APPENDIX M.1
MARINE BIOLOGY TECHNICAL MEMO

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1.0 UNDERWATER ACOUSTICS

1.1 INTRODUCTION

The underwater acoustics portion of this Technical Memo serves as a reference document to be used in support of the Commonwealth of the Northern Mariana (CNMI) Joint Military Training (CJMT) Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS). The proposed construction and operation have the potential to take marine mammals by harassment only (i.e., take would not occur through injury or mortality), primarily through construction activities involving in-water pile driving and extraction. Other activities are not expected to result in take as defined under the Marine Mammal Protection Act (MMPA) or the Endangered Species Act (ESA). However, in-water pile driving and extraction would temporarily increase the local underwater and airborne noise environment in the action area. Research suggests that increased noise may impact marine mammals in several ways and depends on many factors. The following text provides a background on underwater sound, description of noise sources in the action area, applicable noise criteria, and the basis for the calculation of take by Level B harassment. Level A harassment of cetaceans for the proposed action is not expected to occur because the area of potential Level A harassment is small, marine mammals are not expected to approach within this distance, and if they did, monitoring as part of Best Management Practices would ensure curtailment of the activity. Therefore, Level A harassment is not discussed in this text.

1.2 FUNDAMENTALS OF UNDERWATER SOUND

Sound is a physical phenomenon consisting of regular pressure oscillations that travel through a medium, such as air or water. Sound frequency is the rate of oscillation, measured in cycles per second or Hertz (Hz). The amplitude (loudness) of a sound is its pressure, whereas its intensity is proportional to power and is pressure squared. The standard international unit of measurement for pressure is the Pascal, which is a force of 1 Newton exerted over an area of 1 square meter; sound pressures are measured in microPascals (µPa).

Due to the wide range of pressure and intensity encountered during measurements of sound, a logarithmic scale is used, based on the decibel (dB), which, for sound intensity, is 10 times the $\log_{10}$ of the ratio of the measurement to reference value. For sound pressure level (SPL), the amplitude ratio in dB is 20 times the $\log_{10}$ ratio of measurement to reference. Hence each increase of 20 dB in SPL reflects a 10-fold increase in signal amplitude (whether expressed in terms of pressure or particle motion). This means a 20 dB increase results in a 10-fold increase in the amplitude, a 40 dB increase results in a 100-fold increase in the amplitude, a 60 dB increase results in a 1,000-fold increase in the amplitude, and so on. Because the dB is a relative measure, any value expressed in dB is meaningless without an accompanying reference. In describing underwater sound pressure, the reference amplitude is usually 1 µPa, and is expressed as decibels referenced (re) to 1 microPascal (dB re 1 µPa). For in-air sound pressure, the reference amplitude is usually 20 µPa and is expressed as “dB re 20 µPa.”

The method commonly used to quantify airborne sounds consists of evaluating all frequencies of a sound according to a weighted filter that mimics human sensitivity to amplitude as a function of frequency. This is called A-weighting and the decibel level measured is called the A-weighted sound level (dBA). Methods of frequency weighting that reflect the hearing of marine mammals have been proposed (Southall et al. 2007; Finneran and Jenkins 2012) and are being used in new analyses of Navy testing and training effects, but have not been adopted for pile driving and other non-explosive impulsive sounds (Marine Species Modeling Team 2012). Therefore, underwater sound levels are not weighted and measure the entire frequency range of interest. In the case of marine construction work, the frequency range of interest is 20 Hz to 20 kilohertz (kHz).

Table 1 summarizes commonly used terms to describe underwater sounds. Two common descriptors are the instantaneous peak SPL and the root mean square (rms) SPL. The peak pressure is the instantaneous maximum or minimum overpressure observed during each pulse or sound event and is presented in dB re 1 µPa. The rms level is the square root of the mean of the squared pressure (= intensity) level as measured over a specified time period. All underwater sound levels throughout the remainder of this application are presented in dB re 1 µPa unless otherwise noted.

Table 1. Definitions of Acoustical Terms

Term	*Definition*
Decibel (dB)	A unit describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for water is 1 µPa and for air is 20 µPa (approximate threshold of human audibility).
Sound Pressure Level (SPL)	Sound pressure is the force per unit area, usually expressed in microPascals where 1 Pascal equals 1 Newton exerted over an area of 1 square meter. The SPL is expressed in decibels as 20 times the logarithm to the base 10 of the ratio between the pressure exerted by the sound to a reference sound pressure. SPL is the quantity that is directly measured by a sound level meter.
Frequency, Hz	Frequency is expressed in terms of oscillations, or cycles, per second. Cycles per second are commonly referred to as Hertz (Hz). Typical human hearing ranges from 20 Hz to 20 kHz.
Peak Sound Pressure, dB re 1 µPa	Peak SPL is based on the largest absolute value of the instantaneous sound pressure over the frequency range from 20 Hz to 20 kHz. This pressure is expressed in this application as dB re 1 µPa.
Root-Mean-Square (rms), dB re 1µPa	The rms level is the square root of the mean of the squared pressure level(s) as measured over a specified time period. For pulses, the rms has been defined as the average of the squared pressures over the time that comprise that portion of waveform containing 90 % of the sound energy for one impact pile driving impulse.
Sound Exposure Level (SEL), dB re 1 µPa2 sec	Sound exposure level is a measure of energy. Specifically, it is the dB level of the time integral of the squared-instantaneous sound pressure, normalized to a 1-sec period. It can be an extremely useful metric for assessing cumulative exposure because it enables sounds of differing duration; to be compared in terms of total energy.
Waveforms, µPa over time	A graphical plot illustrating the time history of positive and negative sound pressure of individual pile strikes shown as a plot of µPa over time (i.e., seconds).
Frequency Spectrum, dB over frequency range	The amplitude of sound at various frequencies, usually shown as a graphical plot of the mean square pressure per unit frequency ($\mu Pa^2/Hz$) over a frequency range (e.g., 10 Hz to 10 kHz in this application).

Table 1. Definitions of Acoustical Terms

Term	*Definition*
A-Weighting Sound Level, dBA	The SPL in decibels as measured on a sound level meter using the A- weighting filter network. The A-weighting filter de-emphasizes the low and high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective human reactions to noise.
Ambient Noise Level	The background sound level, which is a composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.

1.3 Effects of Pile Installation and Removal Activities

1.3.1 Description of Noise Sources

Underwater sound levels are comprised of multiple sources, including physical noise, biological noise, and anthropogenic noise. Physical noise includes waves at the surface, earthquakes, ice, and atmospheric noise. Biological noise includes sounds produced by marine mammals, fish, and invertebrates. Anthropogenic noise consists of vessels (small and large), dredging, aircraft overflights, and construction noise. Known noise levels and frequency ranges associated with anthropogenic sources similar to those that would be used for the proposed action are summarized in Table 2. Details of each of the sources are described in the following text.

Table 2. Representative Noise Levels of Anthropogenic Sources

Noise Source	*Frequency Range (Hz)*[1]	*Underwater Noise Level (dB re 1 µPa)*	*Reference*
Small vessels	250 – 1,000	151 dB rms @ 1 m	Richardson et al. 1995
Tug docking gravel barge	200 – 1,000	149 dB rms @100 m	Blackwell and Greene 2002
Vibratory driving of 72-in Steel Pipe pile	10 – 1,500	180 dB rms @10m	California Department of Transportation (CALTRANS) 2007
Impact driving of 36-in Steel Pipe pile	10 – 1,500	195 dB rms @10m	Washington State Department of Transportation (WSDOT) 2007
Impact driving of 66-in Cast in Steel Shells (CISS) piles	100 – 1,500	195 dB rms @10 m	Reviewed in Hastings and Popper 2005

Notes: [1]These are the dominant frequency ranges but there is often considerable energy outside these ranges. *Legend:* m = meter.

In-water construction activities associated with the project would include impact pile driving and vibratory pile driving. The sounds produced by these activities fall into one of two sound types: pulsed and non-pulsed (defined below). Impact pile driving produces pulsed sounds, while vibratory pile driving produces non-pulsed (or continuous) sounds. The distinction between these two general sound types is important because they have differing potential to cause physical effects, particularly with regard to hearing (e.g., Ward 1997 as cited in (Southall et al. 2007).

Pulsed sounds (e.g., explosions, gunshots, sonic booms, seismic airgun pulses, and impact pile driving) are brief, broadband, atonal transients (American National Standards Institute 1986; Harris 1998) and occur either as isolated events or repeated in some succession (Southall et al. 2007). Pulsed sounds are all characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a decay period that may include a period of diminishing, oscillating maximal and minimal pressures (Southall et al. 2007). Pulsed sounds generally have an increased capacity to induce physical injury as compared with sounds that lack these features (Southall et al. 2007).

Non-pulse (intermittent or continuous sounds) can be tonal, broadband, or both (Southall et al. 2007). Some of these non-pulse sounds can be transient signals of short duration but without the essential properties of pulses (e.g., rapid rise time) (Southall et al. 2007). Examples of non-pulse sounds include vessels, aircraft, machinery operations such as drilling or dredging, vibratory pile driving, and active sonar systems (Southall et al. 2007). The duration of such sounds, as received at a distance, can be greatly extended in highly reverberant environments (Southall et al. 2007).

1.3.2 Sound Exposure Criteria and Thresholds

Under the MMPA, National Marine Fisheries Service (NMFS) has defined levels of harassment for marine mammals. Level A harassment is defined as “Any act of pursuit, torment, or annoyance which has the potential to injure a marine mammal or marine mammal stock in the wild.” Level B harassment is defined as “Any act of pursuit, torment, or annoyance which has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to migration, breathing, nursing, breeding, feeding or sheltering.” These definitions would apply to the proposed construction activities. For military readiness activities, which include operations and training, Level A harassment is defined as “Any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild,” whereas Level B harassment is defined as “Any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including but not limited to migration, breathing, nursing, breeding, feeding or sheltering, to a point where such behavioral patterns are abandoned or significantly altered.”

Under the federal ESA, the definition of “take” is to “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct (ESA§3[19]).” Harm, which is a form of take, is further defined to include “…significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering” (USFWS and NMFS 1998).

Since 1997, NMFS has used generic sound exposure thresholds to determine when an activity in the ocean that produces sound might result in impacts to a marine mammal such that a take by harassment might occur (NMFS 2005). Recent studies of pile driving used to construct offshore wind turbines have validated the distances over which underwater sound from pile driving may exceed NMFS thresholds (Bailey et al. 2010), as well as behavioral responses of harbor porpoises (*Phocoena phocoena*) to intense sound from pile driving (Thompson et al. 2010; Brandt et al. 2011). Current NMFS practice regarding exposure of marine mammals to high level sounds is that cetaceans and pinnipeds exposed to impulsive sounds of 180 and 190 dB rms or above, respectively, are considered to have been taken by Level A (injurious) harassment. Level A acoustic harassment under the MMPA constitutes harm under the ESA, whereas Level B acoustic harassment under the MMPA is also harassment under the ESA.

Level A harassment is assumed to result in a “stress response.” The stress response per se is not considered injury, but refers to an increase in energetic expenditure that results from exposure to the stressor and that is predominantly characterized by either the stimulation of the sympathetic nervous system or the hypothalamic-pituitary-adrenal axis (Reeder and Kramer 2005). The presence and magnitude of a stress response in an animal depends on the animal’s life history stage, environmental conditions, reproductive state, and experience with the stressor (DoN 2010).

Behavioral harassment (Level B) is considered to have occurred when marine mammals are exposed to sounds at or above 160 dB rms for impulse sounds (e.g., impact pile driving) and 120 dB rms for continuous noise (e.g., vibratory pile driving), but below injurious thresholds. Behavioral harassment may or may not result in a stress response. The criteria for vibratory pile driving would also be applicable to vibratory pile extraction or the use of a pneumatic chipper (an air powered tool used for cutting metal or stone). The application of the 120 dB rms threshold can sometimes be problematic because this threshold level can be either at or below the ambient noise level of certain locations. As a result, these levels are considered precautionary (NMFS 2009). NMFS is developing new science-based thresholds to improve and replace the current generic exposure level thresholds, but the criteria have not been finalized (Southall et al. 2007; NMFS 2013). The current Level A (injury) and Level B (disturbance) thresholds are provided in Table 3. Airborne threshold criteria exist for marine mammals that spend much of their time on land but do not apply to the species that occur in the action area, all of which are cetaceans that spend most of their time under water.

Table 3. Injury and Disturbance Thresholds for Underwater Pile Driving

Marine Mammal Group	***Vibratory Pile Driving (re 1 µPa)***		***Impact Pile Driving (re 1 µPa)***	
	Level A (Injury)	***Level B (Disturbance)***	***Level A (Injury)***	***Level B (Disturbance)***
Cetaceans (whales, dolphins, porpoises)	180 dB rms	120 dB rms	180 dB rms	160 dB rms
Pinnipeds (seals, sea lions, walrus, harbor seal)	190 dB rms	120 dB rms	190 dB rms	160 dB rms

1.3.3 Limitations of Existing Noise Criteria

To date, there are no research or data supporting a response by pinnipeds or odontocetes to continuous sounds from vibratory pile driving as low as the 120 dB rms threshold. The 120 dB rms threshold level for continuous noise originated from research conducted by Malme et al. (1984, 1986) for California gray whale response to continuous industrial sounds such as drilling operations. The 120 dB rms continuous sound threshold should not be confused with the 120 dB rms pulsed sound criterion established for migrating bowhead whales in the Arctic as a result of research in the Beaufort Sea (Richardson et al. 1995). Southall et al. (2007) reviewed studies conducted to document behavioral responses of harbor seals and northern elephant seals to continuous sounds under various conditions, and concluded that those limited studies suggest that exposures between 90 dB and 140 dB re 1 µPa rms generally do not appear to induce strong behavioral responses.

1.3.4 Ambient Noise

Ambient noise by definition is background noise and it has no single source or point. Ambient noise varies with location, season, time of day, and frequency. Ambient noise is continuous, but with much variability on time scales ranging from less than one second to one year (Richardson et al. 1995). Ambient noise in the area associated with the proposed action has not been characterized. However, given the relatively low ship traffic and general lack of human use for the area, ambient noise would likely be predominately due to biological (e.g., marine mammals, invertebrates, or fish) or environmental (e.g., waves, wind, or rain) phenomena. The ambient noise spectra associated with biological and environmental sounds generally tend to be in the mid-frequency (500 to 25,000 Hz) and from 50 to 90 dB, but is highly dependent on water depth and underwater features in the area (Dahl et al. 2007; Hildebrand 2009). It is assumed that ambient noise levels in the area associated with the proposed action would be similar to these levels, with dolphins, fish, and snapping shrimp being the predominant source of biological underwater noise in the action area.

1.4 DISTANCE TO SOUND THRESHOLDS

1.4.1 Underwater Sound Propagation Formula

Impact and vibratory pile driving would generate underwater noise that potentially could result in disturbance to marine mammals swimming by the action area. Transmission loss (TL) underwater is the decrease in sound intensity due to sound spreading and chemistry- and viscosity-based absorption as an acoustic pressure wave propagates out from a source. These TL parameters vary with frequency, temperature, sea conditions, current, source and receiver depth, water depth, water chemistry, and bottom composition and topography. The general formula for transmission loss is:

$$TL = B * \log_{10}(R) + C * R, \text{ where}$$

B = logarithmic (predominantly spreading) loss

C = linear (scattering and absorption) loss

R = ratio of receiver distance to source reference distance (usually 1m or 10m)

The C term is strongly dependent on frequency, temperature, and depth, but is conservatively assumed to equal zero for pile driving. The B term has a value of 10 for cylindrical spreading and 20 for spherical spreading. A “practical spreading” value of 15 is often used in shallow water conditions where spreading may start out spherically but then end up cylindrically as the sound is constrained by the surface and the bottom. The model is based on historical temperature-salinity data and location-dependent bathymetry. In the model, TL is the same for different sound source levels and is applied to each of the different activities to determine the point at which the applicable thresholds are reached as a function of distance from the source.

1.4.2 Underwater Noise from Pile Driving and Extraction

For the proposed action, pile driving of steel pipe piles and steel sheet piles would use two different pile driving techniques: impact pile driving and vibratory pile driving. Impact pile driving involves a large piston (the “hammer”) inside a framework structure that fits around the steel pipe pile or onto the sheet pile. The “hammer” moves up and down inside the structure and uses the weight of the piston to drive the pile into the ground. Vibratory pile driving uses a "hammer" unit with counter-rotating eccentric weights inside the unit. The mechanism and weights are designed so that the horizontal vibrations are cancelled, while vertical vibrations are transmitted into the pile. The unit clamps to the top of the pile and when the weights rotate, the whole unit vibrates the pile into the ground. Vibratory pile driving would most likely be used to also extract the sheet or pipe piles out of the ground. Sheet piles are driven into the ground in similar ways using both types of hammers.

The intensity of pile driving or sounds is greatly influenced by factors such as the type of piles, hammers, and the physical environment in which the activity takes place. A large quantity of literature regarding SPLs recorded from pile driving projects is available for consideration. In order to determine reasonable SPLs and their associated effects on marine mammals that are likely to result from pile driving in the action area, studies with similar properties to the proposed action were evaluated. Piles to be installed via both vibratory and impact pile driving techniques for the proposed action include 24-inch (61-centimeter) steel pipe and steel sheet piles. Construction is anticipated to take approximately 36 weeks; the in-water work window would be about 21 weeks (or 105 days). Temporary causeways would be constructed to allow an excavator access over the water. The temporary causeways would be constructed using pile-supported trestles through the surfzone and out to 12 feet (4 meters) depth. Steel sheet piles and steel pipe piles would be installed into the reef and penetrate approximately 40 feet (12 meters) into the substrate. There would be approximately 33 piles per causeway and 6 causeways built at different times during the construction phase. The causeways would be constructed using dredged material and would be removed after amphibious landing ramp construction was complete.

To obtain a realistic estimate of the sound levels that would occur during pile driving and extraction, acoustic monitoring results from other pile driving projects using similar materials and equipment in comparable environments were reviewed. These monitoring results are available from the Washington Department of Transportation (WSDOT 2015); the California Department of Transportation (CALTRANS 2012); and on the National Oceanic and Atmospheric Administration (NOAA) Fisheries web page for (NOAA 2015). Table 4 lists the values from representative projects, all of which involved the installation or removal of 24-inch (61-centimeter) steel pipe or sheet piles. Due to the similarity of these actions and the proposed action in terms of pile size and type, installation method, and water depth, as well as substrate and expected sound speed, they provide reasonable peak and root mean square SPLs, and sound exposure levels (SEL), which can be anticipated.

For the acoustical analysis, the selected values in Table 4 represent averages or reasonable worst-case values that would occur for the two types of pile driving (impact and vibratory) that could occur on any given day.

Table 4. Underwater Sound Pressure Levels from Similar in-situ Monitored Construction Activities

Project and Location	***Pile Size, Type (number)***	***Installation Method***	***Water Depth***	***Sound Pressure Levels (SPL) or Sound Exposure Level (SEL) at 10 m distance***		
				Average Peak SPL, dB re 1 µPa	***Average Root Mean Square SPL, dB re 1 µPa***	***Average SEL, dB re 1 µPa^2-sec***
Bainbridge Island Ferry Terminal,	24-inch Steel Pipe (5)	Impact	7-11 ft (2.1-3.4 m)	206	195	181

Table 4. Underwater Sound Pressure Levels from Similar in-situ Monitored Construction Activities

Project and Location	*Pile Size, Type (number)*	*Installation Method*	*Water Depth*	*Sound Pressure Levels (SPL) or Sound Exposure Level (SEL) at 10 m distance*		
				Average Peak SPL, dB re 1 µPa	*Average Root Mean Square SPL, dB re 1 µPa*	*Average SEL, dB re 1 µPa²-sec*
WA[1]						
Friday Harbor Ferry Terminal, WA[2]	24-inch Steel Pipe (5)	Impact	33-47 ft (20-14.3 m)	207	189	181
Port of Oakland Berth 23, CA[3]	24-inch Steel Sheet (5)	Impact	50 ft (15 m)	205	189	179
Selected Value for Impact Pile Driving				**207**	**192**	**181**
Columbia River Crossing Test Pile Project, WA[4]	24-inch Steel Pipe (5)	Vibratory Driving and Extraction	~33 ft (10 m)	N/A	166	166
Manette River Bridge, WA[5]	24-inch Steel Pipe (1)	Vibratory	12 ft (3.6 m)	N/A	166	166
Sacramento River, CA[3]	24-inch Steel Pipe (2)	Vibratory	~1 ft (0.3 m)	N/A	158	158
Trinidad Pier, CA[3]	24-inch Steel Pipe (2)	Vibratory	ND	N/A	160	160
Berths 23 and 35/37, Port of Oakland, CA[3]	24-inch Steel Sheet (2)	Vibratory	50 ft (15 m)	N/A	163	163
Friday Harbor, WA[6]	24-inch Steel Pipe (1)	Vibratory		N/A	162	162
Naval Base Bangor Test Pile Program, WA	24-inch Steel Pipe (1)	Vibratory		N/A	160	160
Selected Value for Vibratory Pile Driving/Extraction					**163**	**163**

Legend: N/A = not applicable, because of the low peak sound level associated with vibratory driving/extraction; ND = no data; ft = feet.
Sources: [1]WSDOT (2005a); [2]WSDOT (2005b); [3]CALTRANS (2012); [4]David Evans and Associates (2011); [5]WSDOT (2010).

Activities are assumed to occur simultaneously and, for purposes of a realistic worst case, are assumed to include steel pipe and sheet pile installation by impact and/or vibratory driving on each day of the in-water work window (21 weeks [or 105 days]). As such, other activities which generate lower sound pressures (see below), are not analyzed for take estimates.

As noted by NMFS (2010), there is a paucity of data on airborne and underwater noise levels associated with vibratory hammer extraction. However, it can reasonably be assumed that vibratory extraction emits SPLs that are no higher than SPLs caused by vibratory hammering of the same materials, and results in lower SPLs than caused by impact hammering comparable piles (NMFS 2010).

1.4.3 Auditory Masking

Natural and artificial sounds can disrupt behavior by masking, or interfering with a marine mammal's ability to hear other sounds. Masking occurs when the receipt of a sound is interfered with by another coincident sound at similar frequencies and at similar or higher levels. If the second sound is manmade and disrupts hearing-related behavior such as communications or echolocation (Wartzok et al. 2003/04), it could be considered harassment. Noise can only mask a signal if it is within a certain "critical band" around the signal's frequency and its energy level is similar or higher (Holt 2008). Noise within the critical band of a marine mammal signal will show increased interference with detection of the signal as the level of the noise increases (Wartzok et al. 2003/04). In delphinid subjects, for example, relevant signals needed to be 17 to 20 dB rms louder than masking noise at frequencies below 1 kHz in order to be detected and 40 dB greater at approximately 100 kHz (Richardson et al. 1995). It is important to distinguish temporary threshold shift (TTS) and permanent threshold shift (PTS), which persist after the sound exposure, from masking, which occurs during the sound exposure. Because masking (without a resulting in a threshold shift) is not associated with abnormal physiological function, it is not considered a physiological effect, but rather a potential behavioral effect.

The most intense underwater sounds in the proposed action are those produced by impact pile driving. Given that the energy distribution of pile driving covers a broad frequency spectrum, sound from these sources would likely be within the audible range of dolphin and whale species that may potentially occur in the action area associated with the proposed action. Impact pile driving activity is relatively short-term, with rapid pulses occurring for approximately 15 minutes per pile. Vibratory pile driving is also relatively short-term, with rapid oscillations occurring for approximately 1.5 hours per pile. It is possible that impact and vibratory pile driving resulting from this proposed action may mask some acoustic signals that are relevant to the daily behavior of marine mammal species, but the short-term duration and limited areas affected make it very unlikely that survival would be affected. Masking effects are, therefore, treated as insignificant. Any masking event that could possibly rise to Level B harassment would occur concurrently within the zones of behavioral harassment already estimated for vibratory and impact pile driving, and that have already been taken into account in the exposure analysis.

1.5 General Threats

Marine mammal populations can be influenced by various factors and human activities. Human impacts on marine mammals have received much attention in recent decades, and include hunting (both commercial and native practices), fisheries interactions (such as gear entanglement or shootings by fishers), bycatch (accidental or incidental catch), indirect effects of fisheries through takes of prey species, ship strikes, chemical pollution, noise pollution, and general habitat deterioration or destruction (Twiss and Reeves 1999).

Direct hunting, as in whaling operations, provided the original impetus for marine mammal management efforts and has driven much of the early research on cetaceans (Twiss and Reeves 1999). However, fishery bycatch is likely the most impactful problem presently and may account for the deaths of more marine mammals than any other cause (Northridge 2008; Read 2008; Hamer et al. 2010). In

1994, the MMPA was amended to formally address bycatch. In the U.S., cetacean bycatch declined by 85% from 342 in 1994 to 53 in 2006, and pinniped bycatch declined from 1,332 to 53 over the same time period. Another general threat to marine mammals are ship strike, which is a growing issue for most marine mammals, particularly baleen whale species.

Chemical pollution is also of great concern although, for the most part, its effects on marine mammals are just starting to be understood (Aguilar de Soto et al. 2008). Chemical pollutants found in pesticides and other substances flow into the marine environment from human use on land and are absorbed into the bodies of marine mammals, accumulating in their blubber or internal organs, or are transferred to the young from mother's milk (Fair et al. 2010; Ocean Alliance 2010). Important factors that determine the levels of pesticides, heavy metals, and industrial pollutants that accumulate in marine mammals are gender (i.e., adult males have no way to transfer pesticides whereas females may pass pollutants to their calves through milk), habitat, and diet. The buildup of human-made persistent compounds in marine mammals not only increases their likelihood of contracting diseases or developing tumors but also compromises the function of their reproductive systems (Fair et al. 2010).

