
Variance	431.26144	901.4028811
Observations	27	6
Hypothesized Mean Difference	0	
df	6	
t Stat	3.56268345	
P(T<=t) one-tail	0.0059443	
t Critical one-tail	1.94318028	
P(T<=t) two-tail	0.0118886	
t Critical two-tail	2.44691185	

Appendix Table 8. Hatching success T-test: On-slope vs Behind-slope.

T-TEST: TWO-SAMPLE ASSUMING UNEQUAL VARIANCES	VARIABLE 1	VARIABLE 2
Mean	82.66292757	75.5668
Variance	387.5172893	1106.797
Observations	13	20
Hypothesized Mean Difference	0	
df	31	
t Stat	0.76900997	
P(T<=t) one-tail	0.223853571	
t Critical one-tail	1.695518783	
P(T<=t) two-tail	0.447707141	
t Critical two-tail	2.039513446	

Appendix Table 9. Hatching success T-test: Predation: No predation vs Depredated

T-TEST: TWO-SAMPLE ASSUMING UNEQUAL VARIANCES	**GROUP1**	**GROUP2**
Mean	43.478261	81.850643
Variance	2627.5992	579.48761
Observations	3	30
Hypothesized Mean Difference	0	
df	2	
t Stat	-1.2825164	
P(T<=t) one-tail	0.164113	
t Critical one-tail	2.9199856	
P(T<=t) two-tail	0.328226	
t Critical two-tail	4.3026527	

Appendix Table 10. Hatching success analysis of variance (ANOVA), Vegetation cover: No-vegetation vs Under-vegetation vs In-vegetation

ANOVA: SINGLE FACTOR SOURCE OF VARIATION	**SS**	**DF**	**MS**	**F**	**P-VALUE**	**F CRIT**
Between Groups	182.2049	2	91.10245	0.105549	0.900163	3.31583
Within Groups	25893.88	30	863.1293			
Total	26076.08	32				

Appendix Table 11. Hatching success analysis of variance (ANOVA), Vegetation Type: No vegetation vs Native vegetation vs Non-native vegetation.

ANOVA: SINGLE FACTOR						
SOURCE OF VARIATION	SS	DF	MS	F	P-VALUE	F CRIT
Between Groups	1381.771	2	690.8857	0.839326	0.441894	3.31583
Within Groups	24694.31	30	823.1437			
Total	26076.08	32				

Appendix Table 12. Emergence success T-test on Predation: No predation vs Depredated

T-TEST: TWO-SAMPLE ASSUMING UNEQUAL VARIANCES		
	VARIABLE 1	VARIABLE 2
Mean	81.075229	19.088017
Variance	570.973081	276.51423
Observations	30	3
Hypothesized Mean Difference	0	
df	3	
t Stat	5.87817081	
P(T<=t) one-tail	0.00491157	
t Critical one-tail	2.35336343	
P(T<=t) two-tail	0.00982313	
t Critical two-tail	3.18244631	

Appendix Table 13. Emergence success T-test on inundation: Inundated vs Not Inundated.

T-TEST: TWO-SAMPLE ASSUMING UNEQUAL VARIANCES		
	VARIABLE 1	VARIABLE 2
Mean	83.141647	48.939292
Variance	549.04916	627.783955
Observations	27	5
Hypothesized Mean Difference	0	
df	5	
t Stat	2.8316551	
P(T<=t) one-tail	0.0183017	
t Critical one-tail	2.0150484	
P(T<=t) two-tail	0.0366035	
t Critical two-tail	2.5705818	

Appendix Table 14. Emergence success T-test on slope: On-slope vs Behind-slope

T-TEST: TWO-SAMPLE ASSUMING UNEQUAL VARIANCES		
	VARIABLE 1	VARIABLE 2
Mean	82.54018	70.82493
Variance	389.0438	1149.5102
Observations	13	20
Hypothesized Mean Difference	0	
df	31	
t Stat	1.253115	
P(T<=t) one-tail	0.109767	
t Critical one-tail	1.695519	
P(T<=t) two-tail	0.219534	
t Critical two-tail	2.039513	

Appendix Table 15. Emergence success analysis of variance (ANOVA), Vegetation cover: No-vegetation vs Under-vegetation vs In-vegetation