All marine mammals have parasites that, under normal circumstances, probably do little overall harm, but under certain conditions can cause serious health problems or even death (Jepson et al. 2005; Houser and Finneran 2006; Fauquier et al. 2009). Disease affects some individuals (especially older animals), and occasionally disease epidemics can injure or kill a large percentage of the population (Paniz-Mondolfi and Sander-Hoffman 2009; Keck et al. 2010). For example, between June 1987 and May 1988, a morbillivirus epizootic caused a tenfold increase in bottlenose dolphin stranding along the U.S. Atlantic coast from New Jersey to Florida (Taubenberger et al. 1996), which left the stock "depleted" under the MMPA. Recently, the first case of cetacean morbillivirus in the Central Pacific was documented for a whale (Longman's beaked whale, *Indopacetus pacificus*) that stranded at Homa Beach, Hana, Maui (West et al. 2012).

Habitat deterioration and loss is a major factor for almost all coastal and inshore species of marine mammals, especially those that live in rivers or estuaries, and it may include such factors as depleting a habitat's prey base and the complete loss of habitat (Kemp 1996; Smith et al. 2009; Ayres et al. 2012). In some locations, especially where urban or industrial activities or commercial shipping is intense, anthropogenic noise is also being increasingly considered as a potential habitat level stressor. Noise is of particular concern to marine mammals because many species use sound as a primary sense for navigating, finding prey, avoiding predators, and communicating with other individuals. Noise may cause marine mammals to leave a habitat, impair their ability to communicate, or increase cortisol levels (Hildebrand 2009; Tyack et al. 2011; Rolland et al. 2012). Noise can cause behavioral disturbances, mask other sounds including their own vocalizations, may result temporary or permanent shifts in hearing capabilities and, in some cases, may result in behaviors that ultimately lead to death (Nowacek et al. 2007; Southall et al. 2009; Tyack 2009; Würsig and Richardson 2009). Anthropogenic noise is generated from a variety of sources including commercial shipping, oil and gas exploration and production activities, commercial and recreational fishing (including noise from fish finding sonar, fathometers, and acoustic deterrent and harassment devices), recreational boating and whale watching activities, offshore power generation, research (including sound from sonar and telemetry), and military training and testing activities. Vessel noise in particular is a large contributor to noise in the ocean. Commercial shipping's contribution to ambient noise in the ocean has increased by as much as 12 dB over the last few decades (McDonald et al. 2008; Hildebrand 2009).

Marine mammals, in general, are subject to the various influences and factors delineated in this section. If additional specific threats to individual species within the action area are known, those threats are described below in the descriptive accounts of those species.

1.6 SPECIES DESCRIPTIONS

1.6.1 Endangered Species Act-listed Species

1.6.1.1 Blue Whale (*Balaenoptera musculus*)

1.6.1.1.1 Species Description

Blue whales have a long body with a mottled gray color pattern that appears blue when seen through the water. They can weigh up to 330,000 pounds (150,000 kilograms) and their size is dependent on their location. For example, blue whales are largest in the Antarctic (measuring up to 110 feet [33 meters]) (Carretta et al. 2014).

1.6.1.1.2 Listing Status

The blue whale is federally listed throughout its range as endangered under the ESA and "depleted" throughout its range under the MMPA (Carretta et al. 2014). Due to differences in call types with the Eastern North Pacific stock (Stafford et al. 2001; Stafford 2003), blue whales found in the vicinity of the action area are considered as part of the Central North Pacific stock (Carretta et al. 2014).

1.6.1.1.3 Threats

In the past, the main threat to blue whales was from whaling that occurred in the late 1800s through late 1900s. Populations in the Antarctic and North Atlantic were reduced to the low hundreds by the time whaling ceased. Blue whales are currently subject to potential ship strikes and entanglement but their remote distribution makes the probability of these human impacts in the action area low (Reilly et al. 2008). However, no specific ship strike or entanglement data are available for the Central North Pacific stock (Berman-Kowalewski et al. 2010; Carretta et al. 2014).

1.6.1.1.4 Ecology

Blue whales become sexually mature between 5 and 15 years with births and mating taking place predominantly during the winter. The diet of blue whales primarily consists of krill for which they follow their diurnal vertical migrations, feeding both at the surface and generally to depths of 330 feet (100 meters) (Reilly et al. 2008; Carretta et al. 2014), with some feeding occurring at depths greater than 330 feet (100 meters) (Acevedo-Gutiérrez et al. 2002; Calambokidis et al. 2003). The species is predominantly found in the offshore, deep water environments (Sears 2002).

Direct studies of blue whale hearing have not been conducted. However, based on their low-frequency sound production, it is assumed that blue whales can hear the same frequencies and are likely most sensitive to sounds in the low-frequency range (Ketten 1997; Mellinger and Clark 2003). Similar to other low-frequency cetaceans for which data are lacking, the hearing range is estimated at approximately 7

Hz to 22 kHz (Southall et al. 2007). Blue whales vocalizations are low frequency or infrasonic sounds from 17 to 30 Hz at up to 189 dB re 1 µpa (Širović et al. 2007; Miller et al. 2013).

1.6.1.1.5 Historical and Current Distribution

The blue whale is present in all oceans with separate populations occurring by ocean basin in the North Atlantic, North Pacific, and Southern Hemisphere. Blue whales in the North Pacific likely occur in three sub-populations (Eastern North Pacific, Central North Pacific, and Western North Pacific). The central North Pacific stock is the stock most likely to occur within the Northern Mariana Islands. This stock feeds in the summer in the southwest of Kamchatka, south of the Aleutians, and in the Gulf of Alaska, and is generally found off shore in areas of cold current upwelling (Sears 2002). Winters are spent migrating to lower latitudes in the Western Pacific and, less frequently, in the Central Pacific (Carretta et al. 2014).

1.6.1.1.6 Status of Species within the Action Area

There are no occurrence records for blue whales in the vicinity of Tinian and Pagan, though this area is in the distribution range for this species. Blue whales would be most likely to occur in the Mariana Islands area during the winter (Carretta et al. 2014), although none were visually detected during surveys conducted January through April of 2007 (DoN 2007), as well as surveys from 2010 to 2013 (Hill et al. 2013b; Hill et al. 2014; DoN 2014) and in March, and May to July of 2012 (HDR 2012; Hill et al. 2013a). Oleson (2013) reported that in 2010 and 2011 blue whales were acoustically detected by autonomous recording devices off Tinian; however, since blue whale calls can travel for thousands of kilometers under optimal conditions (Sears 2002), it is unknown whether the animals were actually within the action area. According to the Department of the Navy (DoN), the density estimate for the Mariana Islands Training Complex (MIRC) is 0.00001 animals/square kilometer (DoN 2012). Based on the lack of visual detections, the relatively few acoustic detections, as well as the low densities in the general area, blue whale presence in the action area is likely transitory in nature.

1.6.1.2 Fin Whale (*Balaenoptera physalus*)

1.6.1.2.1 Species Description

Fin whales have streamlined bodies with distinctive coloration patterns that consist of a black or dark brownish-gray dorsal and sides and a white ventral surface. They can grow to a length of 75 to 80 feet (22 to 26 meters) and weigh from 80,000 to 160,000 pounds (36,000 to 73,000 kilograms) (Carretta et al. 2014).

1.6.1.2.2 Listing Status

The fin whale is federally listed throughout its range as endangered under the ESA and "depleted" throughout its range under the MMPA (Carretta et al. 2014). The three stocks of fin whale have been designated by NMFS in the North Pacific: (1) the Hawaii stock, (2) the California/Oregon/Washington stock, and (3) the Alaska stock (Carretta et al. 2014). The International Whaling Commission recognizes two management stocks in the North Pacific: a single widespread stock in the North Pacific and a smaller stock in the East China Sea (Donovan 1991). However, there is little information on the stock structure of fin whales in the action area.

In the North pacific, the total pre-whaling population of fin whales was estimated at between 42,000 and 45,000 whales (Ohsumi and Wada 1974). In 1973, fin whale abundance in the entire North Pacific basin was estimated between 13,620 and 18,680 whales (Ohsumi and Wada 1974). A lack of sighting data preclude an estimate of fin whale abundance specific to the action area and no data on current population trends in the vicinity of the action area are available. Tentative population trends in the eastern North Pacific indicate that the population may be increasing, but a lack of data makes it hard to determine definitive population trends (Carretta et al. 2014).

1.6.1.2.3 Threats

Historical commercial whaling was the main threat that resulted in reduced fin whale populations. Whaling ceased in the mid-1980s but still occurs for subsistence in Greenland and is subject to catch limits under the International Whaling Commission's "aboriginal subsistence whaling" regulations. Current potential threats to fin whales are predominately from vessel strikes, fishing gear entanglements, and low-frequency in-water noise (Douglas et al. 2008; Carretta et al. 2014).

1.6.1.2.4 Ecology

Fin whales usually occur in social groups of from 2 to 7 whales. They fast during their winter migrations to warmer waters but feed during the summer on krill, small schooling fish (i.e., herring, capelin, and sand lance), and squid (Aguilar 2002; Goldbogen et al. 2006). As a result of alternating migrations, the southern and northern hemisphere populations do not interact at the lower latitudes (Aguilar 2002). Sexual maturity is reached for males at 6 to 10 years and for females at 7 to 12 years. Females give birth to a single calf in tropical and subtropical areas during midwinter. Fin whales are generally long-lived at 80 to 90 years (Aguilar 2002).

Fin whales produce a variety of sounds with a frequency range up to 750 Hz. The long, patterned 15 to 30 Hz vocal sequence is most typically recorded; only males are known to produce these calls (Croll et al. 2002). The most typical fin whale sound is 20 Hz infrasonic pulse that is actually an FM sweep from about 23 to 18 Hz that lasts approximately 1 second. Source levels can reach from 184 to 186 dB re 1 µPa-m, with a maximum of up to 200 dB re 1 µPa-meter (Charif et al. 2002; Thomson and Richardson 1995). It has been suggested that these long, patterned vocalizations might function as male breeding displays, much like those of the male humpback whale's song (Croll et al. 2002). Similar to low-frequency cetaceans where there is a lack of information on their exact hearing range, the fin whale is thought to hear in roughly the same general frequency range as it is able to produce sound, from approximately 7 Hz to 22 kHz (Southall et al. 2007).

1.6.1.2.5 Historical and Current Distribution

Fin whales in the North pacific spend the summer feeding along the cold eastern boundary currents (Perry et al. 1999). A high abundance of Fin whales have been recorded in central offshore waters of the Okhotsk Sea, based on Japanese surveys (Reilly et al. 2013), and the species generally has higher densities off the continental shelf and in oceanic waters (Gregr and Trites 2001; Aguilar 2002). Miyashita et al. (1995) presented a compilation of at-sea sighting results by species, from commercial fisheries vessels in the Pacific Ocean from 1964 to 1990. For fin whales in mid-summer, Miyashita et al. (1995) reported no sightings south of 20°N, and significantly more sightings north of 40°N. However, Miyashita et al. (1995) had limited search effort south of 20°N.

1.6.1.2.6 Status of Species within the Action Area

In general, fin whales are known to occur in the Western Pacific during winter (Carretta et al. 2014). No fin whales were visually detected during surveys conducted January through April of 2007 (DoN 2007), as well as surveys from 2010 to 2012 (Hill et al. 2013b) and in March, and May to July of 2012 (HDR 2012; Hill et al. 2013a). More recently, a 2013 marine mammal survey in support of the CJMT EIS/OEIS also did not visually or acoustically detect fin whales (DoN 2014). Ten unidentified *Balaenoptera* species were detected during visual surveys (DoN 2007). Given that blue, fin and sei whales are all similar in size and have similar characteristics, these visual detections could have been fin whales, but also could have been a different *Balaenoptera* species. Oleson (2013) reported that in 2010 and 2011 fin whales were acoustically detected by autonomous recording devices off Tinian and Saipan, but the exact location of these individuals could not be determined. Based on DoN (2012), the density estimate for the MIRC is 0.00001 animals/square kilometer. Based on the lack of visual detections, the relatively few acoustic detections, as well as the low densities in the general area, fin whale presence in the action area is likely transitory in nature.

1.6.1.3 Humpback Whale (*Megaptera novaeangliae*)

1.6.1.3.1 Species Description

Humpback whales are primarily dark grey in color with some areas of white with large pectoral flippers and knobs on their heads. They can reach up to 60 feet (18 meters) in length and have a lifespan of 50 years (Carretta et al. 2014). They are a cosmopolitan species with generally small and unstable groups of individuals forming to feed, mate, or travel together (Clapham 2002). Males are generally smaller than females but can be very aggressive for access to females during mating (Tyack and Whitehead 1983). The species can be found in deep water, but are typically found in coastal environments (Clapham 2002).

1.6.1.3.2 Listing Status

The humpback whale is federally listed as Endangered under the ESA throughout its range and depleted throughout its range under the MMPA (Carretta et al. 2014). In the North Pacific, there is one stock that has been divided into three subpopulations primarily based on site-fidelity to feeding grounds. However, there is intermixing of these subpopulations during migratory periods. Carretta et al. (2014) identifies the individuals subpopulations as: (1) the Central North Pacific subpopulation (with feeding areas from Southeast Alaska to the Alaska Peninsula), (2) the Western North Pacific subpopulation (with feeding areas from the Aleutian Islands, the Bering Sea, and Russia), and (3) the American Samoa subpopulation in the South Pacific (with largely undocumented feeding areas as far south as the Antarctic Peninsula).

1.6.1.3.3 Threats

The primary threats to humpback whales include entanglement in fishing gear (bycatch), ship strikes, whale watch harassment, habitat impacts and harvest (Clapham 2002). Humpbacks entangled in gear from longline and crab pot fisheries as well as ship strikes have been observed in Hawaii. With respect to harvest, Japan has a permit for lethal sampling of up to 50 humpbacks; however, the International Whaling Commission has stated that Japan has refrained from taking humpback whales (Carretta et al. 2014). Specific data on human-related mortality are not available for the action area. However, data for southern hemisphere entanglements and mortality have been reported in New Zealand and Australia (Carretta et al. 2014).

1.6.1.3.4 Ecology

Humpbacks spend a majority of their time during the summer months feeding on up to 3,000 pounds (1,360 kilograms) per day on prey species primarily consisting of tiny crustaceans (predominantly krill), and plankton. Primary vertebrate prey include several species of schooling fish (e.g., herring, mackerel, sand lance, sardines, anchovies, and capelin) (Clapham 2002). Breeding period for humpback whales typically occurs once every two years during the winter months. The gestation period lasts approximately 11 months. Newborn humpbacks whales are 13 to 16 feet (4 to 5 meters) in length and wean from their mothers 6 to 10 months after birth (Clapham 2002; Carretta et al. 2014).

Humpback whales produce a wide repertoire of sounds with a hearing sensitivity to frequencies from 700 Hz to 10 kHz, and maximum relative sensitivity between 2 and 6 kHz (Houser et al. 2001). The best-known types of sounds produced by humpback whales are songs, which are thought to be breeding displays used only by adult males (Clapham 2002). Humpback whales are known to produce other classes of vocalizations, including: (1) social sounds within groups while within the wintering (calving) grounds; and (2) sounds while within the feeding grounds (Thomson and Richardson 1995). The songs sung during breeding season are complex and may vary within a season, in-between seasons, as well as by individual (Au et al. 2001; Mercado et al. 2010). Social calls such as underwater "grunts," "groans," and "barks" almost exclusively occur when different groups socially integrate (Dunlop et al. 2008). During increased wind speeds and background noise, humpbacks switch from vocal signals to surface-generated signals (Dunlop et al. 2008). This shift may ensure messages are not lost in the louder environment. Female humpbacks have been shown to also vocalize, but vocalizations tend to be simpler than those produced by males (Simao and Moreira 2005).

1.6.1.3.5 Historical and Current Distribution

Humpback whales are a cosmopolitan species with distinct seasonality driving localized presence. The species spends spring through fall on feedings grounds in the mid-to high-latitudes and winters in calving grounds in the tropics (Clapham 2002). There are three separate subpopulations in the North Pacific with some possible influx of individuals from southern populations (Clapham 2002) as well as between different subpopulations in the North Pacific (Ohizumi et al. 2002; Calambokidis et al. 2008). North Pacific humpback whales are distributed primarily in four more-or-less distinct wintering areas: the Ryukyu and Ogasawara (Bonin) Islands (south of Japan), Hawaii, the Revillagigedo Islands off Mexico, and along the coast of mainland Mexico (Calambokidis et al. 2001). The small winter aggregation of humpback whales observed by the DoN in 2007 (DoN 2007), combined with acoustic detections of song indicate that there is at least a small wintering population in the Mariana Islands (DoN 2007; Rivers et al. 2007) as well. Based on site-fidelity, humpback whales in the action area would likely be part of the American Samoa subpopulation, but may also include individuals from the Western North Pacific or Central North Pacific subpopulations.

Humpback whales were observed during the Mariana Islands Sea Turtle and Cetacean Survey (MISTCS) cruise 2.7 and 7.6 nautical miles (5 and 14 kilometers) (north of Tinian in deep water (2,625 to 3,940 feet [800 to 1,200 meters]) and in shallow water (1234 feet [374 meters]) 1.4 nautical miles (2.6 kilometers) north of Tinian (DoN 2007). Acoustic detections of humpback song were made during these sightings as well as on other occasions (DoN 2007; Norris et al. 2007).

1.6.1.3.6 Status of Species within the Action Area

As stated in Eldredge (2003), there were various reports of humpback whales in the waters of Guam in the 1990s. During surveys conducted in 2007 (DoN 2007), humpback whales were observed 8 nautical miles (15 kilometers) north of Saipan in water depths of 49 feet (148 meters). However, no humpback whales were visually detected during more recent surveys conducted from 2010 to 2012 (Hill et al. 2013b), in March, and May to July of 2012 (HDR 2012; Hill et al. 2013a), as well as during a 2013 surveys in support of the CJMT EIS/OEIS (DoN 2014). Oleson (2013) reported that in 2010 and 2011 humpback whales were acoustically detected by autonomous recording devices off Saipan, but specific whales could not be identified and it is unknown how close they were to the recording device(s). Based on known wintering grounds in the Ogasawara Islands, Ryukyu (Okinawa) Islands, Taiwan, the Philippines, and the Mariana Islands (Ohizumi et al. 2002; Calambokidis et al. 2008; Darling et al. 2014), the humpback whales in the action area are most likely part of the American Samoa subpopulation. Calambokidis et al. (2001) reported that there were confirmed resightings between humpback whales in Japan and Hawaii. However, given that the subpopulations are loosely defined, and there is likely mixing of the subpopulations, individuals in the action area could also be from the Central or Western North Pacific subpopulation. Based on DoN (2012), the density estimate for the MIRC is 0.00089 animals/square kilometer. Based on the relatively few sightings and acoustic detections, humpback whale presence in the action area is likely transitory in nature.

1.6.1.4 Sei Whale (*Balaenoptera borealis*)

1.6.1.4.1 Species Description

The sei whale is a cosmopolitan pelagic species found in subtropical, temperate, and sub-polar oceanic waters worldwide with potentially multiple populations (Masaki 1977; Mizroch et al. 1984). The species has a long and sleek body that is dark bluish-gray to black in color and pale underneath. Individuals can weigh up to 100,000 pounds (45,000 kilograms) and grow to a length of 40 to 60 feet (12 to 18 meters) (NMFS 2012).

1.6.1.4.2 Listing Status

The sei whale is federally listed throughout its range as endangered under the ESA and depleted throughout its range under the MMPA (NMFS 2012). For management purposes, in western and Hawaiian U.S. territorial waters, the sei whale is divided into two stocks: the Hawaiian Stock and the Eastern North Pacific Stock (Carretta et al. 2014). The last population estimate for sei whales in the North Pacific of 42,000 was conducted over 30 years ago and used a variety of different methods based on the history of whale catches and trends in sighting rates for sei whales in the North Pacific (Tillman 1977). Current global abundance is estimated to be approximately 70,000 individuals (Horwood 2002).

1.6.1.4.3 Threats

From 1910 to the start of World War II Prior, a few hundred sei whales were taken each year by whalers based at shore stations in Japan and Korea (Committee for Whaling Statistics 1942). From the mid-1950's, their importance as a species increased and whaling played a larger role in their overall decline

(Carretta et al. 2014). Heavy exploitation by pelagic whalers began in the early 1960s, with total catches throughout the North Pacific averaging 3,643 per year from 1963 to 1974 (total 43,719; annual range 1,280-6,053; Tillman 1977). The total reported kill of sei whales in the North Pacific by commercial whalers was 61,500 between 1947 and 1987 (Carretta et al. 2014). Some areas have not recovered, although commercial whaling ceased in the North Pacific in 1975, in the southern hemisphere in 1979, and in the North Atlantic in 1989. Japan continues to collect sei whales under a scientific permit with annual takes of 100 animals. Threats to sei whales from human impacts (i.e., ship strikes and entanglement) are assumed to be low because this species occurs predominantly far out to sea and they do not appear to be associated with coastal features (Carretta et al. 2014) where there interactions with ships and/or fisheries would be most likely (Reilly et al. 2008).

1.6.1.4.4 Ecology

Sei whales occur in small groups of 2 to 5 animals but single occurrences of these whales have also been observed. They feed on plankton (i.e., copepods and krill), small schooling fish, and cephalopods. Their lifespan is 50 to 70 years (NMFS 2012). Feeding occurs primarily around dawn, which appears to be correlated with vertical migrations of prey species (Horwood 2002). Unlike other rorquals, sei whales skim for their food, with occasional lunging and gulping similar to other rorqual species (Horwood 2002). In the North Pacific, sei whales feed on a diversity of prey, including copepods, krill, fish (specifically sardines and anchovies), and cephalopods (squids, cuttlefish, octopuses) (Horwood 2002; Nemoto and Kawamura 1977).

Similar to other large baleen whale species, the sei whale produces sound in the low frequency range, with sound production from 21 to 100 Hz observed for animals observed off Hawaii (Rankin and Barlow 2007); however, variation in frequency ranges exists between ocean basins (Rankin and Barlow 2007). Similar to other whale species where there is a lack of information on their exact hearing range; however, the fin whale is thought to hear in roughly the same general frequency ranges as it is able to produce sound, from approximately 7 Hz to 22 kHz (Southall et al. 2007).

1.6.1.4.5 Historical and Current Distribution

Sei whales occur in subtropical, temperate, and subpolar waters, preferring temperate waters found in the Atlantic, Indian, and Pacific Oceans, with seasonal distribution occurring from 20°N to 23°N during the winter and from 35°N to 50°N during the summer (Masaki 1977; Horwood 2002). They appear to prefer regions of steep bathymetric relief, such as the continental shelf break, canyons, or basins between banks and ledges (Kenney and Winn 1987; Schilling et al. 1992; Gregr and Trites 2001; Carretta et al. 2014), with most sightings in deep water (10,381 to 30,583 feet [3,164 to 9,322 meters]) and associated with bathymetric relief (e.g., steeply sloping areas), including sightings adjacent to the Chamorro Seamounts (DoN 2001), which are approximately 210 km 129 miles (210 kilometers) to the southeast of Tinian. However, little is known about the distribution and movement of this species and the population has not been defined adequately. Little is known about historical distribution in the CNMI.

1.6.1.4.6 Status of Species within the Action Area

Confirmed visual detections of sei whales were recorded primarily south of the action area, with the closest sighting occurring approximately 49 nautical miles (90 kilometers) to the southeast of Tinian

(DoN 2007). During the MISTCS cruise sightings most often occurred in deep water 10,381 to 30,583 feet (3,164 to 9,322 meters). Most sightings were associated with bathymetric relief (e.g., steeply sloping areas), including sightings adjacent to the Chamorro Seamounts east of the CNMI (DoN 2007). All confirmed sightings of sei whales were south of Saipan (approximately 15°N) with concentrations in the southeastern corner of the MISTCS study area (DoN 2007). Sightings also occurred with the similar Bryde's whale. More recently, vessel surveys in 2012 off Tinian and Saipan did not visually or acoustically sei whales in the vicinity of the islands (HDR 2012), and 2013 surveys in support of the CJMT EIS/OEIS also did not visually or acoustically detect sei whales (DoN 2014). DoN (2012) states that the density estimate for the MIRC is 0.00029 animals/square kilometer. Based on bathymetry in the vicinity of the action area, their presence cannot be precluded. As a result, based on the relatively few sightings and a lack of acoustic detections, as well as the low densities in the general area, sei whale presence in the action area is likely transitory in nature.

1.6.1.5 Sperm Whale (*Physeter macrocephalus*)

1.6.1.5.1 Species Description

Sperm whales are the largest of the toothed whales, with males growing up to 52 feet (16 meters) and weighing up to 90,000 pounds (41,000 kilograms) and females growing up to 36 feet (11 meters) and 30,000 pounds (14,000 kilograms). They have an extremely large head that takes up to one-third of its total body length and are dark gray in color with white patches on the ventral side of some sperm whales (Carretta et al. 2014).

1.6.1.5.2 Listing Status

The sperm whale is federally listed throughout its range as Endangered under the ESA and depleted throughout its range under the MMPA (Carretta et al. 2014). The NMFS has designated three stocks of sperm whale in the North Pacific: (1) the Hawaii stock, (2) the California/Oregon/Washington stock, and (3) the North Pacific stock (Carretta et al. 2014). The International Whaling Commission divided the North Pacific stock management into western and eastern regions with a boundary that starts at the equator and 150°W, moves to 160°W between 40 and 50°N, and finishes at 180°W north of 50°N (Donovan 1991). Little is known about the stock structure of sperm whales in the action area.

1.6.1.5.3 Threats

Sperm whales, were historically reduced by commercial whaling conducted in the 1800s through the late 1980s when virtually all whaling ceased resulting from implementation of a whaling moratorium by the International Whaling Commission in 1988. Currently, sperm whales are vulnerable to ship strikes, fishing gear entanglements, and anthropogenic noise primarily related to shipping (Sigler et al. 2008; Carretta et al. 2014).

1.6.1.5.4 Ecology

Sperm whales spend a majority of their time in deep waters with steep bathymetric relief (Whitehead 2002; Fulling et al. 2011). Their primary source of prey is large squid but they also feed on sharks, skates, fishes, other cephalopods, and bottom-dwelling fish and invertebrates (Whitehead 2002; Davis et al. 2007; Marcoux et al. 2007). Sperm whales dive to an average of 1,312 feet (400 meters) for prey with dive times of approximately 30 to 35 minutes. They are also known to dive as deep as 3,280 feet (1,000 meters) with dives lasting over an hour (Watkins et al. 2002; Whitehead 2002). Females reach sexual maturity at 9 years of age, produce a calf approximately once every 5 years, and form lasting bonds with other females of their family. The family units for female sperm whales average 12 females. Males also create units called “bachelor schools” with males of the same approximate age and size. These bachelor groups eventually reduce in size over time as the smaller males move to higher latitudes and the larger males remain (Whitehead 2002).

The sperm whale produces short bursts of “clicks” that range in frequency from 100 Hz to 30 kHz, with dominant energy in two frequency bands at 2 to 4 kHz and at 10 to 16 kHz. Generally, most of the acoustic energy is present at frequencies below 4 kHz, although diffuse energy exceeding 20 kHz has been reported (Thode et al. 2002). Source levels have been reported up to 236 dB re 1 µPa-meter (Møhl et al. 2003). It has also been suggested that the acoustic directivity (angular beam pattern) from sperm whales must range between 10 and 30 dB in the 5 to 20 kHz region (Thode et al. 2002). Clicks are heard most frequently when sperm whales engage in diving/foraging behavior (Miller et al. 2004; Whitehead and Weilgart 1991), when males produce clicks during 91% of the dive duration (Teloni et al. 2008). These may be echolocation clicks used in feeding, contact calls (for communication), and/or means of orientation during dives (the latter best suited for mid-range echolocations to locate small prey species with low reflectivity [squid]) (Andre 2009). Calls between social units sometimes fall into a repeated series of clicks (codas), which follow a precise rhythm and may last for long periods of time (Watkins and Schevill 1977; Whitehead 2002).

1.6.1.5.5 Historical and Current Distribution

Sperm whales occur throughout the world’s oceans in deep waters between 60° N and 60° S latitudes. Females are regularly sighted in waters deeper than 3,280 feet (1,000 meters) while males are generally sighted in waters less than 984 feet (300 meters) (Whitehead 2002; Fulling et al. 2011). Their distribution varies by prey availability and suitable breeding conditions with mature female and immature sperm whales of both sexes found in more temperate and tropical waters from the equator to around 45˚N throughout the year; these groups are rarely found at latitudes higher than 50˚N and 50˚S (Reeves and Whitehead 1997). There is no obvious seasonal migration for populations that occur within the tropical and temperate areas, but mid-latitude populations typically migrate poleward in the summer (Whitehead 2002). Two stocks that may be present within the vicinity of the Northern Mariana Islands are the North Pacific Stock and the Hawaiian Stock. The North Pacific Stock occurs within the shallow continental shelf with males moving north in the summer to feed in the Gulf of Alaska, Bering Sea, and the waters around the Aleutian Islands. The Hawaiian Stock is widely distributed in the tropics but occurrence of sperm whales decreases moving westward from Hawaii toward the middle of the tropical Pacific and northward toward the tip of Baja California (Carretta et al. 2014).

1.6.1.5.6 Status of Species within the Action Area

Historic records demonstrate sightings of sperm whales year-round in the Marianas (Townsend 1935). A survey conducted in 2007 observed sperm whales in deep waters (2,654 to 32,395 feet [809 to 9,874 meters]) with multiple sightings including young calves and large bulls off the west coast of Guam (DoN 2007). DoN (2007) reported that two groups of 11.5 individuals and 16 individuals were sighted at approximately 2.8 nautical miles (5.1 kilometers) off the northwest coast, and 7.6 nautical miles (14.1 kilometers) off the west coast, respectively, of Tinian during surveys in 2007. During the same survey time period, more sperm whales were sighted off Saipan, but in deeper waters (DoN 2007). Sperm whales have also been sighted off the coast of Saipan in 2010, 2012, and 2013 in waters greater than 3,281 feet (1,000 meters) (Ligon et al. 2011; HDR 2012; Hill et al. 2013a, 2013b). However, subsequent visual surveys from 2010 to 2014 (HDR 2012; Hill et al. 2013a, 2013b, 2013c, 2014; DoN 2014) did not visually detect sperm whales in the action area. Surveys performed during 2013 in support of the CJMT EIS/OEIS (DoN 2014) acoustically detected sperm whales off Pagan, but the exact location of these individuals could not be determined. The data only indicated sperm whale presence within 20 nautical miles (37 kilometers) of Pagan (DoN 2014). Based on DoN (2012), the density estimate for the MIRC is 0.00123 animals/square kilometer. While sperm whale sightings do occur regularly in the general vicinity of the action area, there have been relatively few sightings and acoustic detections specifically in the action area. As a result, sperm whale presence in the action area is likely transitory in nature.

1.6.2 Other Marine Mammal Species

1.6.2.1 Common Minke Whale (*Balaenoptera acutorostrata*)

1.6.2.1.1 Species Description

As a smaller species of the rorquals, common minke whale adults generally range from 21 to 29 feet (6.5 to 8.8 meters) long and weigh up to 20,300 pounds (9,200 kilograms). The body coloration is distinct: dark gray dorsally, white on the ventral side, and streaks of intermediate shades on the sides; some of the streaks extend to the head. The most distinctive marking is a brilliant white patch on each flipper that is generally visible through the water when animals are swimming near the surface. The common minke whale's head is extremely pointed and v-shaped. (NAVFAC 2013).

1.6.2.1.2 Listing Status

The common minke whale is protected under the MMPA. The common minke whale is not listed as "threatened" or "endangered" under the ESA, nor designated as "depleted" under the MMPA. The International Whaling Commission (IWC) recognizes 3 stocks of minke whales in the North Pacific: (1) Sea of Japan/East China Sea, (2) Western Pacific west of 180°N, and (3) "Remainder" of the pacific (Carretta et al. 2014). The "remainder" stock only reflects the lack of exploitation in the eastern Pacific and does not imply that only one population exists in that area (Donovan 1991). NMFS has designated three stocks of minke whale in the north Pacific: (1) the Hawaii stock, (2) the California/Oregon/Washington stock, and (3) The Alaska stock (Carretta et al. 2014). Little is known about the stock structure of minke whales in the MIRC (DoN 2013).

1.6.2.1.3 Threats

With the depletion of the larger rorquals, common minke whales have been heavily hunted in recent years (more than 100,000 were taken in the North Atlantic alone). Some minke whales are caught in fishing gear and others suffer from vessel strikes or habitat disturbance. Other sources of anthropogenic mortality include bycatch from pots, gill nets, and set nets; entanglements can cause severe injury and even death. Minke whales are known to bioaccumulate anthropogenic toxins such as butylins, PCBs, and organochlorine pesticides (OCPs) (NAVFAC 2013). Increased anthropogenic noise in the world's oceans has also been suggested to be a habitat concern for minke whales (Carretta et al. 2014).

1.6.2.1.4 Ecology

Common minke whales are typically sighted alone or in small groups of two to three and congregate in feeding areas within inshore and coastal waters. Minke whales prey on small invertebrates and schooling fish, such as sand eel, Pollock, herring, and cod. Similar to other rorquals, common minke whales are lunge feeders. They are known to feed over underwater slopes at depths ranging between 65 and 330 feet (20 and 100 meters) with average dives of about 4.43 (±2.24) minutes. Minke whales are prey for killer whales and employ the "flight" strategy, with sustained swimming speeds of over 15 kilometer/hr (NAVFAC 2013).

No data on the hearing abilities of this species are available. Recordings in the presence of minke whales have included both high- and low-frequency sounds. Two basic forms of pulse trains that were attributed to minke whales have been described: a "speed up" pulse train with energy in the 200 to 400 Hz band, with individual pulses lasting 40 to 60 milliseconds, and a less common "slow-down" pulse train characterized by a de-accelerating series of pulses with energy in the 250 to 350 Hz band (NAVFAC 2013).

1.6.2.1.5 Historical and Current Distribution

Minke whales generally occupy waters over the continental shelf, including inshore bays and even occasionally estuaries. However, based on whaling catches and surveys worldwide, a deep-ocean component to the minke whale's distribution also exists. Common minke whales are distributed in polar, temperate, and tropical waters; they are less common in the tropics than in cooler waters (NAVFAC 2013). Minke whales are present in the north Pacific from near the equator to the Arctic. In the winter, minke whales are found south to within 2° of the equator. There is no obvious migration from low-latitude, winter breeding grounds to high-latitude, summer feeding locations in the western North Pacific, as there is in the North Atlantic (DoN 2013).

1.6.2.1.6 Status of Species within the Action Area

There are no population estimates for minke whales in the entire north Pacific, and abundance estimates have not been made for the Hawaiian stock of minke whales. Recent line-transect analyses of acoustic detections of minke whales during the 2007 survey of the MIRC resulted in an estimate of approximately 183 to 227 animals; however, methods for estimating density from acoustic detections are currently being developed and numerous assumptions are associated with the calculations. The DoN (2012) density estimate for the entire MIRC is 0.00059 animals/square kilometer. These estimates should thus be considered preliminary (DoN 2013).

1.6.2.2 Short-finned Pilot Whale (*Globicephala macrorhynchus*)

1.6.2.2.1 Species Description

Short-finned pilot whales are large dolphins with bulbous heads, upsloping mouthlines, and short or nonexistent beaks. The dorsal fin is situated only about a third of the way back from the head; it is low and falcate, with a very wide base that varies with age and sex. The flippers of short-finned pilot whales are long and sickle shaped. The body is black to dark brownish-gray, except for a light gray, anchor-shaped patch on the chest, a gray post-dorsal fin saddle, and a pair of roughly parallel bands high on the back that sometimes end as a light streak or teardrop above each eye. Adult females are up to 18 feet

(5.5 meters) long and adult males are up to 24 feet (7.2 meters) long; short-finned pilot whales range from 4 to 5 feet (1.4 to 1.9 meters) long at birth. Adults weigh between 2,200 and 6,500 pounds (1,000 and 3,000 kilograms) (NAVFAC 2013).

1.6.2.2.2 Listing Status

The short-finned pilot whale is protected under the MMPA. Short-finned pilot whales are not listed as "threatened" or "endangered" under the ESA, nor designated as "depleted" under the MMPA (Carretta et al. 2014). For MMPA stock assessment reports, short-finned pilot whales within the Pacific U.S. Exclusive Economic Zone (EEZ) are divided into two discrete areas: (1) Hawaiian waters, and (2) waters off California, Oregon, and Washington. The Hawaii stock includes animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters (Carretta et al. 2014). In Japanese waters, two stocks (northern and southern) have been identified based on pigmentation patterns and head shape differences of adult males; the southern stock of short-finned pilot whales is probably the stock associated with the Mariana Islands (DoN 2013) and are morphologically similar to the pilot whales in Hawaiian waters (Carretta et al. 2014).

1.6.2.2.3 Threats

The main threats to short-finned pilot whales include direct take from harpoon and drive fisheries in the Caribbean, Indonesia, and Japan, bycatch from driftnet fisheries in the North Pacific, anthropogenic vessel noise, mandibular fractures, and infection from a multivirus, the most pathogenic of which is called the pilot whale morbillivirus (NAVFAC 2013).

1.6.2.2.4 Ecology

Pilot whales are often sighted with other cetaceans, in particular bottlenose dolphins, and are the most frequently reported mass-stranded marine mammals globally. Short-finned pilot whales range in group size from several to several hundred individuals and are almost never sighted alone. Pilot whales feed primarily on squid but may also take fish; this species is not known to have any predators. Adult and subadult whales have been found to reach a maximum dive depth of 3,342 feet (1,019 meters) and a maximum dive duration of 21 minutes (NAVFAC 2013).

Hearing was tested in a healthy captive female that was most sensitive to noise at 40 KHz, with upper limits to hearing between 80 and 200 KHz. Short-finned pilot whale whistles and clicks have a dominant frequency range of 2 to 14 KHz. Vocalization patterns of northern and southern forms of the short-finned pilot whale off Japan were compared, and it was found that northern calls were longer in duration and wider in frequency than southern calls (NAVFAC 2013).

1.6.2.2.5 Historical and Current Distribution

Short-finned pilot whales are found in all oceans, primarily in tropical and warm-temperate waters (Carretta et al. 2014). Distribution and seasonal inshore/offshore movements of pilot whales coincide closely with the abundance of squid. This species occurs mainly in deep offshore areas: waters over the continental shelf break, in slope waters, and in areas of high topographic relief. Movements over the continental shelf may occur where the shelf is narrow and deeper waters are found nearby (DoN 2013).

1.6.2.2.6 Status of Species within the Action Area

Miyashita et al. (1996) reported sightings in the vicinity of the Northern Mariana Islands during February through March 1994, but did not provide the actual sighting coordinates. During the 2007 survey of the Marianas, there were a total of five sightings of short-finned pilot whales in waters with bottom depth ranging from 3,041 to 14,731 feet (922 to 4,464 meters), and group size ranging from 5 to 43 individuals (DoN 2013). Three sightings were over the West Mariana Ridge (an area of seamounts), and another sighting was 7 nautical miles (13 kilometers) off the northeast corner of Guam, just inshore of the 9,900 feet (3,000 meters) isobath. There was also an off-effort sighting of a group of 6 to 10 pilot whales near the mouth of Apra Harbor. This survey estimated 909 short-finned pilot whales in the MIRC (DoN 2013). The DoN (2012) density estimate for the entire MIRC is 0.00362/kilometer^2.

1.6.2.3 False Killer Whale (*Pseudorca crassidens*)

1.6.2.3.1 Species Description

The false killer whale has a long slender body with a rounded overhanging melon, and no discernible beak. The dorsal fin is variable in shape and tends to be falcate and narrow located near the midpoint of the back. The flippers of false killer whales have rounded tips and a characteristic hump on the leading edge (NAVFAC 2013; Baird 2009a; Jefferson et al. 2008). The body is dark gray to black, with a faint light gray patch on the chest, and sometimes faint light gray areas on the head. False killer whale adults are up to 19.7 feet (6 meter) (males) or 16.4 feet (5 meter) (females) long and, male specimens may weigh up to 4,400 pounds 2,000 kilograms (NAVFAC 2013).

1.6.2.3.2 Listing Status

The false killer whale is protected under the MMPA. Only Main Hawaiian Islands Insular false killer whales are listed as “endangered” under the ESA, and classified as “depleted” under the MMPA, but this stock is considered resident to the Hawaiian Islands and is not likely to be present in the MIRC (DoN 2013). For the MMPA stock assessment reports, there are currently five Pacific Islands Region management stocks: (1) Main Hawaiian Islands insular, (2) Northwestern Hawaiian Islands, (3) Hawaii pelagic, (4) Palmyra Atoll, and (5) American Samoa (Carretta et al. 2014). Little is known about the stock structure of false killer whales in other regions of the world; and given the lack of information, NMFS currently does not define a stock specific to the MITT (DoN 2013; Chivers et al. 2007).

1.6.2.3.3 Threats

Threats to the false killer whale include bycatch in fisheries (e.g., driftnets and purse seines), direct hunting in Indonesia, Japan, and the West Indies, and anthropogenic containments in the water (e.g., chemicals and insecticides). False killer whales have also been live-captured for public display (NAVFAC 2013).

1.6.2.3.4 Ecology

The false killer whale is an active, fast-moving dolphin. False killer whales may occur in large groups (group sizes as large as 300 have been reported) (NAVFAC 2013; Baird 2009b; Brown et al. 1966), and are considered extremely social. Group sizes of 10 to 60 are most commonly observed (NAVFAC 2013). False killer whales feed primarily on deep-sea cephalopods and fish (NAVFAC 2013; Odell and McClune

1999), and may prefer large fish species such as mahi mahi and tunas. False killer whales have been observed to attack other cetaceans on occasion, and are generally preyed upon by large sharks and killer whales (NAVFAC 2013; Baird 2009a). The maximum known dive depth of false killer whales is about 1,640 feet (500 meters), but based on feeding habits, this species probably dives to depths exceeding that (NAVFAC 2013; Odell and McClune 1999).

The best hearing sensitivity measures for a false killer whale was around 16 to 64 kHz, with peak sensitivity around 30 kHz (NAVFAC 2013; Thomas et al. 1988). Hearing through echolocation may be a dynamic practice whereby alteration of the beam shape and focus may help the animal conserve energy while increasing the accuracy of the transmitted information (NAVFAC 2013; Kloepper et al. 2012). The dominant frequencies of false killer whale whistles are 4 to 9.5 kHz; those of their clicks are 25 to 30 kHz and 95 to 130 kHz (NAVFAC 2013; Thomas et al. 1990).

1.6.2.3.5 Historical and Current Distribution

False killer whales are found worldwide, mainly in tropical and warm-temperate waters, generally between 50°S and 50°N with a few records north of 50°N in the Pacific and the Atlantic. In the North Pacific, this species is well known from southern Japan, Hawaii, and the eastern tropical Pacific (Carretta et al. 2014). False killer whales are not considered a migratory species, although seasonal shifts in density likely occur and may be related to prey distribution (DoN 2013; Odell and McClune 1999). False killer whales occur in offshore waters and around oceanic islands, and only rarely come into shallow coastal waters (NAVFAC 2013; Baird 2009a; Odell and McClune 1999).

1.6.2.3.6 Status of Species within the Action Area

The false killer whale is an oceanic species, occurring in deep waters, and is known to occur close to the shore near oceanic islands. The false killer whale in the Mariana Islands and vicinity is expected to occur seaward of the 50 meter isobaths. Ten false killer whales were sighted during a 2007 survey conducted in Mariana Islands waters in deeper waters and group sizes ranging from 2 to 26 individuals, and additional individuals were detected in the area acoustically (NAVFAC 2013; Norris et al. 2011; NAVFAC Pacific 2007). There are estimated to be about 6,000 false killer whales in the area surrounding the Mariana Islands. Based on sighting data from the 2007 survey, there were an estimated 637 false killer whales in the MIRC (DoN 2013; Fulling et al. 2011; Miyashita 1993). The DoN (2012) density estimate for the entire MIRC is 0.00111 animals/square kilometer.

1.6.2.4 Melon-headed Whale (*Peponocephala electra*)

1.6.2.4.1 Species Description

The melon-headed whale is a small tropical dolphin, similar in appearance to the pygmy killer whale, and is moderately robust. Adults have a bulbous head, and the melon may overhang the tip of the lower jaw in adult males. The melon-headed whale’s dorsal fin is tall and slightly falcate, and is located near the middle of the back. The flippers are sickle-shaped, with acutely-pointed tips (NAVFAC 2013). Most of the body is generally dark gray to black, with a white urogenital patch. On most individuals is also an anchor-shaped patch of light color on the underside of the head, just ahead of the flippers. A black triangular “mask” on the face of melon-headed whales distinguishes them from the somewhat more uniformly colored pygmy killer whale (NAVFAC 2013; Jefferson et al. 2008). Melon-headed whales grow to a maximum length of about 9 feet (2.7 meters) and a maximum weight of about 600 pounds (275 kilograms). Length at birth is not well-known, but is thought to be about 3 feet (1 meter) or less (NAVFAC 2013).

1.6.2.4.2 Listing Status

The melon-headed whale is protected under the MMPA. Melon-headed whales are not listed as "threatened" or "endangered" under the ESA, nor designated as "depleted" under the MMPA. For the MMPA stock assessment reports, there are two Pacific management stocks within the Hawaiian Islands EEZ: (1) Kohala residents, and (2) Hawaiian Islands. Because data on abundance, distribution, and human-caused impacts are largely lacking for high seas waters, the status of the Hawaiian Islands stock is evaluated based on data from the U.S. EEZ waters of the Hawaiian Islands (Carretta et al. 2014). Little is known about the stock structure of melon-headed whales in the MIRC (NAVFAC 2013).

1.6.2.4.3 Threats

In recent years, there has been increasing concern that loud underwater sounds, such as active sonar and seismic operations, may be harmful melon-headed whales (Carretta et al. 2014). Melon-headed whales are occasionally taken both incidentally in various fisheries and directly in small cetacean fisheries in Japan, the Caribbean, Sri Lanka, the Philippines, and Indonesia (NAVFAC 2013). Melon-headed whales also have a high susceptibility to parasites (NAVFAC 2013; Carvalho et al. 2010).

1.6.2.4.4 Ecology

Melon-headed whales often float at the water's surface in large schools composed of noticeable subgroups. They are typically found in large groups, ranging between 150 and 1,500 individuals (NAVFAC 2013). Melon-headed whales prey on squid, pelagic fishes, and occasionally crustaceans, mostly found in waters up to 5,000 feet (1,500 meters) deep, suggesting foraging deep in the water column. This species is a deep diver and have been found in waters ranging from 2,740 to 10,000 feet (835 to 3,000 meters) deep. (NAVFAC 2013; Jefferson and Barros 1997).

No data on hearing ability are available for this species. Sounds produced by melon-headed whales include whistles, echolocation clicks, and burst-pulse sequences. Whistles had dominant frequencies around 8 to 12 kHz, ranging from 890 Hz to 23.5 kHz, with a duration of 586 milliseconds. Clicks had dominant frequencies of 20 to 40 kHz (NAVFAC 2013; Frankel and Yin 2010; Watkins et al. 1997).

1.6.2.4.5 Historical and Current Distribution

Melon-headed whales are found in tropical and warm-temperate waters throughout the world. The distribution of reported sightings suggests that the oceanic habitat of this species is primarily equatorial waters (Carretta et al. 2014). They have occasionally been reported at higher latitudes, but these movements are considered to be beyond their normal range and associated with incursions of warm water currents (DoN 2013; Perryman et al. 1994). Melon-headed whales near oceanic islands rest near the shore during the day, and feed in deeper waters at night. The melon-headed whale is not known to migrate (DoN 2013).

1.6.2.4.6 Status of Species within the Action Area

The melon-headed whale is a predominantly oceanic species. However, individuals are expected to occur from the shelf break to seaward of the Mariana Islands and vicinity. They may occur from the coastline to the shelf break because deep water is very close to shore at these islands. Occurrence pattern is believed the same throughout the year (NAVAC 2013). Based on sighting data from a 2007 survey, there were an estimated 2,455 melon-headed whales in the MIRC (DoN 2013; Fulling et al. 2011). The DoN (2012) density estimate for the entire MIRC is 0.00428 animals/square kilometer. This estimate is very similar to the abundance estimate for the Hawaiian stock; Baird et al. (2010) determined that the population of melon-headed whales around the main Hawaiian Islands exhibited stable population structure and long-term site fidelity spanning up to 22.6 years.

1.6.2.5 Common Bottlenose Dolphin (*Tursiops truncatus*)

1.6.2.5.1 Species Description

The common bottlenose dolphin is a large, relatively-robust species, and the largest of the "beaked dolphins." It has a short to moderate length, stocky beak distinctly set off from the melon by a deep crease. The Dorsal fin is tall and falcate, relatively narrow, and set near the middle of the back. The flippers are wide and somewhat pointed at the tips (NAVFAC 2013; Jefferson et al. 2008). The color pattern varies from light gray to nearly black on the back and sides, fading to white on the belly. The belly and lower sides are rarely spotted and the back is generally dark gray. Adult common bottlenose dolphins range from 6.3 to 12.5 feet (1.9 to 3.8 meters) in length, with males tending to be larger than females. Maximum weight is at least 1,430 pounds (650 kilograms), although most individuals are much smaller. Common bottlenose dolphins occur as two morphotypes: a nearshore (coastal) and an offshore ecotype (NAVFAC 2013; Hoelzel et al. 1998; Hersh and Duffield 1990).

1.6.2.5.2 Listing Status

The common bottlenose dolphin is protected under the MMPA. Common bottlenose dolphins are not listed as "threatened" or "endangered" under the ESA, nor designated as "depleted" under the MMPA. For the MMPA Pacific stock assessment reports, bottlenose dolphins within the Pacific U.S. EEZ are divided into seven stocks: (1) California, Oregon, and Washington offshore, (2) California costal, and five Pacific Islands Region, (3) Kauai/Niihau, (4) Oahu, (5) 4-Islands (Molokai, Lanai, Maui, Kahoolawe), (6) Hawaii Island, and (7) Hawaiian Pelagic, including animals found both within the Hawaiian Islands EEZ and in adjacent high seas waters (Carretta et al. 2014). Little is known about the structure of the dolphins in the MIRC (DoN 2013).

1.6.2.5.3 Threats

Threats to the common bottlenose dolphin include past and present direct hunting in the Black Sea, Japan, Taiwan, the Caribbean, Peru, Sri Lanka, West Africa, Indonesia, and off the east coast of the United States. Significant numbers have been taken in live-capture fisheries, and many individuals have experienced incidental injury and mortality from fishing gear. Anthropogenic noise can harmfully affect dolphin communication. Exposure to pollutants and biotoxins as well as viral outbreaks are also threats to the common bottlenose (NAVFAC 2013).

1.6.2.5.4 Ecology

Common bottlenose dolphins are highly intelligent and demonstrate self-awareness. They are highly social and are typically found in groups of up to 15 individuals, although groups of up to 100 or more have been reported. Bottlenose dolphins are opportunistic and feed on a wide variety of fishes, cephalopods, and shrimps with a variety of feeding strategies. This species is preyed upon by killer whales and sharks (NAVFAC 2013; Wells and Scott 2008). Captive bottlenose dolphins reach maximum diving depths of about 1,000 feet (300 meters) with durations of up to 15 minutes. Typical dives, however, are usually shallower and shorter. Deep-sea fish in the stomachs of offshore bottlenose dolphins suggest that they dive to more than 1,640 feet, (500 meter) (NAVFAC 2013; Ridgway et al. 1969).

The bottlenose dolphin has a functional high-frequency hearing limit of 160 kHz and can hear sounds at frequencies as low as 40 to 125 Hz. Sounds emitted by bottlenose dolphins have been classified into two broad categories: pulsed sounds (clicks and burst-pulses) and narrow-band continuous sounds (whistles). Whistle characteristics play a vital role in social behavior and have been shown to coincide with particular behaviors; for example, whistles may be an indicator of stress (NAVFAC 2013; Esch et al. 2009).

1.6.2.5.5 Historical and Current Distribution

Bottlenose dolphins are distributed world-wide in tropical and warm temperate waters. In many regions, separate coastal and offshore populations are known (Carretta et al. 2014). This is one of the most widely-distributed dolphin species. They are known to occur in most enclosed or semi-enclosed seas. This species may inhabit shallow, murky, estuarine waters, as well as deep, clear offshore waters in oceanic areas (DoN 2013). In most areas bottlenose dolphins do not migrate; however, seasonal shifts in abundance may occur. Common bottlenose dolphins are often found in bays, lagoons, channels, and river mouths, and are known to occur in very deep waters (NAVFAC 2013).