ANOVA: SINGLE FACTOR SOURCE OF VARIATION	SS	DF	MS	F	P-VALUE	F CRIT
Between Groups	1215.948	2	607.9742	0.691545	0.508608	3.3158295
Within Groups	26374.61	30	879.1537			
Total	27590.56	32				

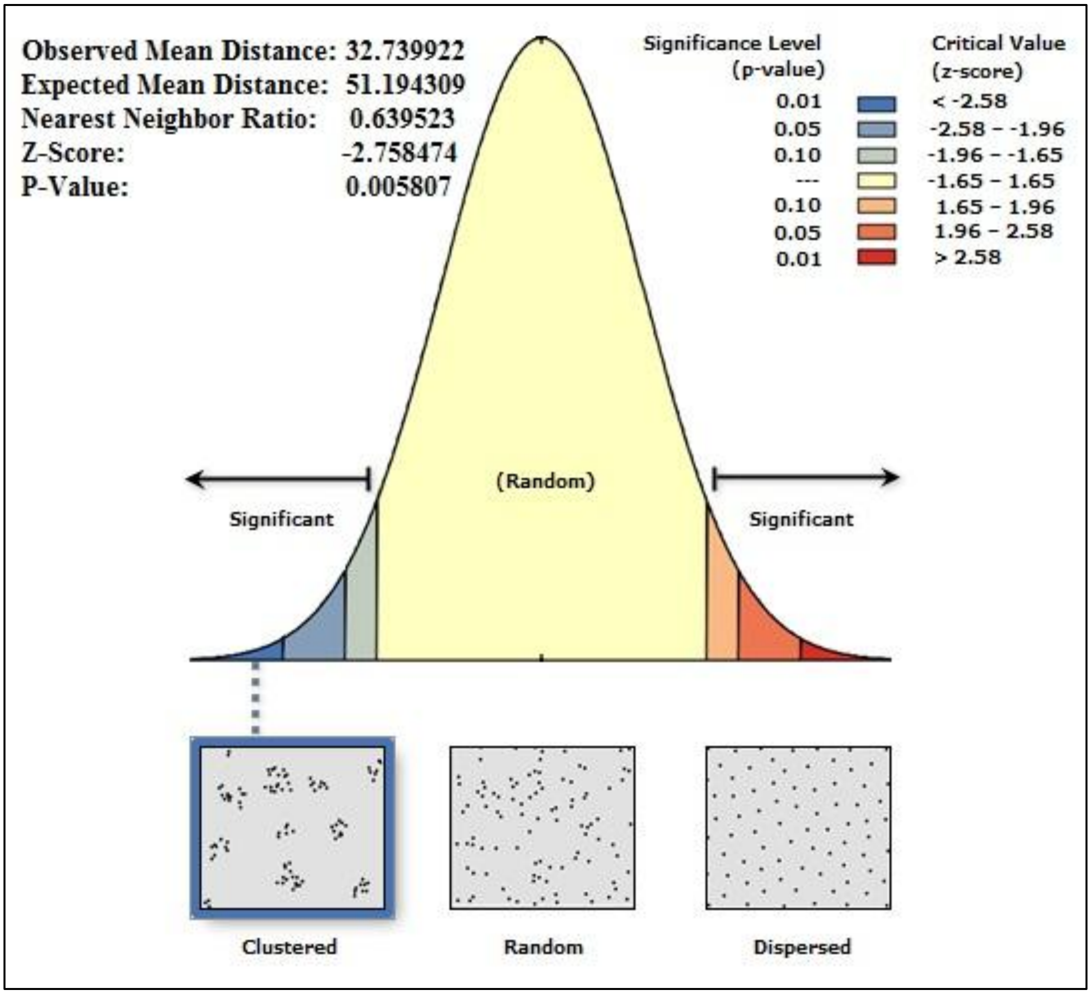
Appendix Table 16. Emergence success analysis of variance (ANOVA), Vegetation Type: No vegetation vs Native vegetation vs Non-native vegetation

ANOVA: SINGLE FACTOR SOURCE OF VARIATION	SS	DF	MS	F	P-VALUE	F CRIT
Between Groups	2516.048	2	1258.024	1.505143	0.238276	3.31583
Within Groups	25074.51	30	835.8171			
Total	27590.56	32				

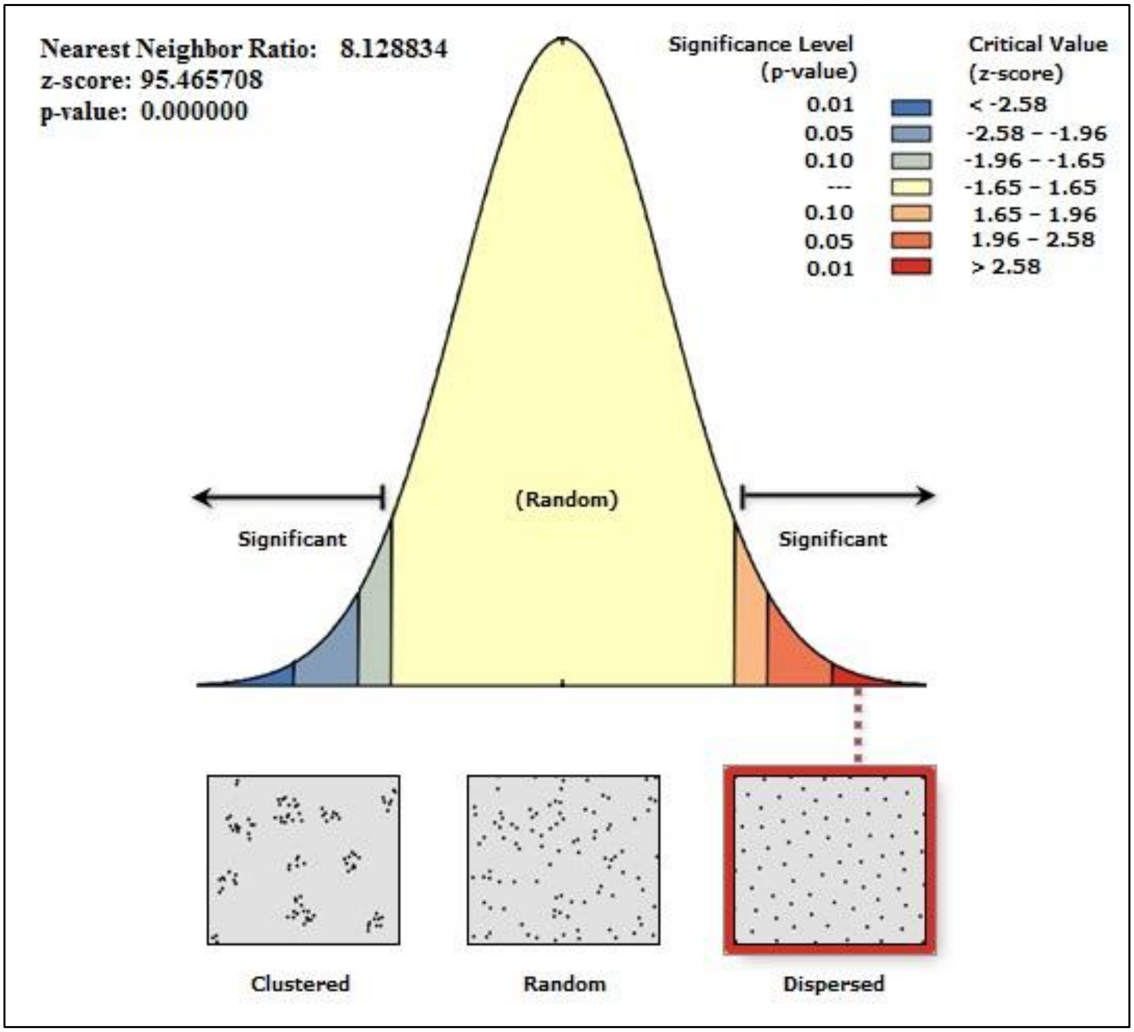
APPENDIX FIGURES

Appendix Figure 1. Before high tide surge photos of Olosega nesting beach.