1.6.2.5.6 Status of Species within the Action Area

Little is known about the stock structure of bottlenose dolphins around the Mariana Islands. A bottlenose dolphin abundance estimate of 31,700 animals was made for the area north of the Marianas (DoN 2013; Miyashita 1993), which may represent a stock of offshore bottlenose dolphins that occurs around the Mariana Islands. Four common bottlenose dolphins were visually sighted in the Marianas (NAVFAC Pacific 2007) and additional individuals have been documented through acoustic recordings (NAVFAC 2013; Norris et al. 2011). Possibly, bottlenose dolphins do not occur in great numbers in the Mariana Island chain. The DoN (2012) density estimate for the entire MIRC is 0.00131/kilometer^2.

1.6.2.6 Pantropical Spotted Dolphin (*Stenella attenuata*)

1.6.2.6.1 Species Description

Pantropical spotted dolphins have cigar-shaped bodies, and are usually fairly slender and streamlined. They have long, slender beaks, separated from the melon by a distinct crease. The dorsal fin is very narrow, falcate, and pointed at the tip. The flippers are slender with a continuous curve along the leading edge (NAVFAC 2013). Adult pantropical spotted dolphins have varying degrees of white mottling. The spotting ranged from very slight in offshore animals to very visible in coastal species. In adults, the lower sides and belly are gray, and the lips and beak tip are usually white. They are unspotted at birth, with a simple counter shaded pattern. The most distinctive color pattern component of the pantropical spotted dolphin is the dark dorsal cape (NAVFAC 2013; Perrin et al. 2009; Perrin and Hohn 1994). Adults of this species are 5 to 8 feet (1.6 to 2.4 meters) long, and can reach weights of 262 pounds (119 kilograms) (NAVFAC 2013).

1.6.2.6.2 Listing Status

The pantropical spotted dolphin is protected under the MMPA. Spotted dolphins are not listed as "threatened" or "endangered" under the ESA, and only the Pacific northeastern offshore stock is designated as "depleted" under the MMPA. For the MMPA stock assessment reports, there are four Pacific management stocks within the Hawaiian Islands EEZ: (1) Oahu, includes spotted dolphins within 12 miles (20 kilometers) of Oahu, (2) 4-Island, includes spotted dolphins found within 12 miles (20 kilometers) of Maui, Molokai, Lanai, and Kahoolawe collectively, (3) Hawaii Island, includes spotted dolphins found within 40 miles (65 kilometers) from Hawaii Island, and (4) Hawaii Pelagic, which includes spotted dolphins inhabiting the waters throughout the Hawaiian Islands EEZ, outside of the insular stock areas, but including adjacent high seas waters (Carretta et al. 2014).

1.6.2.6.3 Threats

Threats to the pantropical spotted dolphin include bycatch in fisheries (especially tuna), direct hunting in Japan, the Caribbean, Sri Lanka, Philippines, Indonesia, St. Helena, and the Laccadive and Solomon Islands, anthropogenic noise pollution, and exposure to pollutants and biotoxins (NAVFAC 2013).

1.6.2.6.4 Ecology

Pantropical spotted dolphins are social animals and are fast swimmers. Group size may range from just a few animals to large schools of several thousand (NAVFAC 2013; Jefferson, Webber, and Pitman 2008). School sizes of coastal populations are usually smaller than offshore schools. Pantropical spotted dolphins prey on near-surface fish, squid, and crustaceans, and on some mid-water species. Dolphins off Hawaii have been shown to feed primarily at night and on the surface (NAVFAC 2013; Baird et al. 2001). Dives of this species are up to 3.4 minutes longer with maximum depths of about 200 m. They may be preyed upon by killer whales and sharks.

No published hearing data are available regarding pantropical spotted dolphins. Pantropical spotted dolphin whistles have a dominant frequency range of 6.7 to 17.8 kHz and click source levels between 197 and 200 dB have been recorded (NAVFAC 2013; Schotten et al. 2004).

1.6.2.6.5 Historical and Current Distribution

Pantropical spotted dolphins are primarily found in tropical and subtropical waters worldwide (Carretta *et al.* 2014). This species is primarily distributed between about 40° N and 40° S in the Pacific, Atlantic, and Indian Oceans (DoN 2013; Perrin 2008; Baldwin et al. 1999), although this species is much more abundant in the lower latitudes of its range. It is found mostly in deeper offshore waters but does approach the coast in some areas. Their range in the Central Pacific is from the Hawaiian Islands in the north to at least the Marquesas Islands in the south (DoN 2013; Perrin and Hohn 1994).

1.6.2.6.6 Status of Species within the Action Area

Pantropical spotted dolphins were sighted throughout the MIRC during the 2007 ship survey in waters with a variable bottom depth, ranging from 374 to 18,609 feet (114 to 5,672 meters) (DoN 2013; Fulling *et al.* 2011). The vast majority of the sightings were in deep waters (greater than 10,000 feet [3,050 meters]). There was only one shallow-water sighting 1.4 nautical miles (2.6 kilometers) north of Tinian, in waters with a bottom depth of 374 feet (114 meters) (DoN 2013). The pantropical spotted dolphin may occur from the coastline to the shelf break around the Mariana Islands, based on sightings reported in the coastal waters of Guam (NAVFAC 2013; Trianni and Kessler 2002). Occurrence pattern is believed to be the same throughout the year (NAVFAC 2013). The DoN (2012) density estimate for the entire MIRC is 0.02260 animals/square kilometer.

1.6.2.7 Spinner Dolphin (*Stenella longirostris*)

1.6.2.7.1 Species Description

Four well differentiated geographical forms of spinner dolphins have been described as separate subspecies: *Stenella longirostris longirostris* (Gray's spinner dolphin) and *Stenella longirostris longirostris* (white belly hybrid) are two forms of the same subspecies; the others are *Stenella longirostris orientalis* (eastern spinner dolphin), *Stenella longirostris centroamericana* (Central American spinner dolphin), and *Stenella longirostris roseiventris* (dwarf spinner dolphin) (NAVFAC 2013). The spinner dolphin is very slender, with an extremely long, narrow beak. The flippers are narrow and the dorsal fin ranges from slightly falcate to erect and triangular. Most spinner dolphin populations have a three-part color pattern: dark gray cape, light gray sides, and white belly, with only slight differences between males and females. The upper beak is dark, and most of the lower jaw is white, the beak tip and lips are dark (NAVFAC 2013; Perrin *et al.* 2009). Adults reach maximum lengths of 6.6 feet (females) and 7.7 feet (males) (2 and 2.35 meters, respectively), with considerable geographical variation. Spinners are known to reach weights of at least 82 Kg (NAVFAC 2013).

1.6.2.7.2 Listing Status

The spinner dolphin is protected under the MMPA. Spinner dolphins are not listed as "threatened" or "endangered" under the ESA and only the eastern stock in the eastern tropical Pacific Ocean is designated as "depleted" under the MMPA. Under the MMPA, there are seven Pacific management stocks for Gray's spinner dolphin (*Stenella longirostris longirostris*): (1) American Samoa, (2) Hawaii Island, (3) Oahu/4-islands, (4) Kauai/Niihau, (5) Pearl & Hermes Reef, (6) Kure/Midway, and (7) Hawaii Pelagic, including animals found both within the Hawaiian Islands EEZ and in adjacent international waters (Carretta *et al.* 2014; Hill *et al.* 2010). Little is known about the stock structure of spinner dolphins in the MIRC (DoN 2013).

1.6.2.7.3 Threats

Threats to the spinner dolphin include direct take in the Caribbean, Sri Lanka, the Philippines, Indonesia, and Japan, by-catch by fisheries (especially the tuna purse seine fishery), interactions with dolphin-watchers and tourists, parasitic infection, and anthropogenic pollution (NAVFAC 2013).

1.6.2.7.4 Ecology

Spinner dolphins are well known for leaping high into the air and spinning. Group sizes range from fewer than 50 to several thousand and some assemblages are characterized by a dynamic social structure (NAVFAC 2013; Jefferson et al. 2008). Spinner dolphins feed primarily on small mid-water fishes, squids, and shrimp, and they dive to at least 660 to 1,000 feet (200 to 300 meters) with maximum dives of over 2,000 feet (600 meters) (NAVFAC 2013; Perrin and Gilpatrick 1994). They forage primarily at night when prey migrates toward the surface. This species may be preyed upon by sharks, killer whales, pygmy killer whales, and short-finned pilot whales.

Pulses, whistles, and clicks have been recorded from this species. Pulses and whistles have dominant frequency ranges of 5 to 60 kHz and 8 to 12 kHz, respectively (NAVFAC 2013; Ketten 1998). Spinner dolphin clicks have a dominant frequency of 60 kHz and the burst pulses are predominantly ultrasonic.

1.6.2.7.5 Historical and Current Distribution

The Gray's spinner dolphin is the most widely distributed subspecies of spinner dolphin and is found in the Atlantic, Indian, and Central and Western Pacific Oceans. In the Pacific, spinner dolphins are island-associated and use shallow protected bays to rest and social during the day then move offshore at night to feed. They are abundant and common throughout the entire Hawaiian archipelago (Carretta *et al.* 2014). Generally, the spinner dolphin can be found in tropical and subtropical waters between 40° N and 40° S and occur in both oceanic and coastal environments (DoN 2013).

1.6.2.7.6 Status of Species within the Action Area

Spinner dolphins travel among the CNMI island chain, using coastal and protected waters (NAVFAC 2013; Trianni and Kessler 2002). The Mariana Islands are likely a high-usage habitat (NAVFAC 2013). One dolphin was seen during a 2007 survey off the Marianas (NAVFAC Pacific 2007), and additional acoustical recordings may indicate the presence of more individuals. Occurrence pattern is believed to be the same throughout the year. Although there are multiple sighting records of spinner dolphins around the Marianas, no abundance estimate is available for the region (DoN 2013). The DoN (2012) density estimate for the entire MIRC is 0.00699/kilometer^2.

1.6.2.8 Blainville's Beaked Whale (*Mesoplodon densirostris*)

1.6.2.8.1 Species Description

Blainville's beaked whales are characterized by a spindle-shaped body with a small head; small dorsal fin located two-thirds of the way back from the snout tip, and a small and narrow flipper. Their beak is moderately long in mature adults, but shorter and stubbier in younger animals (NAVFAC 2013; Jefferson et al. 2008). Blainville's beaked whales are normally brownish or blue-gray above and lighter on their ventral side. This species tends to show more white scratchers than do most other *Mesoplodon* species. A yellowish-orange tinge often appears on the head and thorax, likely from diatom films (NAVFAC 2013; Jefferson et al. 2008). The maximum length of the Blainville's beaked whale is around 15.5 feet (4.7 meters) for both males and females, with a maximum weight of up to 2,277 pounds 1,033 kg (NAVFAC 2013).

1.6.2.8.2 Listing Status

Blainville's beaked whale is protected under the MMPA. This species is not listed as "threatened" or "endangered" under the ESA, nor designated as "depleted" under the MMPA. For the MMPA stock assessment reports, NMFS recognizes a Hawaiian stock of Blainville's beaked whale, including animals found both within the Hawaiian Islands EEZ and in adjacent international waters (Carretta *et al.* 2014). Little is known about the stock structure in the MIRC (DoN 2013); however, Blainville's beaked whales are known to have a primary and secondary range within (NAVFAC 2013).

1.6.2.8.3 Threats

Threats to the Blainville's beaked whale include incidental fisheries bycatch (pelagic drift gillnet fishery off the U.S. Atlantic coast), anthropogenic noise and underwater sounds, and infection (NAVFAC 2013).

1.6.2.8.4 Ecology

Blainville's beaked whales have a tendency to return to the same area repeatedly or to remain in the same area for an extended period. They are observed in small groups of three to seven, although singles and pairs are more common (NAVFAC 2013; Baird et al. 2010). This species preys on squid and possibly deepwater fish, and prefers deep waters for feeding. Blainville's beaked whales can dive to depths of 4,600 feet (1,400 meters) with durations of longer than 54 minutes. They have not been documented to be prey to any other species, although occasional killer whale predation is likely (NAVFAC 2013; Baird *et al.* 2006).

Blainville's beaked whales are predominantly adapted to hear ultrasonic frequencies. Based on the anatomy of the ears, they may be more sensitive than other cetaceans to low frequency sounds. Beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and possibly up to 16 kHz, for social communication (NAVFAC 2013; Macleod 1999). This species is highly vocal, producing high-frequency echolocation clicks with no significant energy below 20 kHz.

1.6.2.8.5 Historical and Current Distribution

Blainville's beaked whale has a cosmopolitan distribution in tropical and temperate waters, apparently the most extensive known distribution of any *Mesoplodon* species (Carretta *et al.* 2014). This species generally occurs in waters past the edge of the continental shelf, between 660 and 3,300 feet (200 and 1,000 meters) in depth, and are known to inhabit enclosed seas with deep water. (NAVFAC 2013). Blainville's beaked whales are found mostly offshore in deeper waters along the California coast, Hawaii, Fiji, Japan, and Taiwan, as well as throughout the eastern tropical Pacific and in the eastern south Pacific (DoN 2013).

1.6.2.8.6 Status of Species within the Action Area

There were two *Mesoplodon* whale sightings during the 2007 survey of the MIRC, over the West Mariana Ridge, but were not identified to a species level (DoN 2013; Fulling *et al.* 2011). No verified occurrence records of this species in the Mariana Islands and vicinity are available, and there are no abundance estimates for Blainville's beaked whales in the MIRC. Beaked whales are believed to occur in the area, including seaward of the shelf break. They could potentially occur on the shelf as deep waters come very close to the shore in this area (NAVFAC 2013). The DoN (2012) density estimate for the entire MIRC is 0.00117 animals/square kilometer.

1.6.2.9 Cuvier's Beaked Whale (*Ziphius cavirostris*)

1.6.2.9.1 Species Description

Cuvier's beaked whales have a relatively short beak, along with a curved jaw. The body is spindle shaped, the flippers are small and narrow, and the dorsal fin is falcate and prominent, set about two-thirds of the way back on the body (NAVFAC 2013). Cuvier's beaked whales are generally dark gray to light rusty brown in color, often with lighter colors around the head. In adult males, the head and much of the back can be light gray to white in color, and many light scratches or circular scars can give the animal a slightly mottled appearance. Cuvier's beaked whales may attain a maximum length of 25 feet (7.5 meters) (males) and 23 feet (7.0 meters) (female). The maximum recorded weight is 6,600 pounds 3,000 kilograms (NAVFAC 2013; Jefferson et al. 2008; Heyning 1989).

1.6.2.9.2 Listing Status

Cuvier's beaked whale is protected under the MMPA. They are not listed as "threatened" or "endangered" under the ESA, nor designated as "depleted" under the MMPA. Cuvier's beaked whale stocks are defined as three separate areas within Pacific U.S. EEZ waters: (1) Alaska, (2) California/Oregon/Washington, and (3) Hawaii (Carretta *et al.* 2014). The Hawaii stock includes animals found within the Hawaiian EEZ and in adjacent high seas waters. Cuvier's beaked whales are known to have primary and secondary range within the MIRC (NAVFAC 2013); however, little is known about the stock of Cuvier's beaked whale in the MIRC.

1.6.2.9.3 Threats

Threats to the Cuvier's beaked whale include small direct take in fisheries in the Caribbean, Chile, Indonesia, Peru, and Taiwan, acoustic disturbance and tissue damage from seismic exploration and military sonar (anthropogenic noise), entanglement in fishing gear, and vessel strikes.

1.6.2.9.4 Ecology

Cuvier's beaked whales are considered cryptic and are not easily sighted at sea. They are most often observed in small groups of two to seven animals, and are rarely observed alone. This species has a tendency to return to the same area repeatedly or to remain in an area for an extended period. Cuvier's beaked whales are deepwater feeders and feed mostly on squid, fish, and crustaceans. Dives of up to 40 minutes with depths of up to 4,760 feet (1,450 meters) have been recorded. They may be preyed upon by killer whales (NAVFAC 2013; Jefferson et al. 2008; Santos *et al.* 2007).

Beaked whales are predominantly adapted to hear ultrasonic frequencies. Very little information is available on characteristics of sound produced by beaked whales. It has been suggested that beaked whales use frequencies of between 300 Hz and 129 kHz for echolocation, and between 2 and 10 kHz, and up to 16 kHz, for social communication (NAVFAC 2013; Macleod 1999). Click pulses of Cuvier's beaked whales had a peak frequency between 13 and 17 kHz (NAVFAC 2013; Frantzis *et al.* 2002).

1.6.2.9.5 Historical and Current Distribution

Cuvier's beaked whales occur in all oceans and major seas. They have an extensive range from the tropics to the polar waters of both hemispheres (Carretta *et al.* 2014). Worldwide, beaked whales normally inhabit continental slope and deep oceanic waters, and are commonly sighted around seamounts, escarpments, and canyons (DoN 2013; MacLeod *et al.* 2004). Cuvier's beaked whales are generally sighted in waters with a bottom depths exceeding 655 feet (200 meters), and are frequently recorded in waters with bottom depths exceeding 3,280 feet (1,000 meters) (NAVFAC 2013).

1.6.2.9.6 Status of Species within the Action Area

Beaked whales may be expected to occur in the Mariana archipelago, mostly seaward of the shelf break. Deep waters come very close to the shore in this area, so beaked whales may be found in waters over the shelf (NAVFAC 2013). A single Cuvier's beaked whale was observed about 65 nautical miles south of Guam at the edge of the Mariana Trench (DoN 2013; Mobley 2007). In August 2011, two stranded Cuvier's beaked whales were found on and near Micro Beach, Saipan (DoN 2013; Hawaii Pacific University 2012). No abundance estimates for Cuvier's beaked whale are available for the MIRC (DoN 2013). Occurrence pattern is believed to be the same throughout the year (NAVFAC 2013). The DoN (2012) density estimate for the entire MIRC is 0.00621 animals/square kilometer.

1.7 DESCRIPTION OF TAKE CALCULATION

The take calculations presented here rely on the best data currently available for marine mammal populations in the action area. The population data used for each species' take calculation is provided in Table 6 below. The formula was developed for calculating take due to pile driving and extraction as applicable and applied to the species-specific noise impact threshold. The formula is founded on the following assumptions:

- Density estimates were derived from the Pacific Navy Marine Species Density Database (DoN 2012). These density estimates are for a much larger area than is associated with the proposed action. However, given that specific density data are not available for the action area, these data were deemed as the best available science for the action area.
- Zones of Influence for underwater sound generating activities in the action area are shown in Figure 1. The Zones of Influence are based on sound emanating from a generalized location in the middle of the pile driving effort. As a result, the distances to the criteria thresholds above would be slightly more, or less, to the northeast or southwest, depending on the actual location of pile driving.
- Pile driving of 24-inch (61-centimeter) steel pipe and sheet piles by impact and/or vibratory is conservatively estimated to occur on every day (total 105 days) of in-water construction.
- An individual can only be taken once per day due to underwater or sound from pile driving, whether from impact or vibratory pile driving, or vibratory extraction
- Pinnipeds are not known to occur within the action area; therefore they are not assessed for effects due to the proposed action.

The calculation for marine mammal takes is estimated by:

Take estimate = n * days of activity * area of effect

where:

n = whole number estimate of number/day within the Zone of Influence as noted above

The exposure assessment methodology is an estimate of the numbers of individuals exposed to the effects of pile driving and extraction activities exceeding NMFS established thresholds. In these exposure estimates, mitigation methods (i.e. hazing animals off of structures and the use of shutdown zones to ensure there are no Level A takes) are assumed to be effective in eliminating Level A takes. Results from acoustic impact exposure assessments should be regarded as conservative estimates that are strongly influenced by limited biological data. While the numbers generated from the pile driving exposure calculations provide conservative overestimates of marine mammal exposures, the intermittent duration and limited geographic extent of in-water construction and demolition activities would further limit actual exposures and their potential biological effects.

Table 5 provides the calculated distances to the NMFS criteria thresholds, as well as the areas of Zones of Influence associated with the maximum sound levels for the impulsive and continuous sounds that are anticipated during the pile driving. It should be noted that the Zone of Influence for level A harassment would be closely monitored and subject to shutdowns if a marine mammal approaches the area. These calculations are based on the modeling of transmission loss and are based on a generalized location in the middle of the pile driving effort. As a result, the distances to the criteria thresholds shown in Figure 1 would be slightly more, or less, to the northeast or southwest, depending on the actual location of pile driving. The figure reflects the conventional assumption that the natural or manmade shoreline acts as a barrier to underwater sound. Although it is known that there can be leakage or diffraction around such barriers, the prediction of resulting sound levels remains in the research modeling world, and it is generally accepted practice to model underwater sound propagation from pile driving as continuing in a straight line past shoreline projections (Dahl 2012). Hence, the projection of sound into the open ocean would be truncated by the shoreline.

Table 5. Calculated Distances to NMFS Threshold Criteria

Pile Driving Technique and Pile Type		***Source Level (dB rms)***	***Areas and Distances associated with NMFS Threshold Criteria[1] (nm²[km²], feet [meters])***		
			Level A	***Level B***	
			180 dB rms	***160 dB rms***	***120 dB rms***
Vibratory	**Steel**	163	NA[1]	NA[1]	25 (86), 24,129 (7,356)
Impact	**Steel**	192	<1 (<1)[2], 207 (63)	<1 (3.1)[2], 4,459 (1,359)	N/A[1]

Notes: [1] NA = No applicable threshold for that measure, [2] Areas were fractions of a square nautical mile (square kilometer).

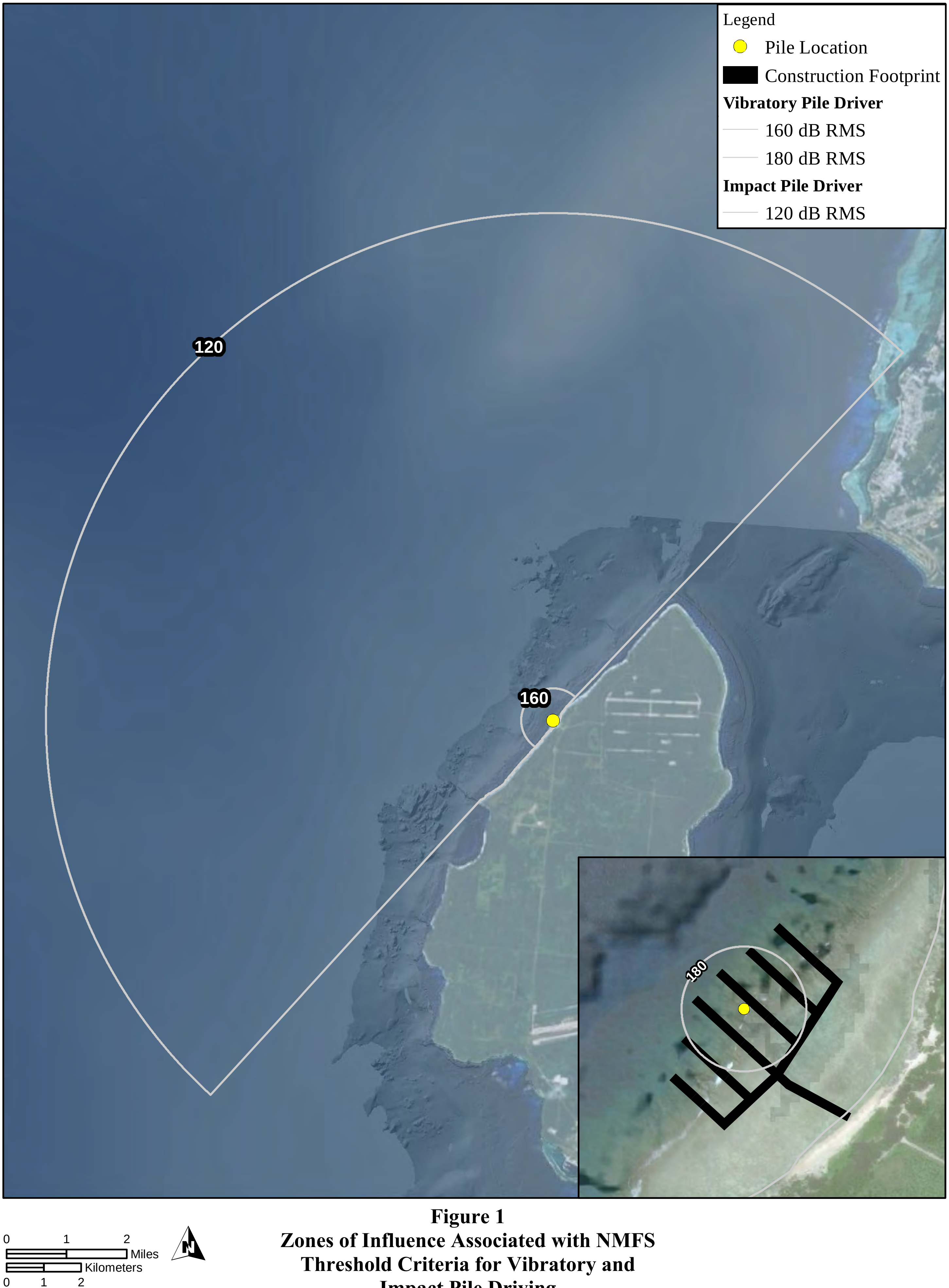


Figure 1
Zones of Influence Associated with NMFS Threshold Criteria for Vibratory and Impact Pile Driving

The cumulative exposure estimates (Table 6) are based on multiplying the density estimate for each species, times the number of pile driving days (105), times the area of the Zone of Influence associated with each threshold and activity (from Table 5). The cumulative exposures are rounded to the nearest whole number. Where the cumulative estimate of Level B exposures is less than 0.5, the fractional numbers are included in the table for further consideration. For the endangered whales, it is recommended to round up from 0.09 to 1 to provide coverage for one take. This analysis assumes 105 days of pile driving and extraction, with the worst-case assumption that either or both of steel impact driving and vibratory driving/extraction of steel piles can occur on each day. Since an animal can be taken only once per day, none of the Level B takes associated with impact driving count towards the total, but they indicate the number of animals likely to experience Level B harassment by both impact and vibratory driving/extraction during the same day. No Level A takes are predicted based on the densities and size of the Level A zone, which extends 207 feet (63 meters) from the source. Level A (injurious) exposures would in any case be prevented by monitoring the Level A "shutdown zone," curtailing pile driving activities whenever an animal is within this zone.