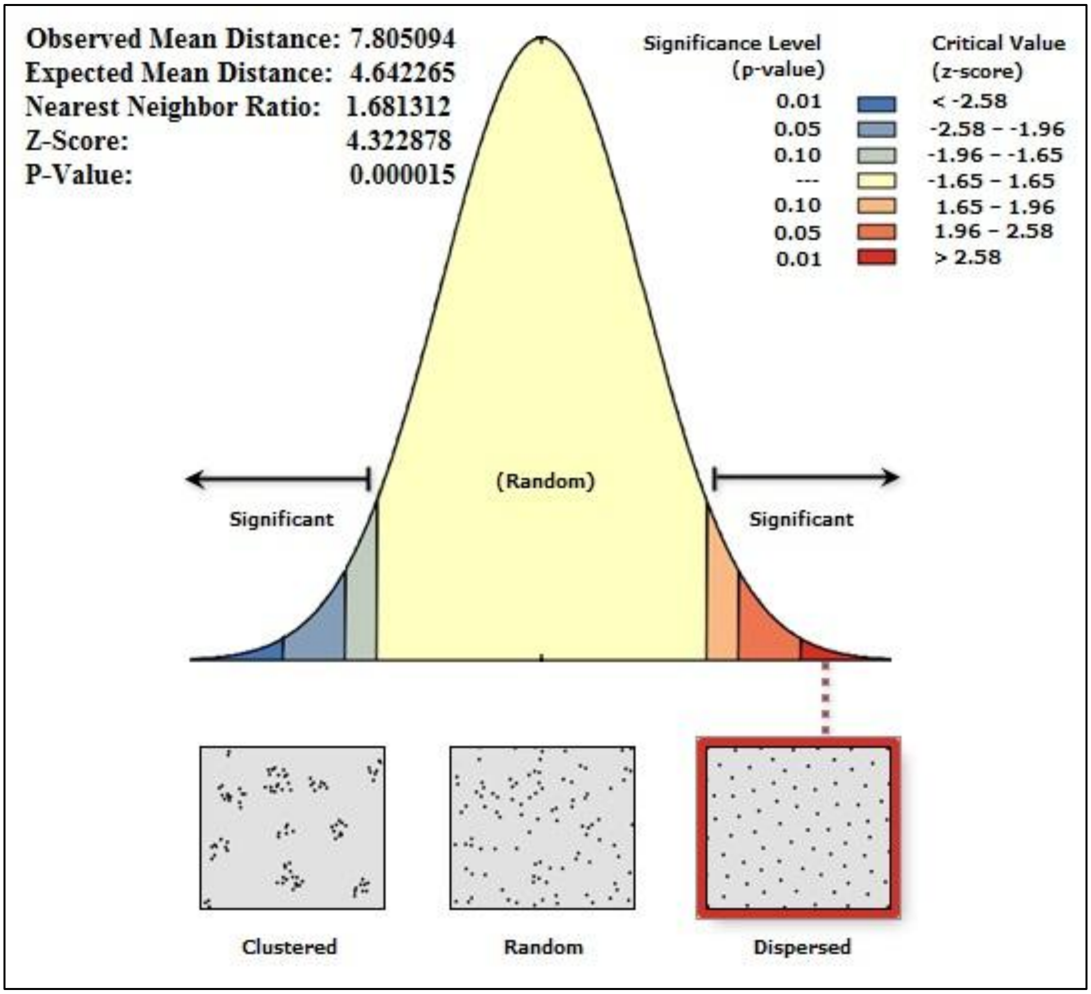
Appendix Figure 2. Olosega nesting beach after high tide surge.