Table 6. Summary of Potential Exposures Constituting Marine Mammal "Takes"

Species	***Density Estimate (animals/km²)¹***	***NMFS Threshold Criteria***		
		Level A*	***Level B*****	
		180 dB rms²	***160 dB rms²***	***120 dB rms³***
Threatened and Endangered Species				
Blue whale	0.00001	0	0.003	0.09
Fin whale	0.00001	0	0.003	0.09
Humpback whale	0.00089	0	0.291	8
Sei whale	0.00029	0	0.145	3
Sperm whale	0.00123	0	0.095	11
Other Marine Mammal Species				
Minke Whale	0.00059	0	0.193	5
Short-finned pilot whale	0.00362	0	1	33
False killer whale	0.00111	0	0.363	10
Melon-headed whale	0.00428	0	2	39
Common bottlenose dolphin	0.00131	0	1	12
Pantropical spotted dolphin	0.02260	0	7	204
Spinner dolphin	0.00699	0	2	63
Blainville's beaked whale	0.00117	0	0.383	11
Cuvier's beaked whale	0.00621	0	2	56

Notes: [1]Source for density data: DoN (2012). [2]Applies to impact pile driving only. [3] Based the area within the maximum 120 dB rms isopleth during vibratory pile extraction.

* Assumes a ~100 m monitored shutdown zone, sufficient to avoid all Level A takes.

** Rounded to nearest whole number except numbers less than 0.5, which are shown as actuals for further consideration.

1.8 RESOURCE MANAGEMENT MEASURES

Resource Management Measures would be implemented in order to reduce the potential for effect relative to construction- and operation-related noise. Appendix D of the EIS/OEIS provides a full description of all Resource Management Measures associated with the proposed action. The Resource Management Measures below are those that are specific to noise-related issues.

1.8.1 Construction Best Management Practices

- All project-related materials and equipment (e.g., dredges) placed in the water should be clear of pollutants prior to use. No project-related materials (fill, revetment rock, etc.) should be stockpiled in the water (intertidal zones, reef flats, etc.).
- Construction contracts would include appropriate biosecurity measures.
- *Erosion Control Measures*. The erosion control measures such as retention ponds, swales, silt fences, fiber rolls, gravel bag berms, mulch, and erosion control blankets would be implemented during construction and operations to eliminate and/or minimize non-point source pollution in surface waters due to sediment.
- *Clean Water Act National Pollutant Discharge Elimination System Program*. A Stormwater Management Plan and Stormwater Pollution Prevention Plan would be prepared and implemented in compliance with the CNMI Stormwater Management Manual. Best management practices could include:
  - Soil stabilization (such as mulch and erosion control blankets).
  - Perimeter and sediment control (such as silt fences, fiber rolls, gravel bag berms, and sediment traps).
  - Management and covering of material, waste, and soil stockpiles when not in use.
  - Storage of fuels and hazardous materials with proper secondary containment, and establishment of designated vehicle and equipment maintenance and fueling areas.
- Management of spills and leaks from vehicles and equipment through inspections and use of drip pans, absorbent pads, and spill kits.
- A contingency plan to control petroleum products accidentally spilled during the project would be developed.
- *Contractor Education Program.* The DoN has developed an education program to ensure construction contractor personnel are informed of the biological resources in the project area, including special-status species, avoidance measures, and reporting requirements.
- If sea turtles or marine mammals are noticed within 150 feet (46 meters) after in-water construction work has begun, that work may continue only if that the activity would not affect the animal(s). For example, divers performing surveys or underwater work would likely be permissible, whereas operation of heavy equipment is likely not.
- Personnel shall remain alert for marine mammals before and during pile driving. Do not commence pile driving if a marine mammal is observed within 300 feet (90 meters) or sea turtle is observed within 50 feet (15 meters) of operation. Wait 30 minutes after the last sighting of the marine mammal before starting to pile drive. If pile driving is already started and a marine

mammal is sighted within 300 feet (90 meters) after drilling has commenced, drilling can continue unless the marine mammal comes within 210 feet (64 meters) during drilling; operations should then cease until the animal is seen to leave the area of its own volition or after 30 minutes have passed since the last sighting.

- During pile driving and removal, the shutdown zone would be sized and established to avoid injury to marine mammals.
- Soft Start – The use of a soft-start procedure is believed to provide additional protection to marine mammals by providing a warning and/or giving marine mammals a chance to leave the area prior to the hammer operating at full capacity. Soft start shall be conducted at the beginning of each day's activity and at any time pile driving has ceased for more than 30 minutes. If vibratory pile driving has been occurring but impact has not for more than 30 minutes, soft start for the impact hammer must occur. The soft start requires contractors to initiate noise from vibratory hammers for 15 seconds at reduced energy followed by a 30-second waiting period. This procedure should be repeated two additional times. If an impact hammer is used, contractors are required to provide an initial set of three strikes from the impact hammer at 40% energy, followed by a 30-second waiting period, then two subsequent 3-strike sets.

1.8.2 Operation Best Management Practices

- All established harbor navigation rules are observed during amphibious operations occurring within an established harbor. During amphibious operations (landings and departures) occurring outside of an established harbor, Landing Craft Air Cushion vessels stay fully on-cushion or hover when over shallow reefs to avoid corals, hard bottom, and other substrate that could potentially damage equipment.
- Flagging or marking of particular coral heads at Green Beach to avoid during training operations.
- Amphibious vehicles and small boats would avoid approaching marine mammals and sea turtles head on, to the greatest extent practical given operational need and vessel safety (necessary steerage, sea state, navigational need).
- A contingency plan to control petroleum products accidentally spilled during the project would be developed.

A complete listing of best management practices is provided in Appendix D of the EIS/OEIS, *Best Management Practices*.

1.9 Potential Effects of Pile Driving on Marine Mammals

1.9.1 Underwater Noise Effects

The effects of pile driving on marine mammals are dependent on several factors, including the size, type, and depth of the animal; the depth, intensity, and duration of the pile driving sound; the depth of the water column; the substrate of the habitat; the standoff distance between the pile and the animal; and the sound propagation properties of the environment. Impacts to marine mammals from pile driving activities are expected to result primarily from acoustic pathways. As such, the degree of effect is intrinsically related to the received level and duration of the sound exposure, which are in turn influenced by the distance between the animal and the source. The further away from the source, the less intense the exposure should be. The substrate and depth of the habitat affect the sound propagation properties of the environment. Shallow environments are typically more structurally complex, which leads to rapid sound attenuation. In addition, substrates that are soft (i.e., mud) will absorb or attenuate the sound more readily than hard substrates (rock), which may reflect the acoustic wave. Soft porous substrates would also likely require less time to drive the pile, and possibly less forceful equipment, which would ultimately decrease the intensity of the acoustic source.

Impacts to marine species are expected to be the result of physiological responses to both the type and strength of the acoustic signature (Viada et al. 2008). Behavioral impacts are also expected, though the type and severity of these effects are more difficult to define due to limited studies addressing the behavioral effects of impulsive sounds on marine mammals. Potential effects from impulsive sound sources can range from brief acoustic effects such as behavioral disturbance, tactile perception, physical discomfort, slight injury of the internal organs and the auditory system, to death of the animal (Yelverton et al. 1973; O'Keeffe and Young 1984; DoN 2001).

1.9.1.1 Physiological Responses

Direct tissue responses to impact/impulsive sound stimulation may range from mechanical vibration or compression with no resulting injury, to tissue trauma (injury). Because the ears are the most sensitive organ to pressure, they are the organs most sensitive to injury (Ketten, 2000). Sound-related trauma can be lethal or sub-lethal. Lethal impacts are those that result in immediate death or serious debilitation in or near an intense source (Ketten 1995). Sub-lethal impacts include hearing loss, which is caused by exposure to perceptible sounds. Severe damage, from a pressure wave, to the ear can include rupture of the tympanum, fracture of the ossicles, damage to the cochlea, hemorrhage, and cerebrospinal fluid leakage into the middle ear (NMFS 2008). Moderate injury implies partial hearing loss. Permanent hearing loss can occur when the hair cells are damaged by one very loud event, as well as prolonged exposure to noise. Instances of temporary threshold shifts (TTS) and/or auditory fatigue are well documented in marine mammal literature as being one of the primary avenues of acoustic impact. Temporary loss of hearing sensitivity (TTS) has been documented in controlled settings using captive marine mammals exposed to strong sound exposure levels at various frequencies (Ridgway et al. 1997; Kastak et al. 1999; Finneran et al. 2005), but it has not been documented in wild marine mammals exposed to pile driving. While injuries to other sensitive organs are possible, they are less likely since pile driving impacts are almost entirely acoustically mediated, versus explosive sounds, which also include a shock wave that can result in damage.

No physiological responses are expected from pile driving operations occurring during the proposed action for several reasons. Firstly, vibratory pile driving, which is being utilized as the primary installation method, does not generate high enough peak SPLs that are commonly associated with physiological damage. Any use of impulsive pile driving would only occur for a short period of time (~30 to 120 minutes per steel pile). Additionally, the mitigation measures (see Appendix D) would greatly reduce the chance that a marine mammal may be exposed to SPLs that could cause physical harm. The DoD would have trained biologists monitoring a shutdown zone equivalent to the Level A

Harassment zone, inclusive of the 180 dB re 1 µ Pa (for cetaceans) isopleth to ensure that no marine mammals are injured.

1.9.1.2 Behavioral Responses

Behavioral responses to sound are highly variable and context specific. For each potential behavioral change, the magnitude of the change ultimately determines the severity of the response. A number of factors may influence an animal's response to noise, including its previous experience, its auditory sensitivity, it's biological and social status (including age and sex), and its behavioral state and activity at the time of exposure.

Habituation can occur when an animal's response to a stimulus wanes with repeated exposure, usually in the absence of unpleasant associated events (Wartzok et al. 2003/04). Animals are most likely to habituate to sounds that are predictable and unvarying. The opposite process is sensitization, when an unpleasant experience leads to subsequent responses, often in the form of avoidance, at a lower level of exposure. Behavioral state may affect the type of response as well. For example, animals that are resting may show greater behavioral change in response to disturbing noise levels than animals that are highly motivated to remain in an area for feeding (Richardson et al. 1995; National Research Council (NRC) 2003; Wartzok *et al.* 2003/04).

Controlled experiments with captive marine mammals showed pronounced behavioral reactions, including avoidance of loud sound sources (Ridgway *et al.* 1997; Finneran et al. 2003). Observed responses of wild marine mammals to loud pulsed sound sources (typically seismic guns or acoustic harassment devices, and also including pile driving) have been varied but often consist of avoidance behavior or other behavioral changes suggesting discomfort (Morton and Symonds 2002; CALTRANS 2001, 2006; also see reviews in Gordon et al. 2004; Wartzok et al. 2003/04; and Nowacek et al. 2007). Responses to continuous noise, such as vibratory pile installation, have not been documented as well as responses to pulsed sounds.

With both types of pile driving, it is likely that the onset of pile driving could result in temporary, short term changes in the animal's typical behavior and/or avoidance of the affected area. A marine mammal may show signs that it is startled by the noise and/or may swim away from the sound source and avoid the area. Other potential behavioral changes could include increased swimming speed, increased surfacing time, and decreased foraging in the affected area. Since pile driving would likely only occur for a few hours per day, over a short period of time, it is unlikely to result in permanent displacement. Any potential impacts due to behavioral harassment (Level B) from pile driving activities could be experienced by individual marine mammals, but would not cause population level impacts, or affect the long-term fitness of the species.

1.10 Conclusions Regarding Impacts to Species or Stocks

Individual marine mammals may be exposed to SPLs during pile driving and extraction operations in the action area may result in Level B Behavioral harassment. Any marine mammals that are taken (harassed), may change their normal behavior patterns (i.e., swimming speed, foraging habits, etc.) or be temporarily displaced from the area of construction. Any takes would likely have only a minor effect on individuals and no effect on the population. The sound generated from vibratory pile driving is non-pulsed (e.g., continuous), which is not known to cause injury to marine mammals. The implementation of Resource Management Measures would reduce the magnitude of underwater impacts. Nevertheless, some level of impact is unavoidable. The expected level of unavoidable impact (defined as an acoustic or harassment "take") is described above. This level of effect is not anticipated to have a substantial effect on population recruitment, survival or recovery.

1.11 IMPACTS TO THE MARINE MAMMAL HABITAT AND THE LIKELIHOOD OF RESTORATION

The proposed activities are expected to have little, if any, effects on the distribution of marine mammals in the action area. The main impact issue associated with the proposed activity would be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed above. The most likely impact to marine mammal habitat occurs from pile driving effects on likely marine mammal prey (i.e., fish) nearby and minor impacts to the immediate substrate during installation and removal of piles. The text below provides an analysis of effects relative to marine mammals. For a full analysis of the effects of the proposed action on fish see Chapter 4, Section 4.10.3.1.1.6, *Fish*, in the EIS/OEIS.

1.11.1 Pile Driving Effects on Potential Prey (Fish)

Construction activities would produce both pulsed (i.e., impact pile driving) and continuous sounds (i.e., vibratory pile driving). Fish react to sounds that are especially strong and/or intermittent low-frequency sounds. Short duration, sharp sounds can cause overt or subtle changes in fish behavior and local distribution. Hastings and Popper (2005) and Popper and Hastings (2009) identified several studies that suggest fish may relocate to avoid certain areas of noise energy. Additional studies have documented effects of pile driving (or other types of continuous sounds) on file, although several are based on studies in support of large, multiyear bridge construction projects (Scholik and Yan 2001, 2002; Govoni et al. 2003; Hawkins 2005; Hastings 1990, 2007; Popper et al. 2006; Popper and Hastings 2009). Sound pulses at received levels of 160 dB re 1 µPa may cause subtle changes in fish behavior. SPLs of 180 dB may cause noticeable changes in behavior (Chapman and Hawkins 1969; Pearson et al. 1992; Skalski et al. 1992). SPLs of sufficient strength have been known to cause injury to fish and fish mortality (CALTRANS 2001; Longmuir and Lively 2001). The most likely impact to fish from pile driving activities at the action area would be temporary behavioral avoidance of the immediate area. The duration of fish avoidance of this area after pile driving stops is unknown, but a rapid return to normal recruitment, distribution and behavior is anticipated. In general, impacts to marine mammal prey species are expected to be minor and temporary.

1.11.2 Pile Driving Effects on Potential Foraging Habitat

Marine mammal surveys (DoN 2007; HDR 2012; Hill et al. 2013a, 2013b, 2013c; Oleson 2013; Hill et al. 2014; DoN 2014) have documented relatively few marine mammal occurrences in the immediate vicinity of the action area. Based on low densities for marine mammals likely to occur in the action area, the placement and removal of pilings, substrate disturbance, and high levels of activity at the project site would be inconsequential in terms of effects on marine mammal foraging.

The duration of fish avoidance of this area after pile driving stops is unknown, but a rapid return to normal recruitment, distribution and behavior is anticipated. Any behavioral avoidance by fish of the disturbed area would still leave significantly large areas of fish and marine mammal foraging habitat in the action area.

1.11.3 Summary of Impacts to Marine Mammal Habitat

Given the short daily duration of noise associated with individual pile driving/removal, seasonal limitations on the in-water activities that have the greatest potential to disturb marine mammals and their prey, and the relatively small areas being affected, pile driving and extraction activities associated with the proposed action are not likely to have a substantial permanent effect on any habitat, or population of fish species. Therefore, pile driving/removal is not likely to have a permanent, adverse effect on marine mammal foraging habitat at the action area.

2.0 CORAL

2.1 INTRODUCTION

2.1.1 Overview

The coral portion of this Technical Memo serves as a reference document to be used in support of the CJMT EIS/OEIS. This Technical Memo is derived from the information gathered and presented in the technical survey report summarizing surveys of the nearshore waters and coral reefs associated with nine beaches at Tinian and Pagan (DoN 2014). Additional data sources were also used in preparation of this Technical Memo. The underlying goal is to summarize the information in the technical survey report into a readily available, easily understandable format for those without experience in coral reef ecology or coral survey methodology.

2.1.2 Corals of the CNMI

Corals are important to the nearshore environments where they are found because they directly and indirectly structure their environment. Complex reefs can diffuse waves, acting as a protective barrier and stabilizing factor for the intertidal zone, beach, and terrestrial environment adjacent to reefs. Reefs grow over time as the coral deposit their skeletons, which are made of calcium and other minerals extracted from the sea water. As reefs grow, the shoreline of islands and continents are reshaped. When geological processes, such as tectonic movement, occur and climate changes cause sea levels to rise and fall, reefs can be exposed to become part of the terrestrial environment. Many of the islands in the Mariana Islands chain are formed of limestone that was historically uplifted and exposed to form parts of the islands that are above sea level. The historical reef is, in turn, shaped by environmental processes such as precipitation, erosion, earthquakes, and vegetative growth, to form the coast of islands and continents (DoN 2014).

The following discussion is a brief summary of the basic biology of corals and the Pacific corals that are proposed for listing under the ESA.

2.1.3 Coral Life History

Corals are categorized in the phylum Cnidaria, which is comprised of four classes: Anthozoa (corals and anemones), Hydrozoa (hydra, Portuguese man-o-war, and fire coral), Scyphozoa (jellyfish), and Cubizoa (box jellyfish). Key common features to the phylum are:

- Radial symmetry
- Two living tissue layers (ectodermis and endodermis)
- A specialized type of stinging cell called the cnidocyte
- Two basic body forms (medusa and polyp)

Medusae are free-swimming or floating, such as adult jellyfish. They typically have radially symmetrical and umbrella-shaped bodies. A cnidarian's mouth is usually on the concave side, and the tentacles originate on the rim of the umbrella. Polyps are sessile and can live individually (one polyp) or in compact colonies (many polyps). They have tubular bodies; one end is attached to the substrate, and a mouth (usually surrounded by tentacles) is found at the other end (Myers 2001). Cnidarians pass through two main forms during their life cycle: free living larvae to sessile adults. High mortality rates (approximately 90%) are experienced in the larval stage due to extreme vulnerability to predation and other environmental stressors during mobile life in the water column (Brainard et al. 2011). Polyps eventually settle and metamorphose into sessile adults.

2.1.3.1 Endangered Species Act Listing of Pacific Corals

Coral reef ecosystems are under increasing threat from many factors. Global climate change, ocean acidification, siltation from land based human activities, and coral harvesting to list a few. Because of the many factors that can harm coral and the relatively slow growth rates of the organism, and reef in general, many species have been proposed for listing under the ESA. Twenty-two coral species are listed under the federal ESA; 20 of which were listed in August 2014. Fifteen of the newly listed species occur in the Indo-Pacific, two are likely to occur in the CNMI, *Acropora globiceps* and *Pavona diffluens* (NMFS 2014; Veron 2014).

Acropora globiceps was recorded in the vicinity of Green Beach, Red Beach, Blue Beach, North Beach, Gold Beach, and South Beach (DoN 2014). Surveys conducted at Green Beach recorded 20 colonies of *Acropora globiceps*. The average size of a colony was 16 square inches (106 square centimeters) with the largest colony measuring 73 square inches (471 square centimeters). A total of 31 colonies were recorded at Red Beach with an average colony size of 11 square inches (73 square centimeters) and 5 colonies were recorded at South Beach, averaging in size of 30 square inches (196 square centimeters) *Pavona diffluens* was not observed during the survey (DoN 2014).

At the time of the coral survey and subsequent reporting, there were a total of 59 species of corals in the Indo-Pacific proposed for listing under the ESA. Of these 59 species, 7 were being considered for listing as endangered, while the remaining 52 species were being considered for listing as threatened (NOAA 2014). During the coral surveys at Tinian and Pagan, special attention was given to recording the demographics of any coral species proposed for listing under the ESA due to potential for them to be listed in the future. Therefore, some of the statistical information for ESA species in this report includes *Acropora globiceps* plus the species observed that were originally proposed for listing. The results are described for each surveyed beach in Section 2.2 of this Technical Memo.

2.1.4 2013 Coral Surveys of Tinian and Pagan

For the CJMT EIS/OEIS, the nearshore coral reefs of nine beaches (or unai in the Chamorro language) on the islands of Tinian and Pagan were investigated in 2013 in order to understand what coral resources were present within the nearshore area and to allow for comparison between beaches and with other beaches within the CNMI in terms of similarity or uniqueness. On Tinian, the four beaches that were assessed are Unai Chulu, Unai Babui, Unai Lam Lam, and Unai Masalok. On Pagan, the five beaches that were assessed are Green Beach, Red Beach, Blue Beach, South Beach, and North Beach. The surveys included areas of Red Beach where a proposed pier and breakwater may be constructed in the future. General descriptions of these areas are found in Chapters 1 and 3 of the EIS/OEIS.

The data needs of the survey objectives were best met with a nested approach to data collection and resolution. At the highest level was a broad-scale, spatially coarse survey of each beach in which a wide range of data were collected. At the lowest level was a small scale (at the scale of individual coral colonies) spatially fine survey within each beach collecting a narrow range of data. The topographic complexity, coral cover, macroalgae cover, and sand cover were all collected *in situ*, meaning they were observed where they occurred.

Identifying coral to the species level in the field can be challenging for some types of coral. In some cases, the exact species identification cannot be resolved without significant background research or laboratory work (e.g., use of microscope). Irresolvable identifications represent those corals that could be identified only to genus, which is the broader level of classification above species. All other identifications represent species that are positively identified or are likely to become positively identified with additional field collections, taxonomic work, or definition of potential novel species.

2.1.5 Data Analysis Methodology

Section 2.2 presents an analysis of coral survey data for beaches on Tinian and Pagan. For each beach, the following information is presented:

- Density. A table summarizes density values for all coral species, providing the average number of colonies per square meter (m^2). A separate table shows the same information for ESA-proposed threatened species. Size data are also included with this table: minimum, maximum, average, mode, and median.
- Coral Species Representation. A figure shows the cumulative representation of the coral community as measured by the quadrat method. The curve on the graph shows the portion of the coral population that is represented by addition, starting with the most abundant species and following through to the least abundant species. Coral community data are helpful in representing how much each species contributes to the raw number of coral colonies counted in quadrats at each beach.
- Relative Abundance. A figure shows the abundance of each species of coral as a percentage of the coral population, plotted against its rank from most plentiful species to least plentiful species. Species abundance is plotted on a logarithmic scale on the y-axis to show the linear relationship of abundance data. The most abundant species is at the far left of the graph.
- Size-Frequency Distribution. A figure shows the distribution of sizes for the most plentiful species. A separate figure shows the same information for ESA-proposed threatened species.

Section 2.3 presents a comparison of data analyzed for the different beaches. The parameters used are:

- Species Richness. Species richness is the scientific term for the number of different species represented in an ecological community or region.
- Diversity Indices. A diversity index takes into account more information than just the number of species present. This statistic incorporates a measure of how common each species is into a measure of diversity.
- Species Evenness. To make the diversity measures more intuitive, another measure called evenness is presented to give a sense of how evenly the species within a community are represented.

2.2 DATA ANALYSIS RESULTS

2.2.1 Tinian

Below are fairly brief summaries of the survey results from each beach on Tinian, as taken from the *Coral Marine Resources Survey Report* (DoN 2014).

2.2.1.1 Unai Chulu

2.2.1.1.1 Overview

Overall, Unai Chulu has low to moderate coral cover with patches of very high coral cover. Among the 121 species recorded during the survey, 98 species were positively identified, including 1 ESA-threatened coral species (*Acropora globiceps*). Most of the area surveyed at Unai Chulu has low to moderate topographic complexity, low to moderate coral cover, and low sand cover. However, patches of Unai Chulu did have very high coral cover (50-70%). The most abundant species was *Goniastrea retiformis*, which is not an ESA-proposed coral (DoN 2014).

The reef area at Unai Chulu was physically complex, with very deep, irregularly spaced grooves (e.g., 20-26 feet or 6-8 meters) in the fore reef, transitioning rapidly to deep fore reef, with broken rock fragments in the grooves. The bases of grooves had polished surfaces and polished cobble-sized fragments, indicating regular, energetic water motion and erosion. Many spurs were undercut by grooves that interconnect with other grooves, resulting in a network of tunnels, grottoes, fissures, and chimneys penetrating from the fore reef under the reef crest and occasionally under the reef flat (DoN 2014).

Reef zonation at Unai Chulu includes distinct deep fore reef, shallow fore reef, reef crest, outer reef flat, inner reef flat, and beach. To the south of the beach, the reef flat zone transitions to a shallow bench. This zone had more abundant coral cover than the reef flat. The habitat was heterogeneous among depth zones, particularly the shallow bench to the south of the beach, but was relatively homogeneous (similar) within depth zones.

2.2.1.1.2 All Coral Species

Table 7 lists the 68 coral species identified by the quadrat survey method at Unai Chulu. Density values provide the average number of colonies per square meter (m^2).

Table 7. Unai Chulu Coral Species Densities from All Quadrats

Species*	***Density (avg. # colonies/m2)***	***Count***
Goniastrea retiformis	5.60	297
Favia stelligera	1.30	69
Leptoria phrygia	1.28	68
Porites sp.	1.00	53
Favia matthaii	0.91	48
Acropora digitifera	0.79	42
Favia pallida	0.68	36
Leptastrea purpurea	0.66	35
Stylophora mordax	0.60	32
Platygyra pini	0.51	27
Pavona varians	0.47	25
Acropora ocellata	0.38	20
Galaxea fascicularis	0.38	20
Acropora globiceps T*	0.34	18
Goniastrea edwardsi	0.34	18
Montipora ehrenbergii	0.32	17
Acanthastrea brevis	0.26	14
Montipora grisea	0.25	13
Montastrea cf. valenciennesi	0.23	12
Pocillopora verrucosa	0.23	12
Acropora verweyi	0.21	11
Acropora valida	0.19	10
Montipora sp.	0.17	9
Acropora sp.	0.15	8
Acropora surculosa	0.15	8
Cyphastrea sp.	0.15	8
Hydnophora microconos	0.15	8
Montipora species 2 (spikey)	0.15	8
Pavona chiriquensis	0.15	8
Pocillopora meandrina	0.15	8
Pocillopora sp.	0.15	8
Pocillopora species 1	0.15	8
Acropora cophodactyla	0.13	7
Montipora peltiformis	0.13	7
Pocillopora eydouxi	0.13	7
Pavona duerdeni	0.11	6
Acropora studeri	0.09	5
Cyphastrea microphthalma	0.09	5
Cyphastrea serailia	0.09	5
Pocillopora ankeli	0.09	5
Favites abdita	0.08	4
Acropora palmerae	0.06	3
Acropora tenuis	0.06	3
Favia favus	0.06	3
Galaxea astreata	0.06	3
Leptastrea transversa	0.06	3
Montastrea curta	0.06	3

Table 7. Unai Chulu Coral Species Densities from All Quadrats

Species*	***Density (avg. # colonies/m2)***	***Count***
Montipora tuberculosa	0.06	3
Montipora informis	0.04	2
Psammocora contigua	0.04	2
Acropora wardii	0.02	1
Astreopora listeri	0.02	1
Astreopora myriophthalma	0.02	1
Fungia scutaria	0.02	1
Goniastrea sp.	0.02	1
Lobophyllia hemprichii	0.02	1
Montipora foveolata	0.02	1
Montipora verrucosa	0.02	1
Pavona clavus	0.02	1
Pocillopora damicornis	0.02	1
Pocillopora setchelli	0.02	1
Porites annae	0.02	1
Porites lobata	0.02	1
Porites rus	0.02	1
Psammocora profundacella	0.02	1
Psammocora species 1 (low, smooth ridges/collines)	0.02	1
Scapophyllia cylindrica	0.02	1
Turbinaria reniformis	0.02	1

Notes: In order by abundance; aggregate for the whole beach.
Legend: sp. = unknown species – identified only to genus; T = Threatened.

Figure 2 shows the cumulative representation of the coral community at Unai Chulu as measured by the quadrat method. The most abundant species, *Goniastrea retiformis,* makes up approximately 28% of the coral colonies counted at Unai Chulu. The first 6 species comprise 54%, and the other 62 species comprise 46% of the coral colonies counted in quadrats as Unai Chulu. The most abundant ESA-proposed species is the 14th most abundant species, *Acropora globiceps*, which comprises about 2% of the coral colonies counted in the quadrat survey method. This type of population structure is not uncommon in natural communities. Some species are dominant in the community while the majority of species are represented to a small degree.

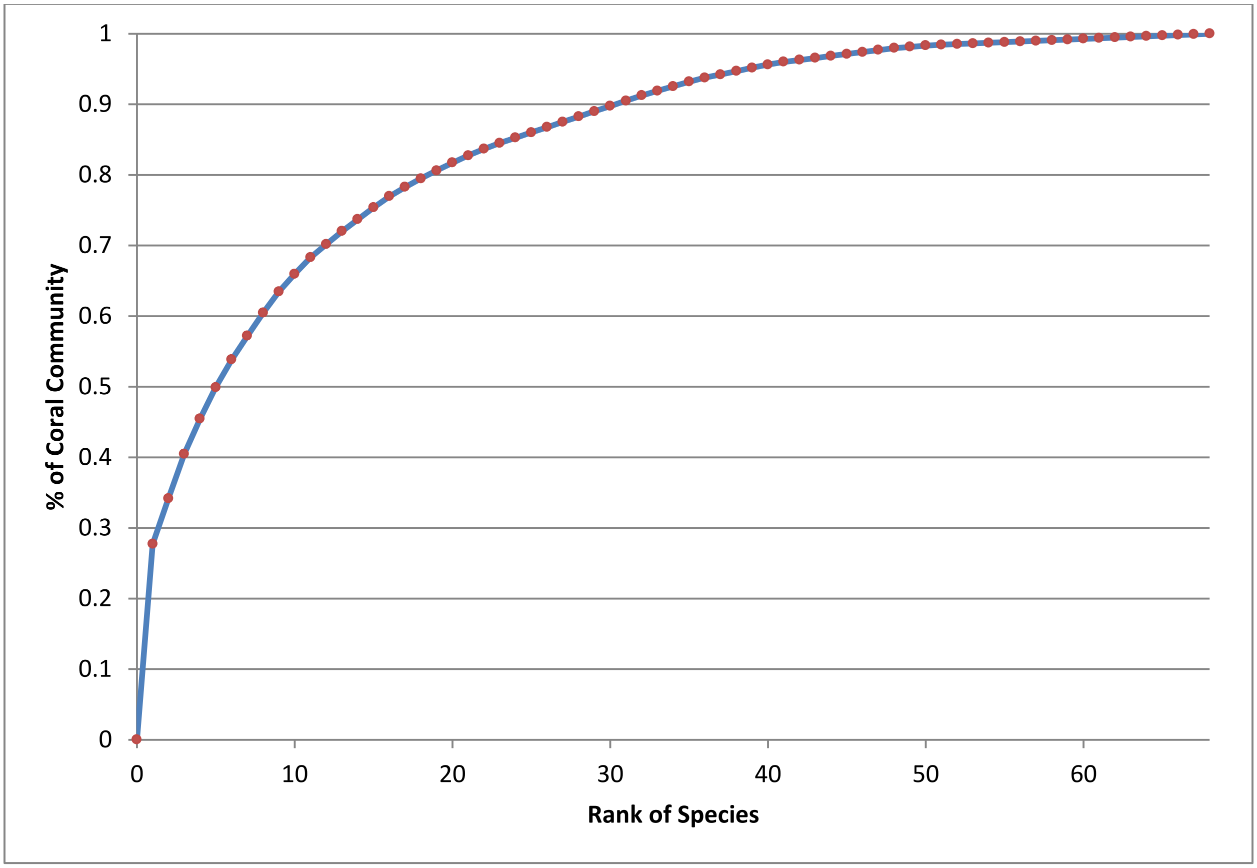


Figure 2. Unai Chulu Cumulative Coral Species Representation Based on Quadrat Colony Counts

Figure 3 shows the abundance of each species of coral at Unai Chulu as a percentage of the coral population plotted against its rank from most plentiful species to least plentiful species. Species abundance is plotted on a logarithmic scale on the y-axis to show the linear relationship of abundance of most of the data. The most abundant species is the red dot at the far left of the graph and is clearly more abundant than the other species and does not fall close to the line as most other species do. This species is, relatively speaking, "overrepresented" at Unai Chulu compared to the other coral species. The row of values at the right end of the graph is for all of the species for which only one colony was seen in the quadrats at Unai Chulu.

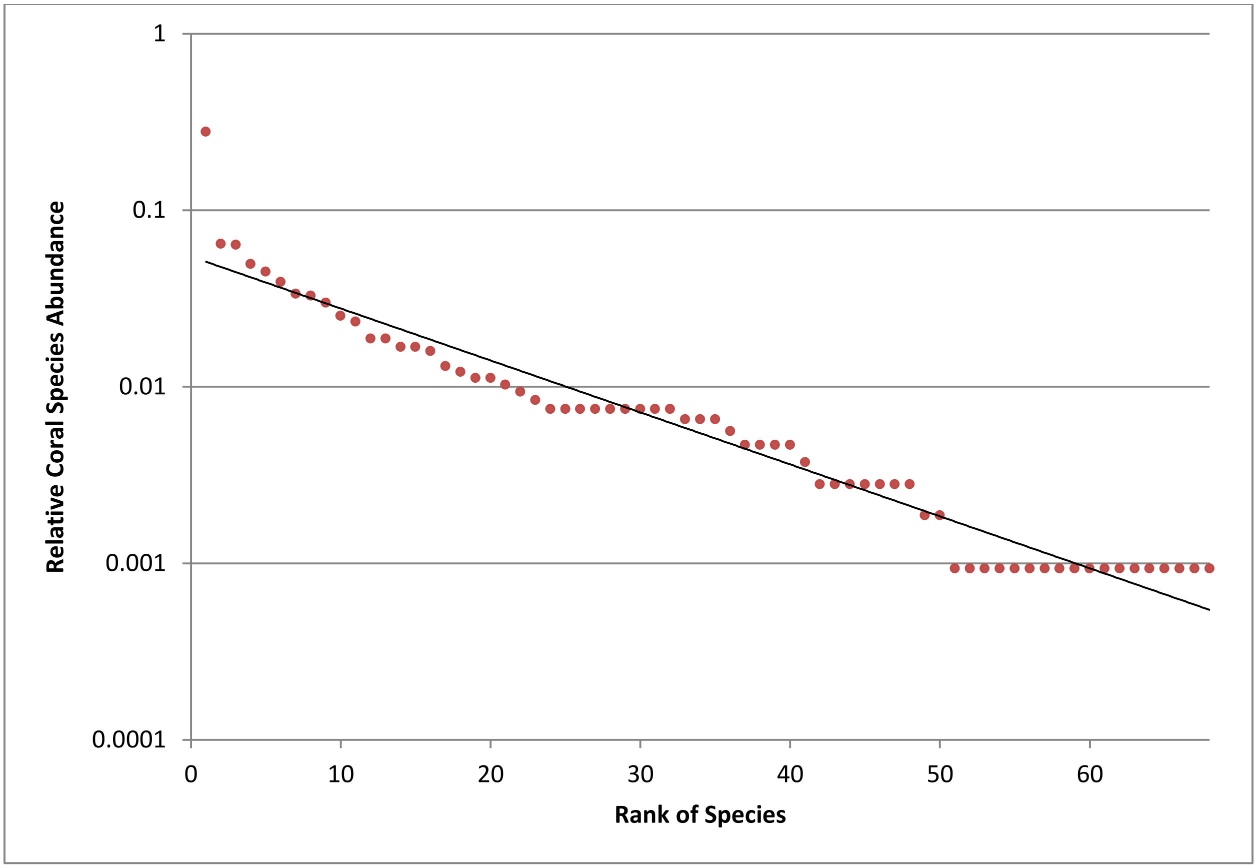


Figure 3. Unai Chulu Relative Abundance of Coral Species Based on Quadrat Colony Counts

Figure 4 shows the distribution of sizes for the six most plentiful species, representing roughly half of the coral colonies in the survey area. All six of the species occur in high frequency but relatively small colonies with diameters less than 6 inches (15 centimeters). Therefore much of the reef is comprised of small colonies that provide fine structure to the reef, but are not major contributors to topographic complexity at the medium scale, which is 1.5-feet (0.5-meter) or larger. The reason for this size distribution of the most plentiful corals is undetermined, but it could be result of several factors, or a combination thereof:

- Environmental factors such as vigorous wave motion, affect the corals to the degree that smaller and more compact growth form is evident in the coral colony structure.
- A recent event, such as a typhoon, removed or affected coral and the new coral that is growing is still relatively young.
- Larger corals are being removed from the environment by factors such as human collectors or predators such as the crown of thorns starfish (*Acanthaster planci*).
- Coral recruitment and growth is unusually slow due to some unknown reason.

2.2.1.1.3 Special-Status Coral Species

Table 8 shows the ESA coral species at Unai Chulu (*Acropora globiceps*). Figure 5 shows the distribution of sizes for *Acropora globiceps* and the most plentiful previously proposed coral species that occurred in the quadrat survey method at Unai Chulu. Three of the species occurred at sizes that were larger than the six most abundant coral species. In particular, *Acropora palmerae*, which is an encrusting coral (a coral that covers the surface of a substrate, but does not grow upward), produced colonies that were up to a relatively large size of 3 feet (1 meter) or more across. Larger corals are more likely to have a local effect on the character of the reef than small colonies. The data for Figure 5 comes from all methods of coral data collection in the summer 2013, because the quadrat method can potentially underrepresent infrequently occurring species and the occurrence of large individual colonies.

Table 8. Unai Chulu Coral Colony Populations of ESA Species from All Surveys

Species	*Density (avg. # colonies/m^2)*	*Count*	*Size (cm^2)*				
			Minimum	*Maximum*	*Average*	*Mode*	*Median*
Acropora globiceps T	0.03	490	1	6,283	272	79	79

Legend: T = threatened.

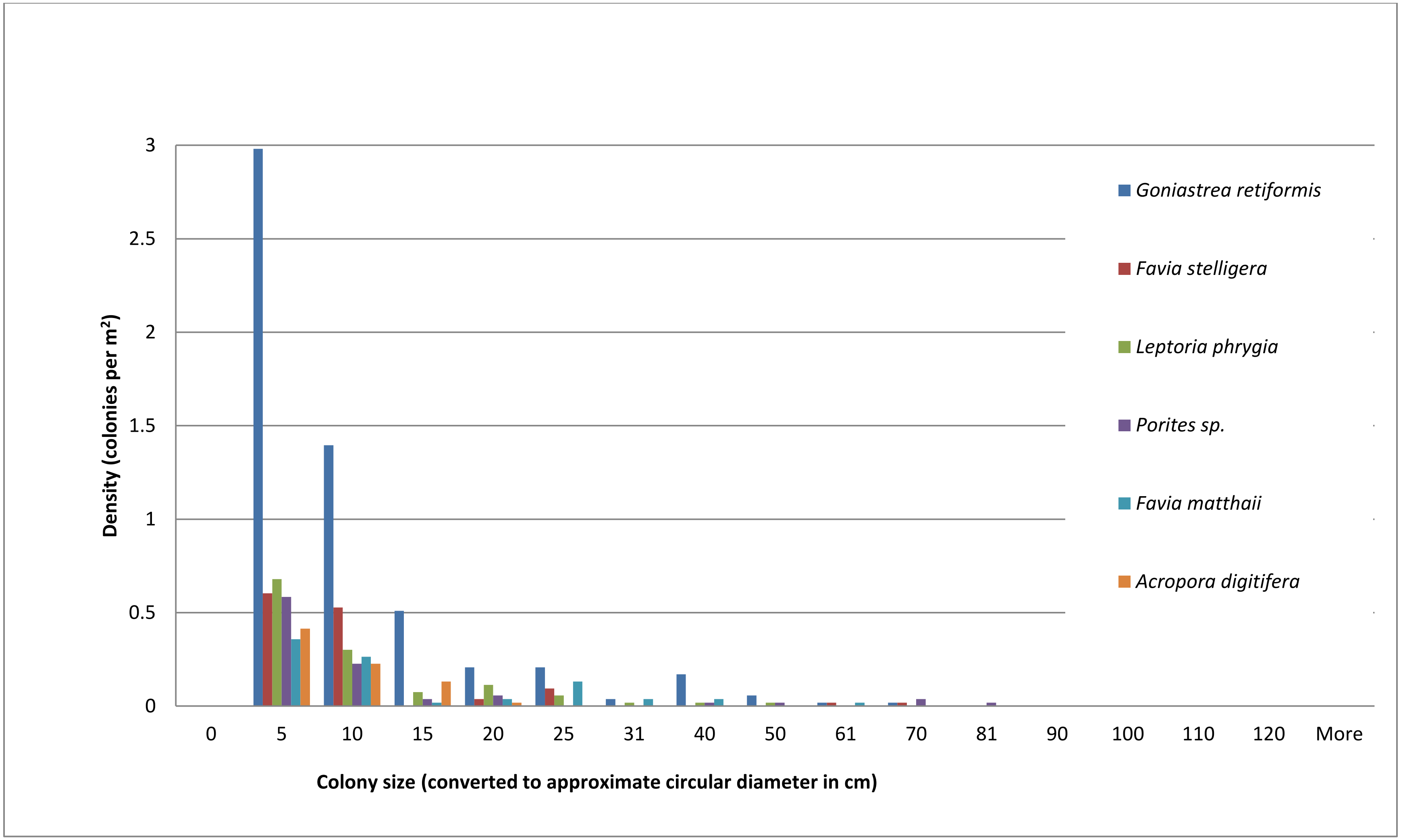
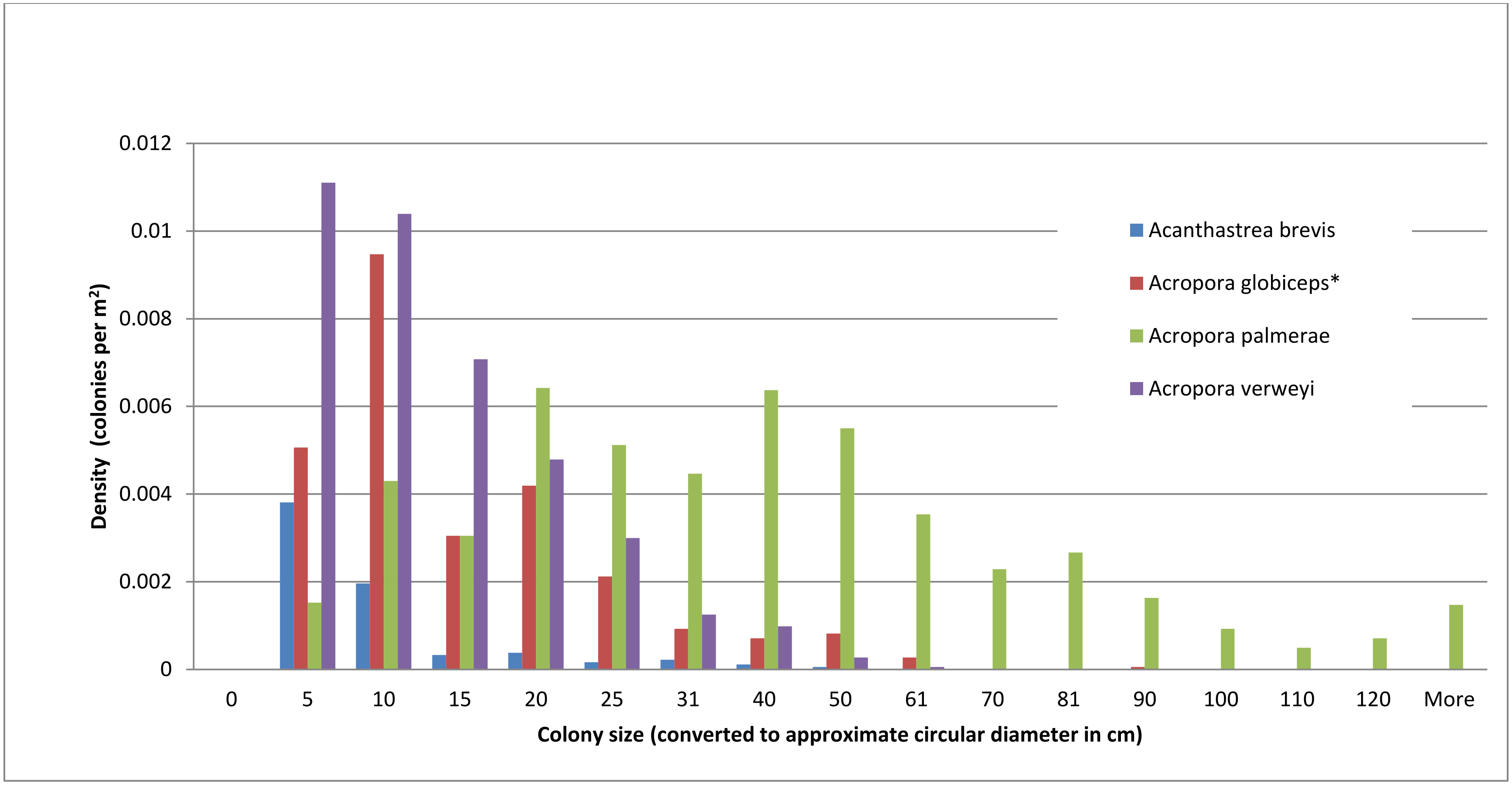


Figure 4. Unai Chulu Size-Frequency Histogram of the Most Abundant Coral Species



Note: Four of eight previously proposed threatened species at Unai Chulu have densities high enough to display on this figure.

Figure 5. Unai Chulu Size-Frequency Histogram of the ESA Coral Species from All Surveys

2.2.1.2 Unai Babui

2.2.1.2.1 Overview

Unai Babui is a much smaller beach than Unai Chulu. Overall, Unai Babui has moderate to high topographic complexity, low to moderate coral cover, and low sand cover. However, patches of Unai Babui had very high coral cover (70-100%). Among the 107 species recorded during the survey, 98 species were positively identified, including 1 ESA-threatened coral species. The most abundant species was *Goniastrea retiformis*, which is not proposed for ESA listing (DoN 2014).

The reef area at Unai Babui is physically complex, with irregularly spaced grooves that were very deep (e.g., 20-26 feet [6-8 meters]) in the fore reef, transitioning rapidly to deep fore reef, with broken rock fragments in the grooves. The bases of grooves often had polished surfaces and polished cobble-sized clasts, indicating high-energy sediment transport and erosion. Many spurs were undercut by grooves that interconnect with other grooves, resulting in a network of tunnels, grottoes, fissures, and chimneys penetrating from the fore reef under the reef crest, and occasionally under the reef flat.

Reef zonation at Unai Babui was quite clear and includes distinct deep fore reef, shallow fore reef, reef crest outer reef flat, inner reef flat, and beach. To the south of the beach, the reef flat zone transitions to a shallow bench, which was more abundant with coral cover than the reef flat. The habitat was heterogeneous among depth zones, particularly the shallow bench to the south of the beach, but was relatively homogeneous within depth zones.

2.2.1.2.2 All Coral Species

Table 9 lists all the 54 coral species identified by the quadrat survey method at Unai Babui.

Table 9. Unai Babui Coral Species Densities from All Quadrats

Species*	***Density (avg. # colonies/m^2)***	***Count***
Goniastrea retiformis	2.76	116
Leptoria phrygia	0.81	34
Acropora surculosa	0.60	25
Pocillopora verrucosa	0.60	25
Acropora palmerae	0.48	20
Favia matthaii	0.38	16
Acropora valida	0.29	12
Favia stelligera	0.29	12
Galaxea fascicularis	0.24	10
Pocillopora meandrina	0.24	10
Acropora ocellata	0.21	9
Montipora grisea	0.21	9
Acropora digitifera	0.19	8
Acropora monticulosa	0.17	7
Acropora verweyi	0.14	6
Goniastrea pectinata	0.14	6
Pocillopora setchelli	0.14	6
Porites sp.	0.14	6
Stylophora mordax	0.14	6
Acropora globiceps T	0.12	5

Table 9. Unai Babui Coral Species Densities from All Quadrats

Species*	***Density (avg. # colonies/m²)***	***Count***
Acropora secale	0.12	5
Montipora ehrenbergii	0.12	5
Montipora sp.	0.12	5
Montipora tuberculosa	0.12	5
Pavona varians	0.12	5
Platygyra pini	0.12	5
Pavona chiriquensis	0.10	4
Acanthastrea brevis	0.07	3
Goniastrea edwardsi	0.07	3
Montastrea curta	0.07	3
Psammocora digitata	0.07	3
Favia pallida	0.05	2
Hydnophora exesa	0.05	2
Hydnophora microconos	0.05	2
Montastrea cf. valenciennesi	0.05	2
Pocillopora ankeli	0.05	2
Acanthastrea echinata	0.02	1
Acropora abrotanoides	0.02	1
Acropora aff. humilis	0.02	1
Acropora cophodactyla	0.02	1
Acropora selago	0.02	1
Acropora sp.	0.02	1
Cyphastrea microphthalma	0.02	1
Cyphastrea sp.	0.02	1
Favia favus	0.02	1
Goniopora minor	0.02	1
Leptastrea purpurea	0.02	1
Leptastrea transversa	0.02	1
Leptoseris incrustans	0.02	1
Montipora cf. turgescens	0.02	1
Pavona duerdeni	0.02	1
Pocillopora eydouxi	0.02	1
Pocillopora sp.	0.02	1
Psammocora nierstraszi	0.02	1

Notes: *In order by abundance; aggregate for the whole beach.
Legend: sp. = unknown species – identified only to genus; T = ESA threatened species.

Figure 6 shows the cumulative representation of the coral community at Unai Babui as measured by the quadrat method. As with Unai Chulu, the most abundant species was *Goniastrea retiformis,* which makes up approximately 28% of the coral counts at Unai Babui. The first five species in Table 9 comprise 52% of the coral colonies counted in quadrats, while the other 49 species comprise the remaining 48% of the coral colonies. The most abundant ESA-proposed species is the 5th most abundant species, *Acropora palmerae*, which comprises about 5% of the coral colonies counted in quadrats.

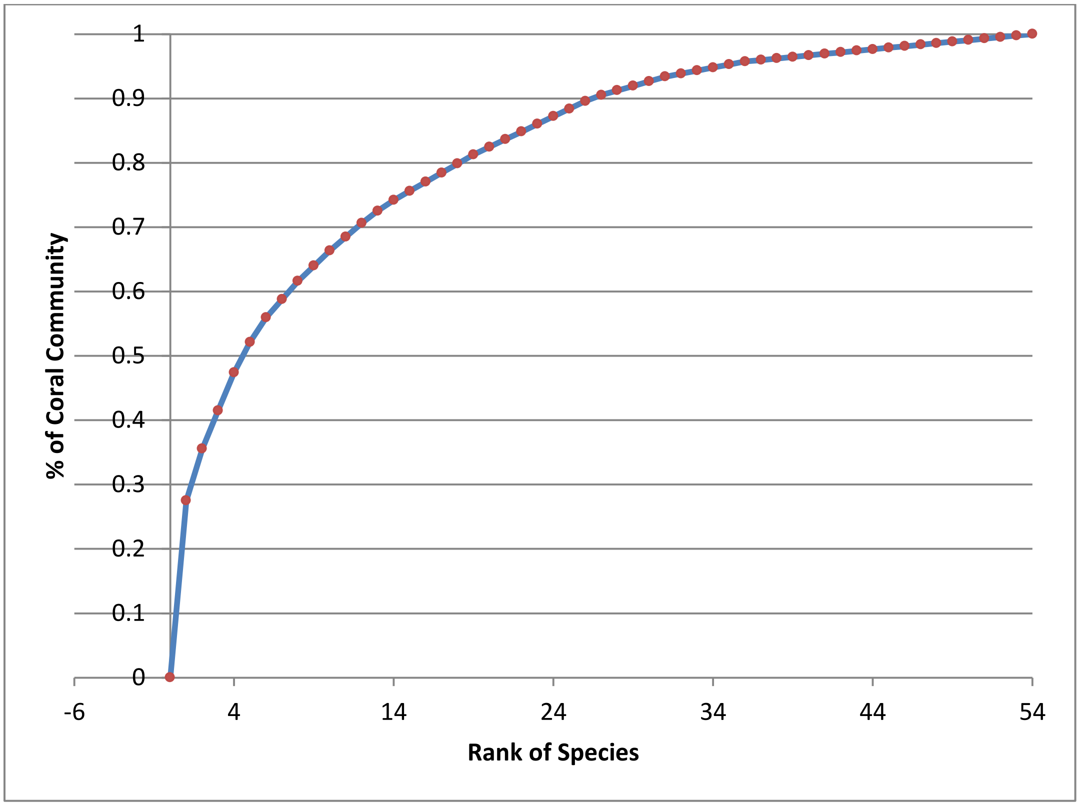


Figure 6. Unai Babui Cumulative Coral Species Representation Based on Quadrat Colony Counts

Figure 7 shows the abundance of each species of coral at Unai Babui as a percentage of the coral population plotted against its rank from most plentiful species to least plentiful species. The most abundant two species at the far left is more abundant than the other species and does not fall close to the line as most other species do. The row of values at the right end of the graph is for all of the species for which only one colony was seen in the quadrats at Unai Babui.