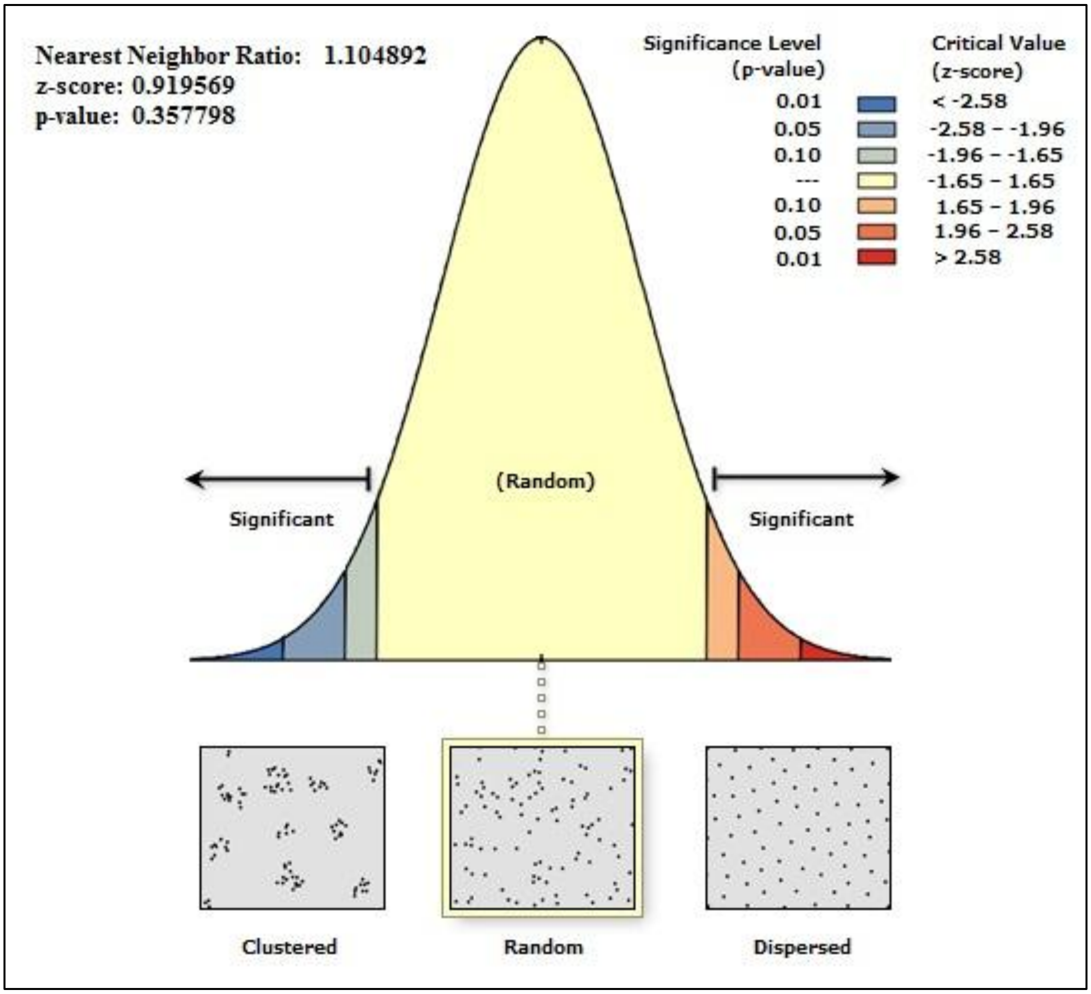
Appendix Figure 3. Toaga nesting beach nesting emergence average nearest neighbor summary, 99% confidence level.



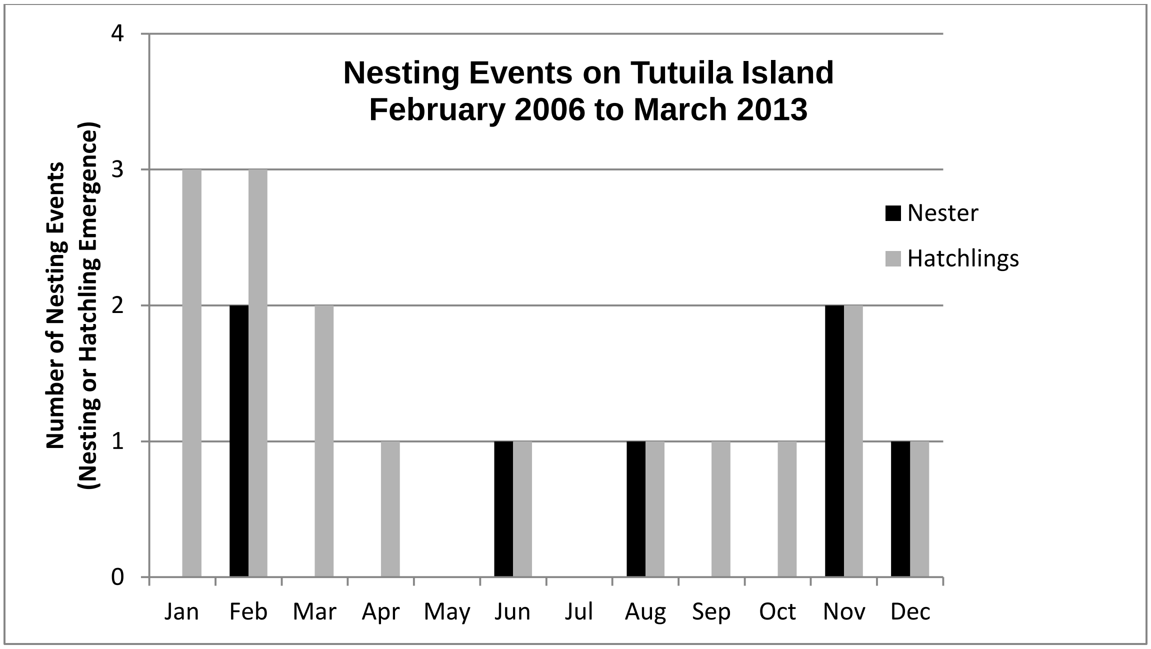
Appendix Figure 4. Toaga nesting beach nesting and non-nesting emergence (NE + NNE) average nearest neighbor analysis summary, 99% confidence level.