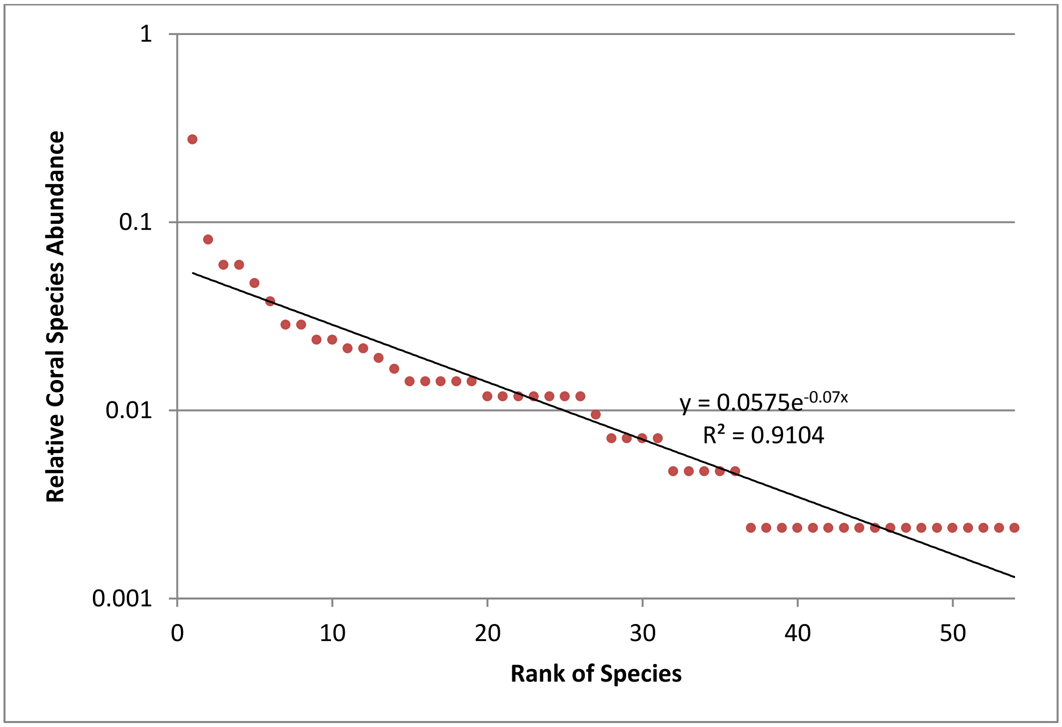
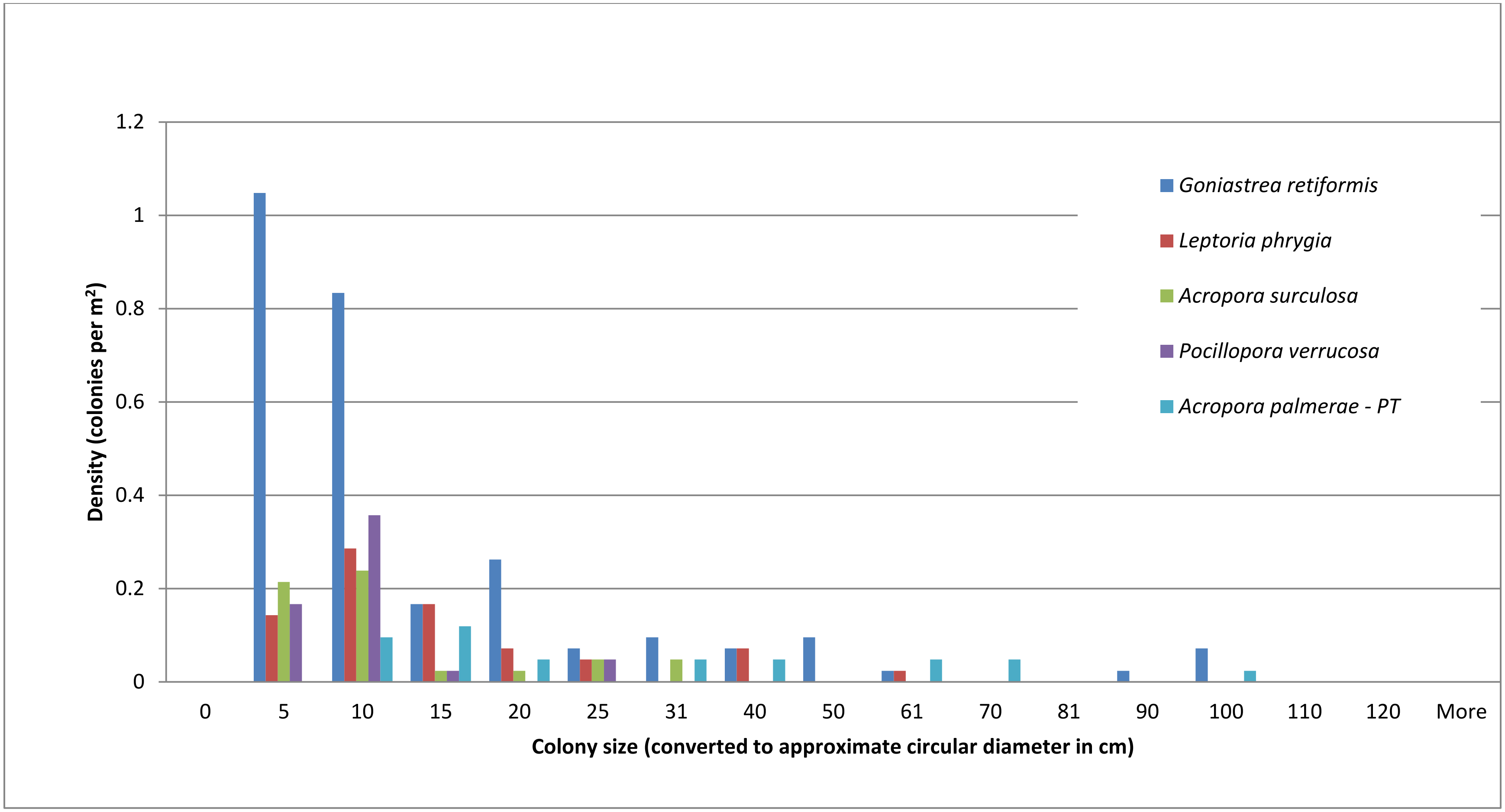


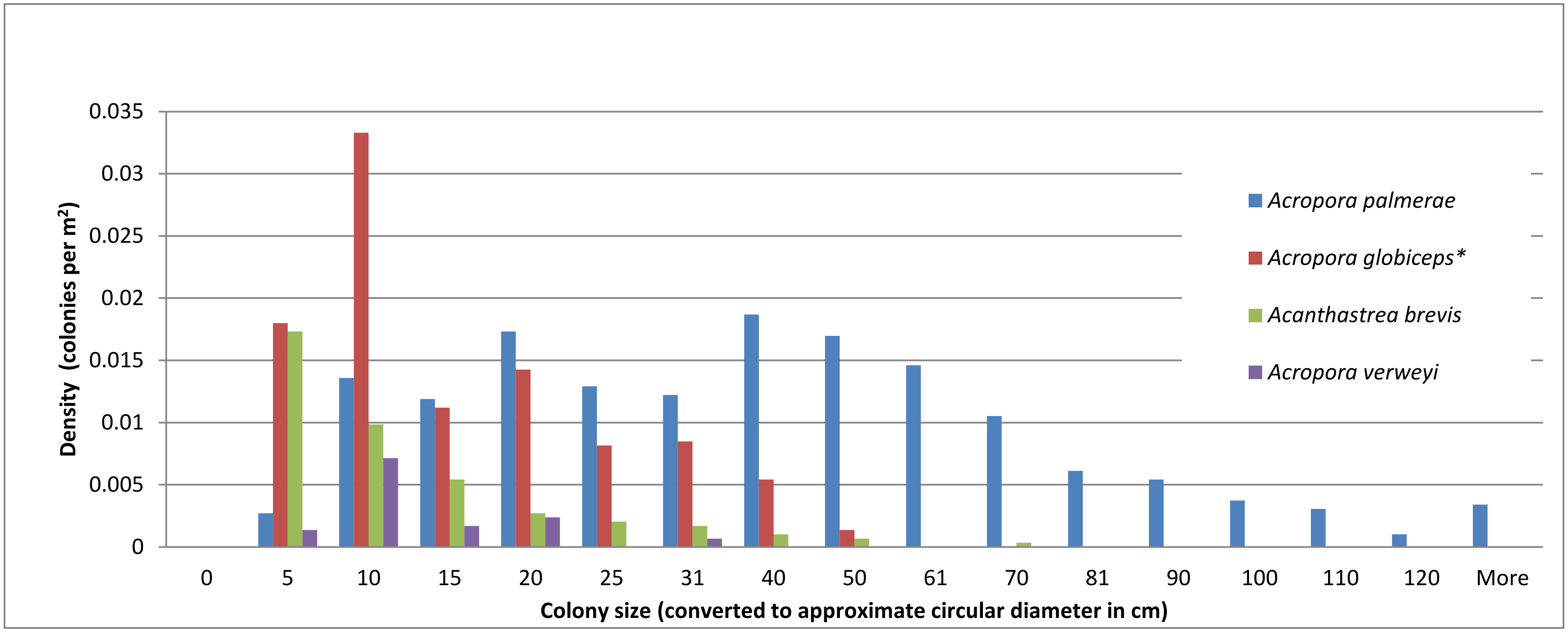
Figure 7. Unai Babui Relative Abundance of Coral Species Based on Quadrat Colony Counts

In light of the complete community at Unai Babui, it is useful to consider the first five species that comprise 52% of the coral community, as they define much of the character of the coral reef at less than 12 feet (3 meters) depth at Unai Babui. Figure 8 shows the distribution of sizes for the most plentiful colonies at Unai Babui. The most abundant coral, *Goniastrea retiformis*, has a very similar character as that observed at Unai Chulu, which is numerous small colonies, the vast majority of which have diameters less than 6 inches (15 centimeters). The other four species are biased in size distribution toward smaller colonies, but there is a relatively more even representation of larger sizes in the right tail of the distribution than was seen at Unai Chulu. This is a qualitative assessment, but it appears that the more abundant coral occur in larger sizes that may contribute to local topographic complexity at Unai Babui.



Notes: Five species make up the top 50th percentile at Unai Babui. *Legend*: PT = Proposed Threatened.

Figure 8. Unai Babui Size-Frequency Histogram of the Most Abundant Coral Species Based on Quadrat Counts



Note: Four of seven previously proposed threatened species have densities high enough to depict on this figure.

Figure 9. Unai Babui Size-Frequency Histogram of the Most Abundant ESA-Proposed Threatened Coral Species from all Surveys

2.2.1.2.3 Special-Status Coral Species

Table 10 shows the ESA coral species at Unai Babui (*Acropora globiceps*). Figure 9 shows the distribution of sizes for *Acropora globiceps* and the most plentiful previously proposed coral species that occurred in the quadrat survey method at Unai Babui. Like Unai Chulu, three of the species occurred at sizes that were larger than the most abundant coral species. *Acropora palmerae*, an encrusting coral, occurs in colonies that were up to 3 feet (1 meter) or more across and the size distribution of the species has the most colonies occurring at about 1.3 feet (0.4 meter) in diameter. A similar size distribution for this species was observed at Unai Chulu (see Figure 5). The data for Figure 9 come from all methods of coral data collection in the summer 2013 surveys, because the quadrat method can potentially underrepresent infrequently occurring species and the occurrence of large individual colonies.

Table 10. Unai Babui Coral Colony Densities for ESA-Proposed Threatened Species from All Surveys

Species	*Density (avg. # colonies/m2)*	*Count*
Acropora globiceps T	0.10	295

Legend: T = threatened.

Unai Babui, like Unai Chulu, had patches where ESA-proposed corals were dominant. In total, 919 colonies of ESA-proposed coral species were reported during the survey. The most common ESA-proposed species include *Acropora globiceps*, *Acropora palmerae*, and *Acropora verweyi* (DoN 2014).

2.2.1.3 Unai Lam Lam

2.2.1.3.1 Overview

Overall, Unai Lam Lam has moderate to high topographic complexity, moderate coral cover, and low sand cover, except for one large offshore patch of 90-100% sand. Patches of Unai Lam Lam had very high coral cover (70%-90%). Among the 108 species recorded, 87 species were positively identified, including 1 ESA-threatened coral species. The most abundant coral species was *Goniastrea retiformis*, which is not proposed for ESA listing (DoN 2014).

The reef area at Unai Lam Lam was physically complex, with regularly spaced grooves that were very deep (e.g., 13-26 feet [4-8 meters]) in the fore reef, transitioning rapidly to deep fore reef. The groove aligned with the center of the pocket beach was strewn with cobble and boulder-sized rubble, while most other grooves were lined with coarse carbonate sand. This structure is a sign of past physical disturbance to the groove aligned with the center of the pocket beach. Many spurs were undercut by grooves interconnecting with other grooves, resulting in a network of tunnels, grottoes, fissures, and chimneys penetrating from the fore reef under the reef crest and occasionally under the reef flat (DoN 2014).

Reef zonation at Unai Lam Lam includes distinct deep fore reef, shallow fore reef, reef crest, outer reef flat, inner reef flat, and beach. The reef crest and outer reef flat were very broad and well developed relative to Unai Babui and Unai Chulu. To the south of the beach, the reef flat zone transitions to a shallow bench. Like Unai Babui and Unai Chulu, this zone was very rich, with exceptionally high coral cover (90%). The habitat was somewhat heterogeneous among depth zones and relatively homogeneous within depth zones, but this distinction was less pronounced than at Unai Chulu and Unai Babui. Zonation was still identifiable, but each zone was richer than its counterpart at Unai Chulu and Unai Babui.

2.2.1.3.2 All Coral Species

A total of 52 coral species fell within quadrats. The most abundant species was *Goniastrea retiformis,* as with broad scale survey methods. Table 11 lists the 52 coral species identified in quadrat surveys at Unai Lam Lam.

Table 11. Unai Lam Lam Coral Species from All Quadrats

Species*	***Density (avg. # colonies/m^2)***	***Count***
Goniastrea retiformis	6.07	85
Pocillopora setchelli	1.93	27
Favia stelligera	1.64	23
Galaxea fascicularis	1.50	21
Stylophora mordax	1.14	16
Acropora valida	1.07	15
Montipora grisea	0.93	13
Pocillopora sp.	0.93	13
Platygyra pini	0.86	12
Leptoria phrygia	0.79	11
Favia pallida	0.64	9
Acropora cophodactyla	0.57	8
Acropora palmerae PT	0.57	8
Montipora peltiformis	0.57	8
Acropora surculosa	0.50	7
Cyphastrea microphthalma	0.50	7
Acropora ocellata	0.43	6
Montipora hoffmeisteri	0.43	6
Montipora informis	0.43	6
Montipora sp.	0.43	6
Pavona chiriquensis	0.43	6
Leptastrea purpurea	0.36	5
Acropora sp.	0.29	4
Favia matthaii	0.29	4
Pocillopora meandrina	0.29	4
Acropora verweyi PT	0.21	3
Montipora ehrenbergii	0.21	3
Pavona varians	0.21	3
Pocillopora verrucosa	0.21	3
Acanthastrea brevis PT	0.14	2
Acropora cf. cerealis	0.14	2
Acropora globiceps PT	0.14	2
Acropora secale	0.14	2
Montastrea cf. valenciennesi	0.14	2
Montipora elshneri	0.14	2
Acropora abrotanoides	0.07	1
Acropora digitifera	0.07	1
Acropora monticulosa	0.07	1
Acropora studeri	0.07	1
Astreopora randalli	0.07	1
Favia helianthoides	0.07	1
Favia sp.	0.07	1

Species*	Density (avg. # colonies/m^2)	Count
Hydnophora microconos	0.07	1
Isopora palifera	0.07	1
Montastrea curta	0.07	1
Montipora tuberculosa	0.07	1
Pavona maldivensis	0.07	1
Pocillopora elegans PT	0.07	1
Porites lichen	0.07	1
Porites rus	0.07	1
Porites solida	0.07	1
Porites sp.	0.07	1

Notes: *Ranked by abundance; aggregate for the whole beach.
Legend: PT = ESA proposed threatened.

Figure 10 shows the cumulative representation of the coral community at Unai Lam Lam as measured by the quadrat method. As was true at Unai Chulu and Unai Babui, the most abundant species was *Goniastrea retiformis,* which makes up 23% of the coral counts at Unai Lam Lam. The first six species in Table 11 comprise 50% of the coral colonies counted in quadrats as Unai Lam Lam. The other 46 species comprise the remaining 50% of the coral colonies.

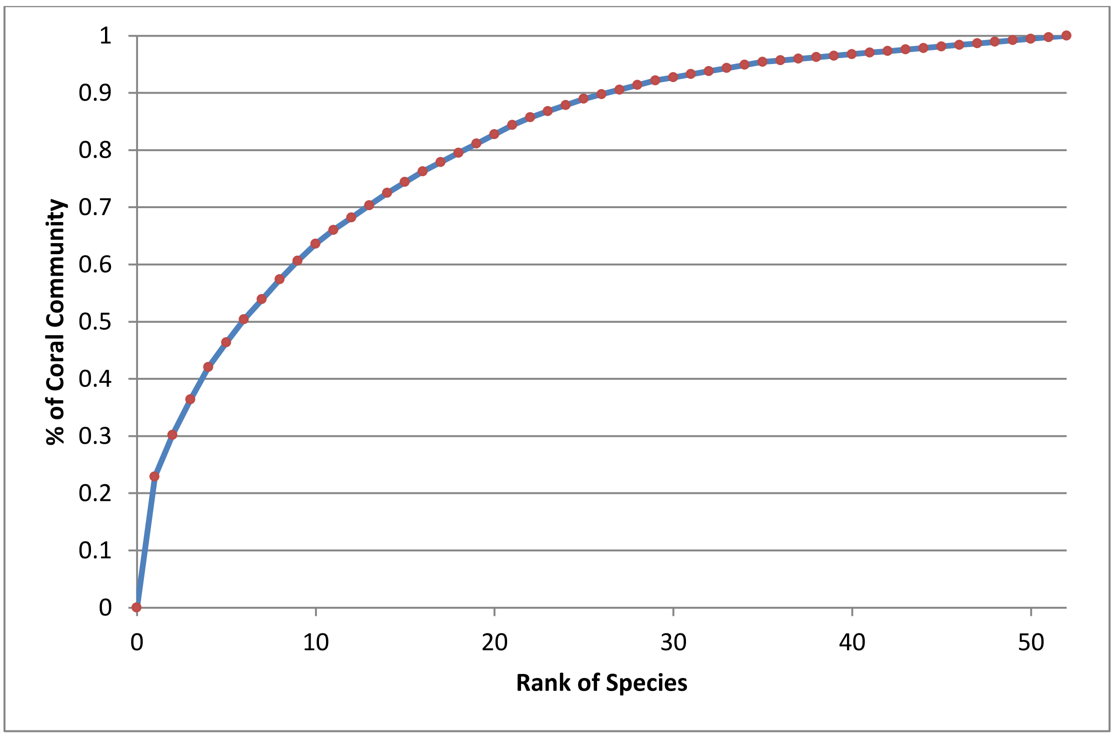


Figure 10. Unai Lam Lam Cumulative Coral Species Representation Based on Quadrat Colony Counts

Figure 11 shows the abundance of each species of coral at Unai Lam Lam as a percentage of the coral population plotted against its rank from most plentiful species to least plentiful species. The most abundant species at the far left is more abundant than the other species and does not fall close to the line as do most other species. The line of values at the right end of the graph is for all of the species for which only one colony was seen in the quadrats at Unai Lam Lam.

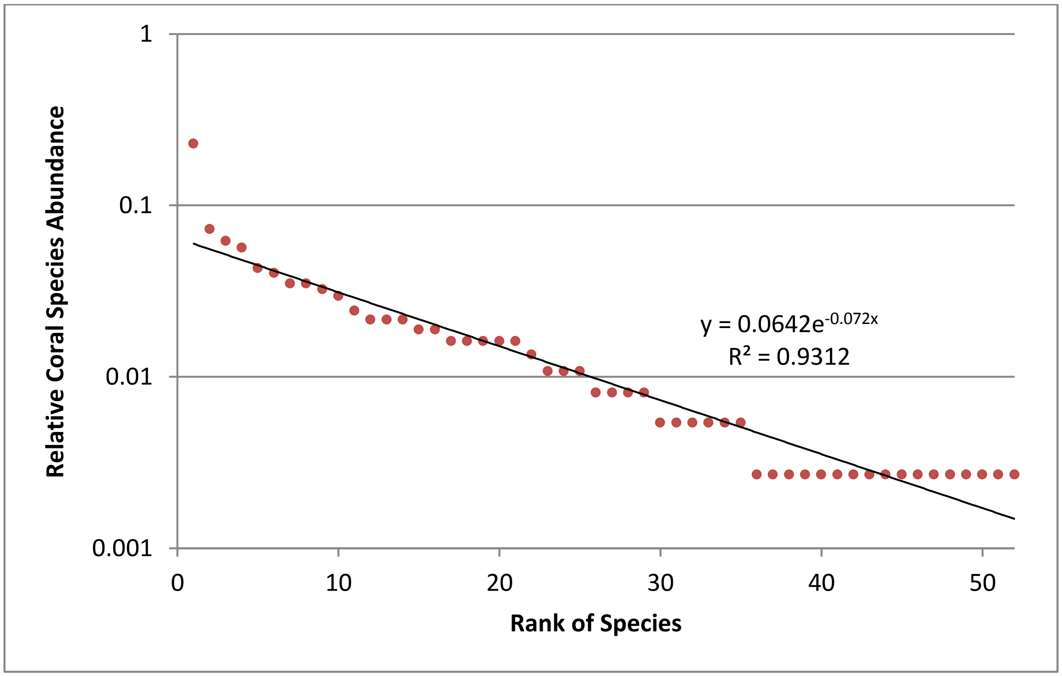
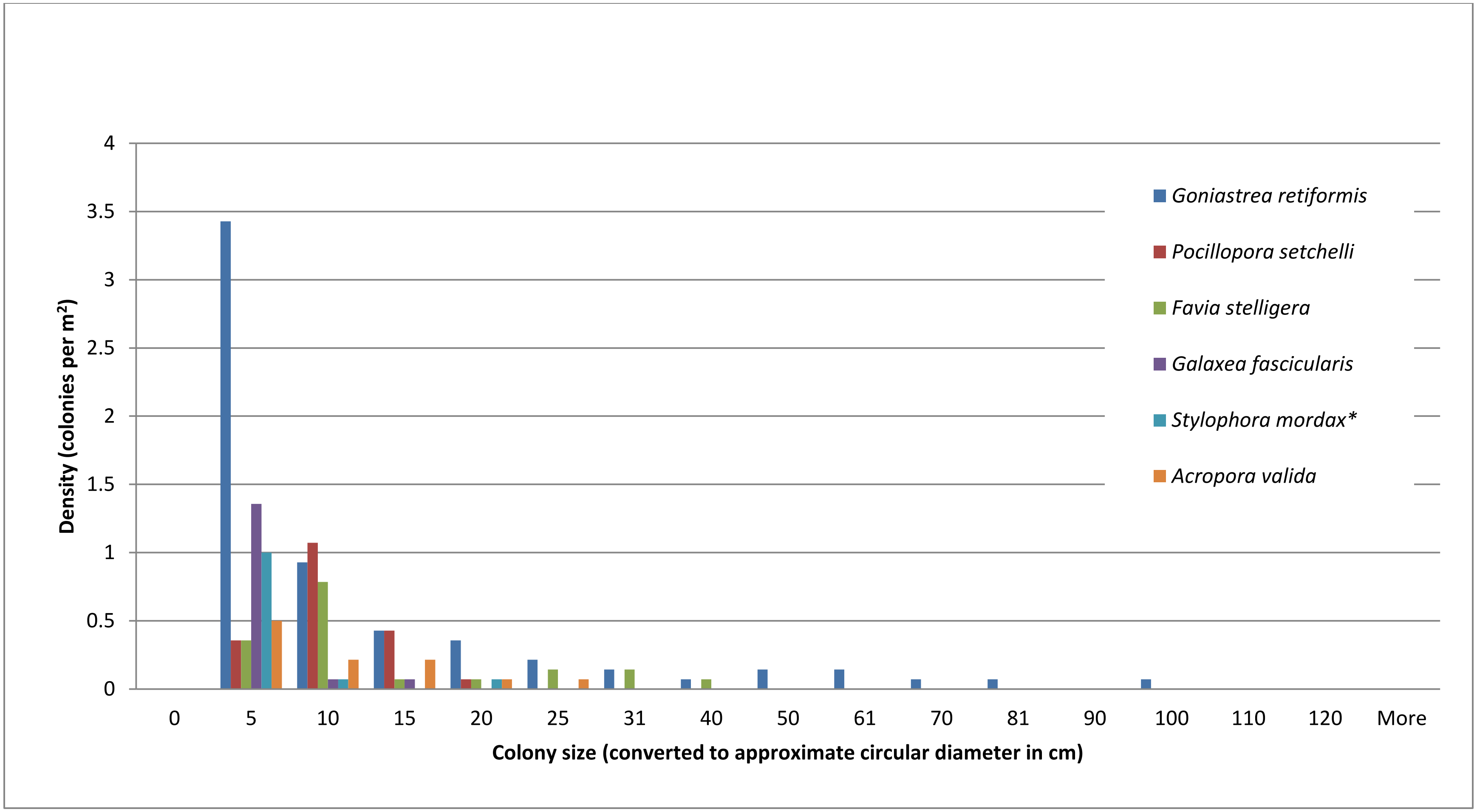


Figure 11. Unai Lam Lam Relative Abundance of Coral Species Based on Quadrat Colony Counts

Figure 12 shows the distribution of sizes for the most plentiful colonies. The most abundant corals have a very similar character to that observed at Unai Chulu, which is numerous small colonies, the vast majority of which have diameters less than 6 inches (15 centimeters).