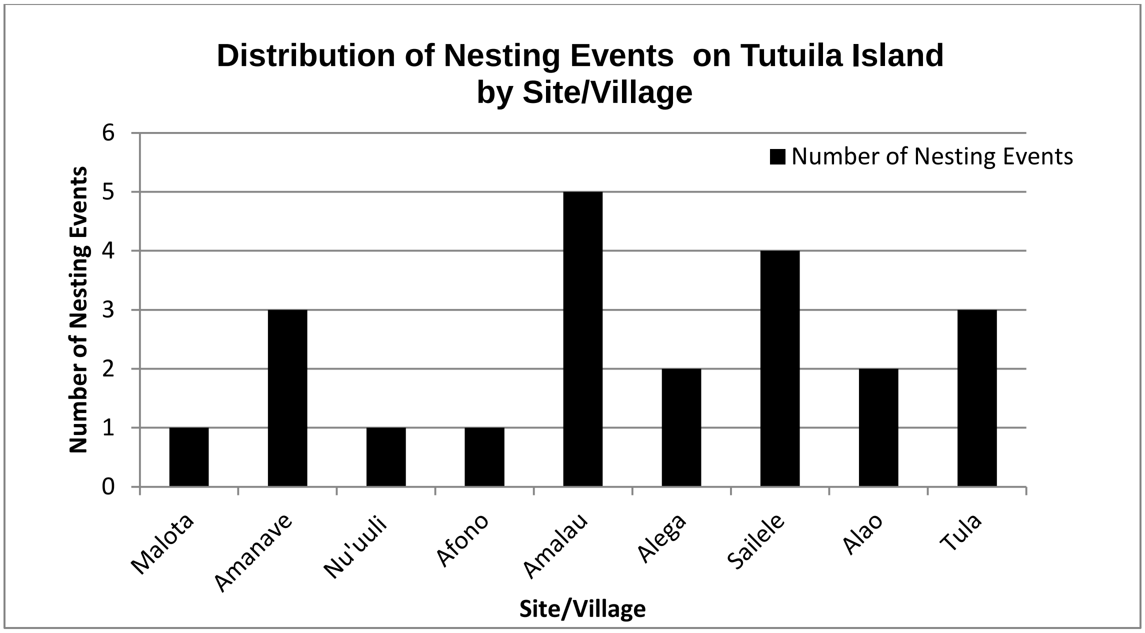
Appendix Figure 5. Mafafa nesting beach nesting emergence average nearest neighbor summary, 99% confidence level.



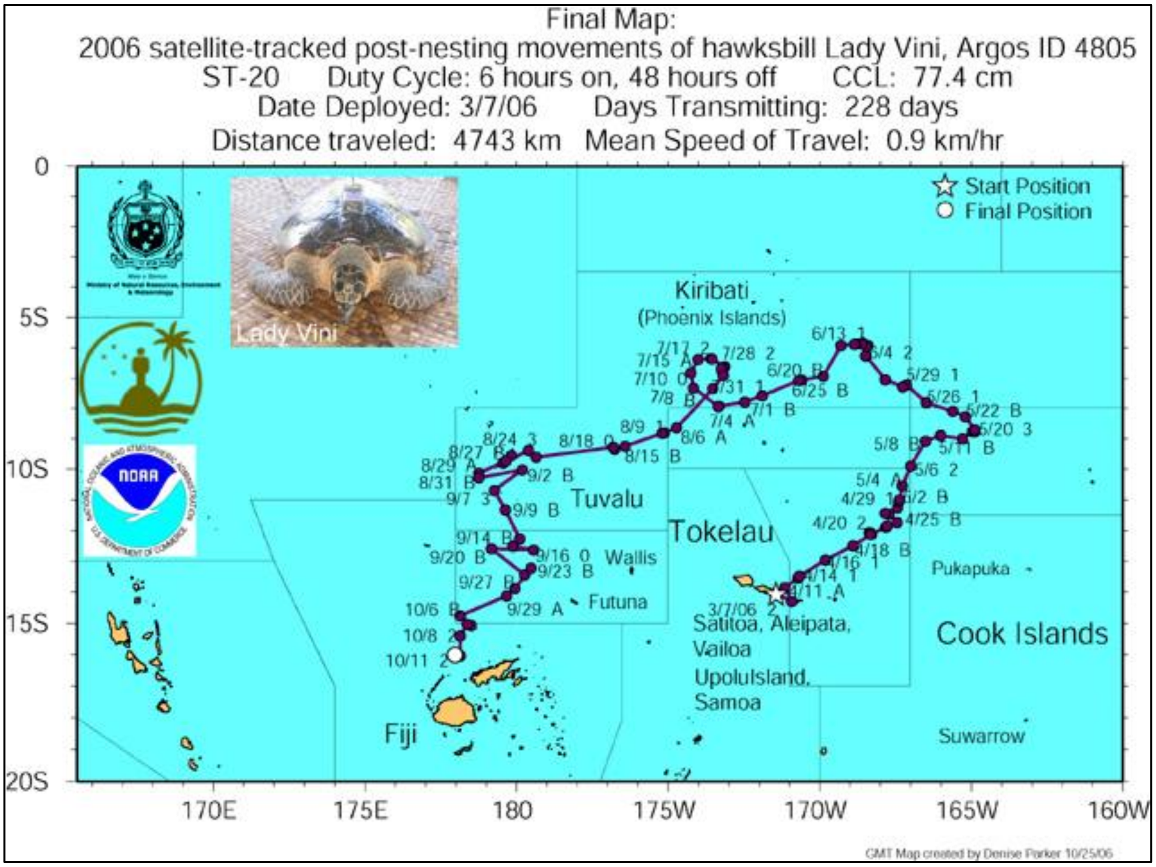
Appendix Figure 6. Mafafa nesting beach nesting and non-nesting emergence (NE + NNE) average nearest neighbor analysis summary, 99% confidence level.



Appendix Figure 7. Nesting events on Tutuila Island from February 2006 to March 2013.



Appendix Figure 8. Distribution of nesting events on Tutuila Island by site/village.



Appendix Figure 9. Movements of post nesting hawksbill turtle from Samoa (SPREP 2007).

Appendix Figure 10. Adult Male (Top), Juvenile (Bottom left) and Adult Female (Bottom Right) Hawksbill turtles of American Samoa.

APPENDIX

Appendix 1. American Samoa Government (ASG) Department of Marine and Wildlife Resources (DMWR) letter of support.

Department of Marine and Wildlife Resources

American Samoa Government
PO Box 3730
Pago Pago American Samoa 96799

TEL: (684) 633-4456
FAX: (684) 633-5944

LOLO .MATALASI. MOLIGA
Governor

LEMANU .PELETI. MAUGA
Lt. Governor

Ruth S. Matagi-Tofiga, Ph.D.
Director

Selaina Vaitautolu Tuimavave
Deputy Director

Official Document # 001-15

May 1, 2015

The Graduate School
University of the Philippines at Los Baños
College, Laguna 4031
Philippines

Dear Sir/Madam,

I would like to take this opportunity to express our support of Mr. Alden P. Tagarino's thesis entitled, "Spatio-temporal patterns of hawksbill turtle nesting and migration in American Samoa." As the territorial agency charged with managing the natural resources of American Samoa, we are pleased to see this thoughtful analysis completed which will be useful in our future management of sea turtles in American Samoa. The data Mr. Tagarino is using was funded by National Oceanographic and Atmospheric Administration Pacific Islands Regional Office a federal agency. Given that Mr. Tagarino collected these data himself, we feel he is the best candidate to analyze and interpret this information and we look forward to using his thesis in our future sea turtle management decisions.

In conclusion, we support Mr. Tagarino's thesis analysis and look forward to using his interpretations in the future.

Sincerely,

Ruth S. Matagi-Tofiga PhD
Director
Department of Marine and Wildlife Resources
American Samoa Government