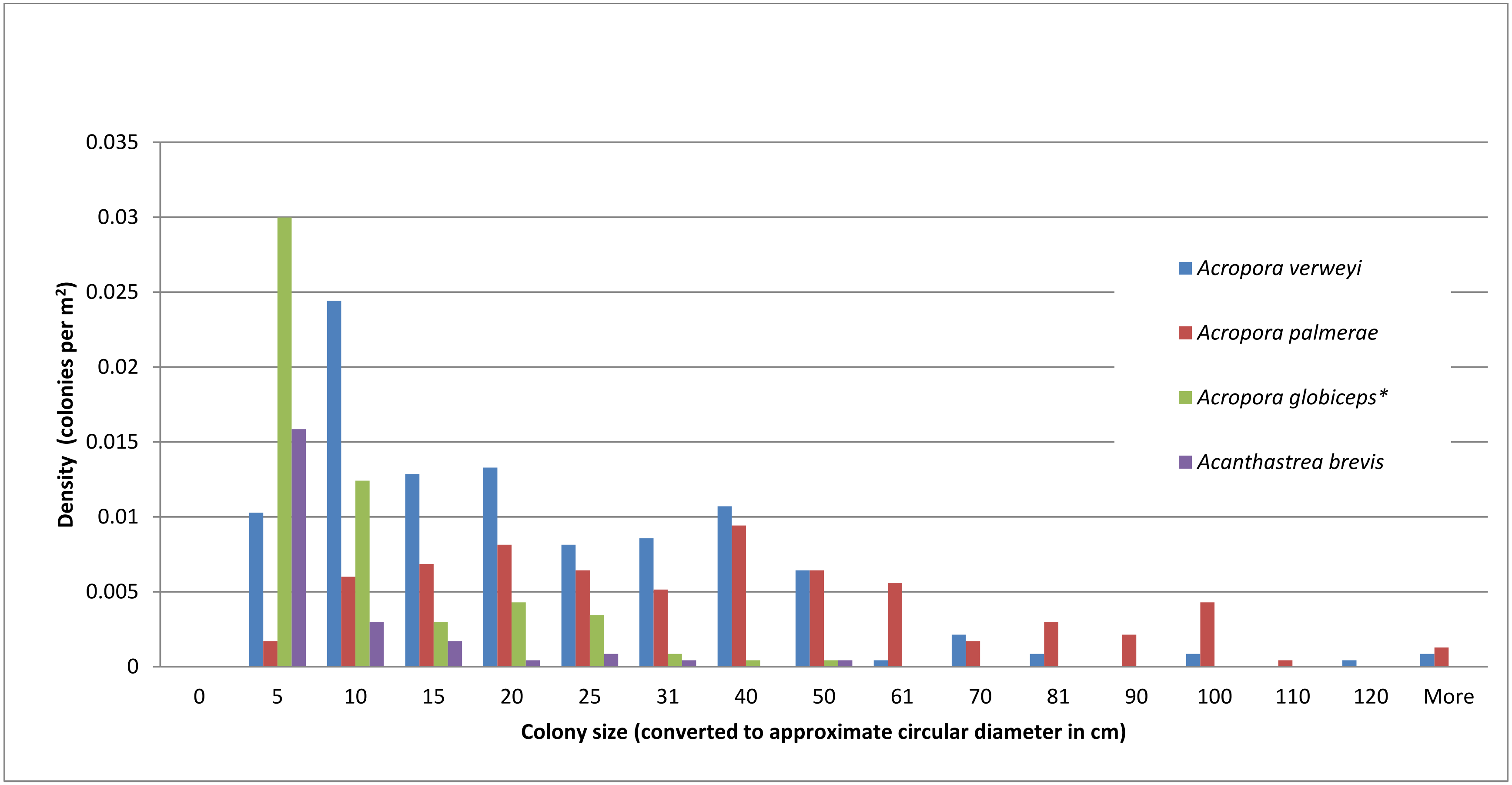
2.2.1.3.3 Special-Status Coral Species

Table 12 shows the ESA coral species at Unai Lam Lam (*Acropora globiceps*). Figure 13 shows the distribution of sizes for *Acropora globiceps* and the most plentiful previously proposed coral species that occurred in the quadrat survey method at Unai Lam Lam. Two of the species occurred at sizes that were quite a bit larger than the most abundant coral species. *Acropora palmerae*, an encrusting coral, occurs in colonies that were up to a meter or more across and the size distribution of the species has the most colonies occurring at about 16 inches (40 centimeters) in diameter. A similar size distribution for this species was observed at Unai Chulu and Babui. *Acropora verweyi* also occurred at relatively large sizes compared to the most abundant corals counted in quadrats at Unai Lam Lam. This species is a branching coral that can provide significant three dimensional local structure to a reef. It is significant that it occurs at a relatively high density (0.1 colony/m^2, Table 12) at Unai Lam Lam. It is also important to note that the larger colonies of this species would be underrepresented when applying the quadrat method, so the fact that this species ranked 26th using quadrats (Table 11) but has a higher density than *Acropora palmerae*, which has a density of 0.07 colony/m (Table 12), suggests *Acropora verweyi* is a significant contributor to the coral community and possibly to the reef structure at Unai Lam Lam.



Note: Six species make up the top 50th percentile at Unai Lam Lam.

Figure 12. Unai Lam Lam Size-Frequency Histogram of the Most Abundant Coral Species



Note: Four of seven previously proposed species in this sample have densities high enough to display on this y-axis.

Figure 13. Unai Lam Lam Size-Frequency Histogram of ESA Coral Species from All Samples

The data for Figure 13 come from all methods of coral data collection during the summer 2013 survey, because the quadrat method can potentially underrepresent infrequently occurring species and the occurrence of large individual colonies.

Table 12. Unai Lam Lam Coral Colony Densities for ESA-Proposed Threatened Species from all Surveys

Species	*Density (avg. # colonies/m^2)*	*Count*
Acropora globiceps T	0.05	128

Legend: T = threatened.

Unai Lam Lam, like Unai Chulu and Unai Babui, has patches where formerly proposed corals are dominant. In total, 128 *Acropora globiceps* coral colonies were directly recorded during the surveys at Unai Lam Lam. The most common formerly proposed species include *Acropora palmerae* and *Acropora verweyi* (DoN 2014).

2.2.1.4 Unai Masalok

2.2.1.4.1 Overview

Most of the offshore area at Unai Masalok has high topographic complexity, high coral cover (50%), and low sand cover. The reef area was physically complex, with regularly spaced grooves that were moderately deep (e.g. 12-26 feet [4-6 meters]) in the fore reef, transitioning quickly to deep fore reef that was much more topographically complex than the deep fore reef on the leeward beaches. Relatively few spurs were undercut or tunneled.

Most of the reef flat area was low topographic complexity, low coral cover (10%-30%), and low sand cover. The reef flat area was physically and biologically homogenous. The reef crest was not formally surveyed during the 2013 summer surveys because of dangerous surf conditions, but the zone appeared to have relatively high coral cover. The habitat was highly stratified among depth zones and relatively homogeneous within depth zones. Due to surf and surge, the reef crest was inaccessible at both high and low tides, on two separate days of typical weather. Most of the reef flat at Unai Masalok was lacking in numbers and variety of species and characteristic of inner reef flat habitat consequently, there are quadrats with no corals.

2.2.1.4.2 All Coral Species

Among the 113 coral species records, 108 were positively identified, including 9 ESA-proposed threatened coral species. The most abundant species was *Goniastrea retiformis*, which is not proposed for ESA listing (DoN 2014; NOAA 2014). Table 13 lists the 43 coral species identified by the quadrat survey method at Unai Masalok.

Table 13. Unai Masalok Coral Species Densities from All Quadrats

*Species**	*Density (avg. # colonies/m²)*	*Count*
Goniastrea retiformis	1.50	21
Favia matthaii	1.00	14
Acropora secale	0.64	9
Acropora surculosa	0.64	9
Galaxea fascicularis	0.57	8
Leptoria phrygia	0.50	7
Montipora sp.	0.43	6
Acanthastrea brevis	0.36	5
Acropora selago	0.36	5
Favia pallida	0.36	5
Pocillopora verrucosa	0.36	5
Porites lutea	0.36	5
Acropora globiceps T	0.29	4
Acropora valida	0.29	4
Favia stelligera	0.29	4
Leptastrea purpurea	0.29	4
Goniastrea edwardsi	0.21	3
Hydnophora microconos	0.21	3
Pocillopora ankeli	0.21	3
Acropora cf. cerealis	0.14	2
Acropora cophodactyla	0.14	2
Astreopora myriophthalma	0.14	2
Pavona chiriquensis	0.14	2
Platygyra pini	0.14	2
Acanthastrea echinata	0.07	1
Acropora digitifera	0.07	1
Acropora palmerae	0.07	1
Acropora sp.	0.07	1
Acropora tenuis	0.07	1
Acropora verweyi	0.07	1
Cyphastrea serailia	0.07	1
Favia helianthoides	0.07	1
Favia sp.	0.07	1
Favites abdita	0.07	1
Leptastrea pruinosa	0.07	1
Montastrea curta	0.07	1
Montipora tuberculosa	0.07	1
Pavona clavus	0.07	1
Pavona varians	0.07	1
Pocillopora meandrina	0.07	1
Porites rus	0.07	1
Psammocora nierstraszi	0.07	1
Turbinaria reniformis	0.07	1

Notes: *Ranked by abundance; aggregate for the whole beach.
Legend: sp. = unknown species – identified only to genus; T = Threatened.

Figure 14 shows the cumulative representation of the coral community at Unai Masalok as measured by the quadrat method. As with the other three beaches on Tinian, the most abundant species was *Goniastrea retiformis,* which makes up 14% of the coral counts at Unai Masalok. This is a smaller proportion of the coral community that was observed at Unai Chulu, Unai Babui, and Unai Lam Lam. The first eight species in Table 13 comprise 52% of the coral colonies counted in quadrats, while the other 34 species comprise the remaining 48% of the coral colonies at Unai Masalok.

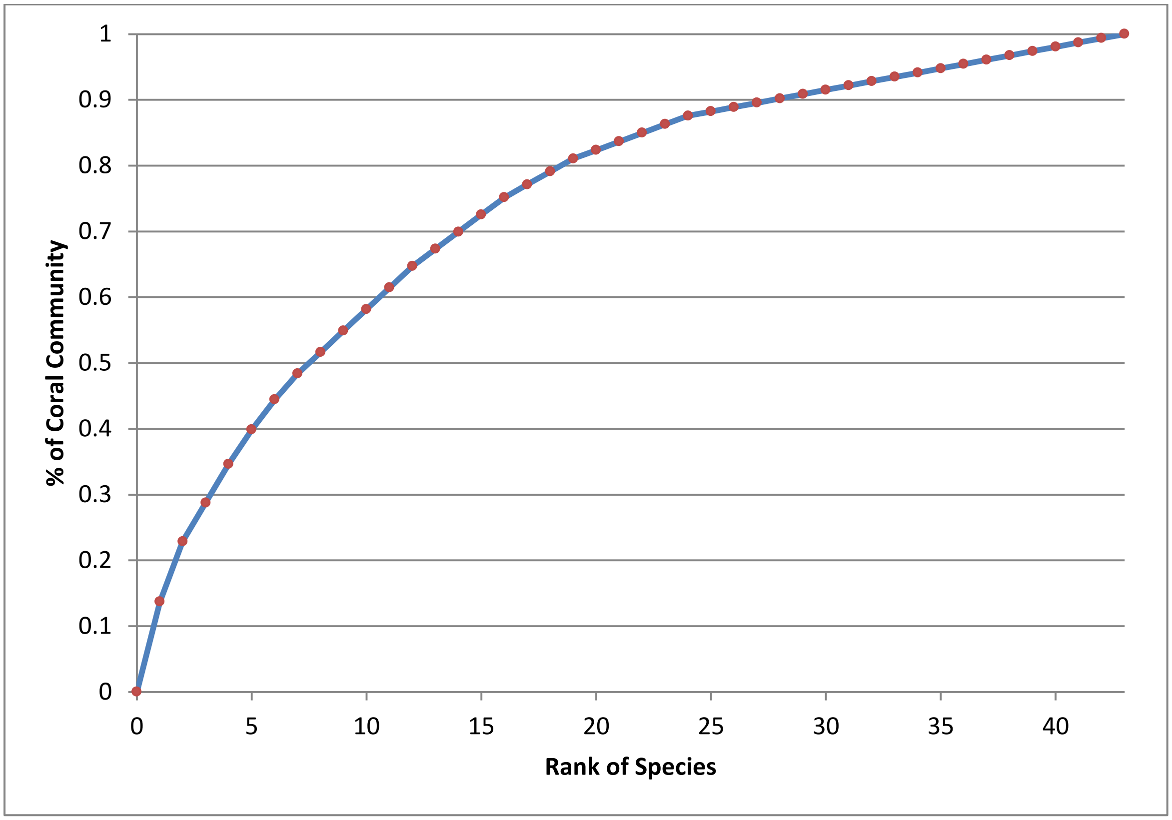


Figure 14. Unai Masalok Cumulative Coral Species Representation Based on Quadrat Colony Counts

Figure 15 shows the abundance of each species of coral at Unai Masalok as a percentage of the coral population plotted against its rank from most plentiful species to least plentiful species. The most abundant two species at the far left are clearly more abundant that the other species and do not fall close to the line as most other species do. The row of values at the right end of the graph is for all of the species for which only one colony was seen in the quadrats at Unai Masalok.

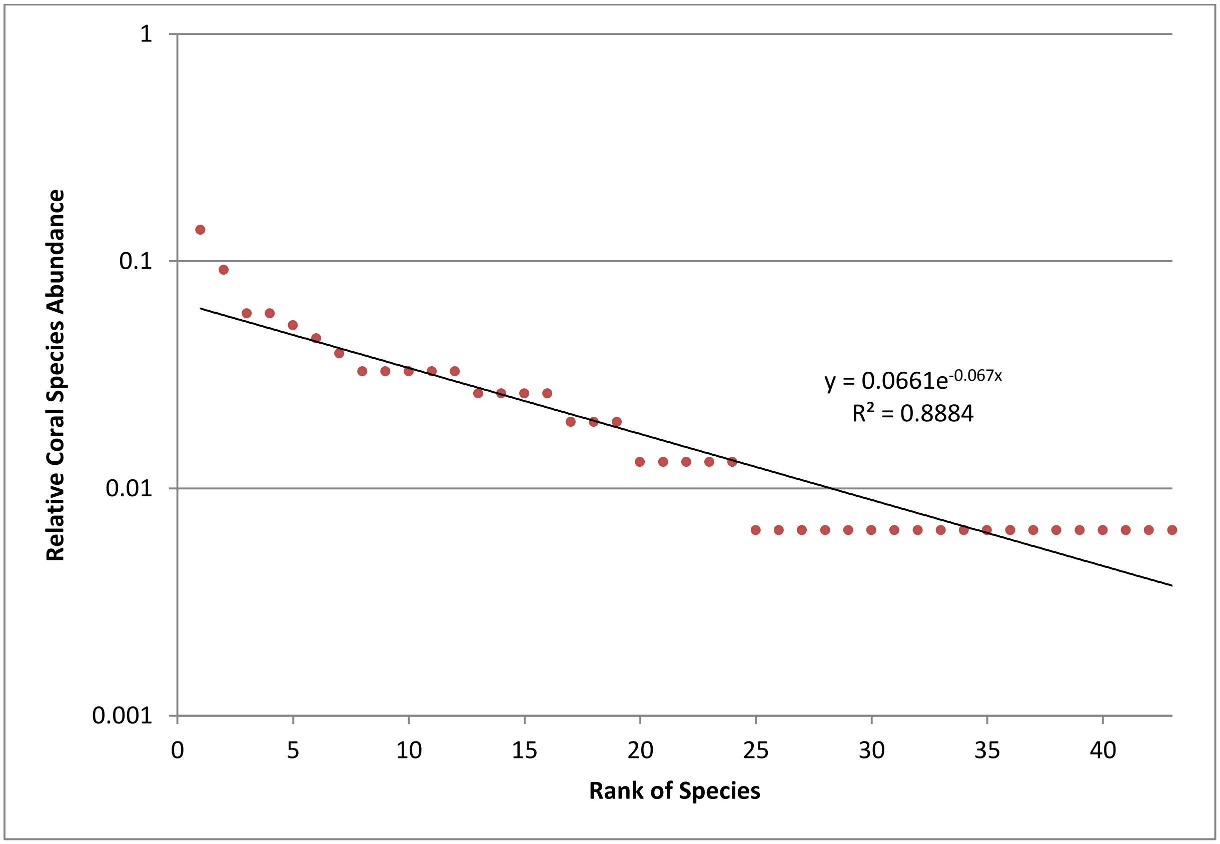
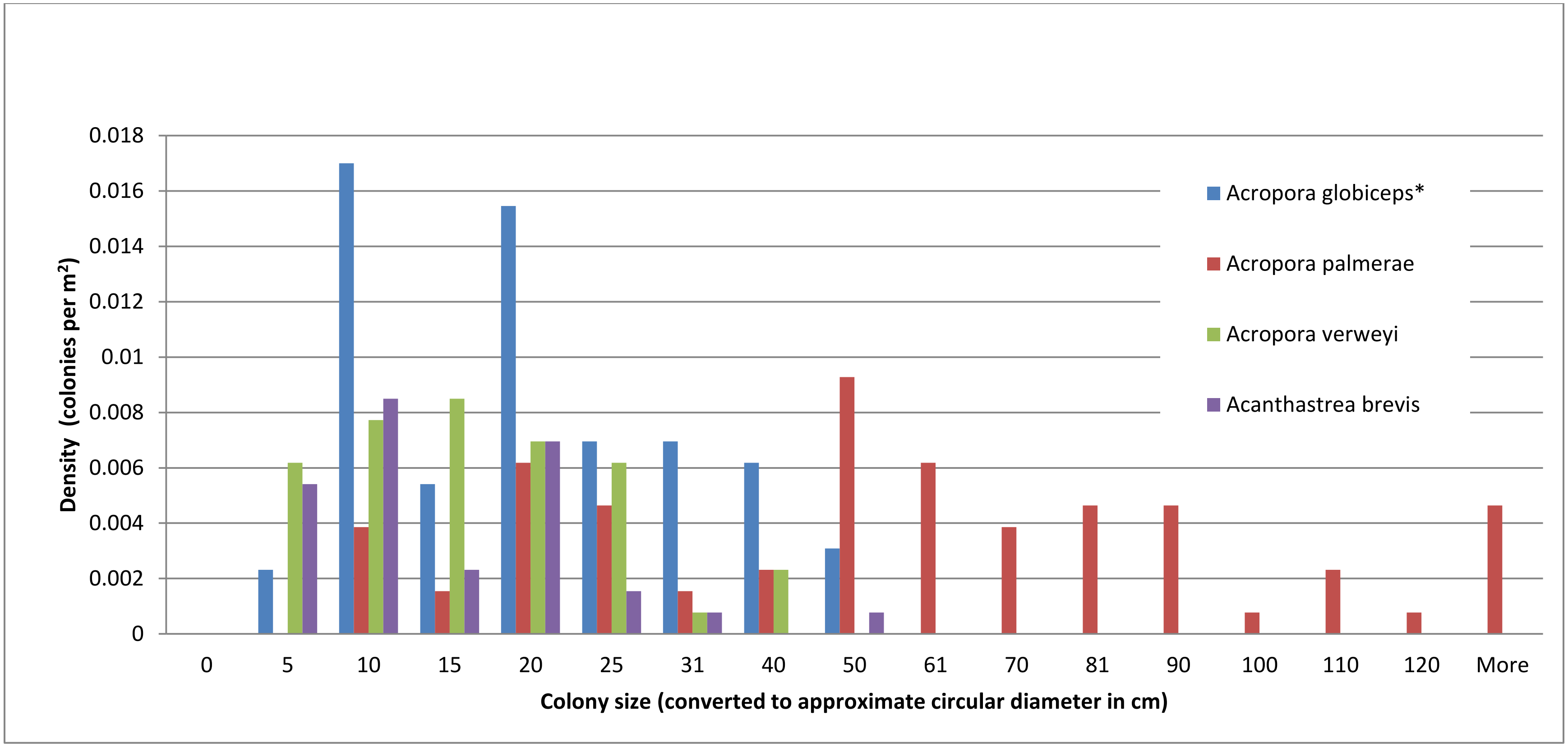


Figure 15. Unai Masalok Relative Abundance of Coral Species Based on Quadrat Colony Counts

The most abundant corals have a very similar character to that observed at the other beaches, but a number of the colonies occur at slightly larger sizes. While there is still an abundance of colonies that are in the 4 inches (10 centimeters) diameter range, there is a greater density of colonies in the 6-10 inches (15-25 centimeters) range classes. This suggests the reef at Unai Masalok may have a little bit greater coarse structure due to coral colony size than see at the other reefs. That could be because Unai Masalok is slightly protected by its position on the coast, although it is found on the windward side of Tinian.



Note: Four of eight previously proposed species in this sample have densities high enough to display on this figure.

Figure 16. Unai Masalok Size-Frequency Histogram of the Most Abundant ESA-Proposed Threatened Coral Species from all Surveys

2.2.1.4.3 Special-Status Coral Species

Table 14 shows the ESA coral species at Unai Masalok (*Acropora globiceps*). Figure 16 shows the distribution of sizes for *Acropora globiceps* and the most plentiful previously proposed coral species that occurred in the quadrat survey method at Unai Masalok. The species occurred at sizes that were quite a bit larger than 6 inches (15 centimeters). *Acropora palmerae*, an encrusting coral, occurs again in colonies that were a meter or more across. The size distribution of the species has the most colonies occurring at about 15.7 inches (50 centimeters) in diameter, which is slightly larger than the other beaches. As seen at Unai Lam Lam, *Acropora verweyi* occurred at relatively large sizes, as well. The data for Figure 16 come from all 2013 coral surveys, because the quadrat method can potentially underrepresent infrequently occurring species and the occurrence of large individual colonies.

Table 14. Unai Masalok Coral Colony Populations of ESA Species from All Surveys

Species	*Density (avg. # colonies/m^2)*	*Count*
Acropora globiceps T	0.06	82

Legend: T = Threatened.

Unlike the leeward reefs at Tinian, Unai Masalok did not have patches where ESA-proposed corals were dominant. In total, 82 *Acropora globiceps* colonies were reported. Among the most common species at Unai Masalok were *Acanthastrea brevis, Acropora globiceps*, *Acropora palmerae*, and *Acropora verweyi*. In total, only 16 ESA-proposed coral colonies were directly recorded during the surveys at the Unai Masalok reef flat (DoN 2014; NOAA 2014).

2.2.2 Pagan

Five beaches are proposed for training on Pagan. Green, Red, and Blue beaches are on the west side; North Beach is a small, isolated beach on the northern tip of the island; and South Beach is a long, crescent-shaped beach on the east (windward) side that experiences persistent wave energy due to the persistent trade winds from the east.

Suhkraj *et al.* (2010) provided much of the existing detailed information for Green, Red, and Blue beaches. They did not use identical names or boundaries for these locations, but they are near the beaches of interest for this report. The baseline data for North and Gold Beaches are limited and were not covered in Suhkraj *et al.* (2010).

Suhkraj *et al.* (2010) survey sites were not divided by reef flat and reef slope, but all of the randomly selected sites were less than 30 feet (10 meters) deep (Sukhraj et al. 2010). Coral surveys along benthic transects were conducted by coral taxonomists with considerable experience in the Mariana Islands. In addition, algae quadrats included coral identification. All coral colonies were identified to the lowest possible taxonomic level. Marianas Archipelago Reef Assessment and Monitoring Program surveys provided additional information from towed diver surveys conducted at each of the areas of interest (Brainard 2012).

Based on a review of the limited data available on Pagan coral reefs, approximately 74 species of corals may occur on Pagan reefs within the region of influence. A 2012 survey conducted by the Pacific Islands Fisheries Science Center observed 32 coral genera at Pagan, the highest genera richness among the northern islands (Brainard 2012).

A coral marine resource survey was conducted in Summer 2013 in support of the CJMT EIS/OEIS (DoN 2014). The coral survey focused on substrate shallower than 12 feet (4 meters). The benthic habitat of the beaches in the region of influence are described below.

2.2.2.1 Green Beach

2.2.2.1.1 Overview

Overall, Green Beach has low topographic complexity, low coral cover, and high sand cover. Among the 70 species recorded, 68 species were able to be positively identified, including 1 ESA-threatened coral species. There is a relatively large and contiguous area in the center of Green Beach that is especially low cover for biota and high cover for sand. The central portion of Green Beach is largely devoid of sessile biota. The visibility and apparent water quality at Green Beach was degraded relative to the other leeward beaches on Pagan, potentially from anthropogenic sources. Furthermore, the seafloor had a number of kitchen scraps including poultry and cow bones.

Green Beach has relatively large heads of *Porites* corals, one of the largest measuring 98 feet (30 meter) in circumference. These large corals were mostly across the entrance to Green Beach from north to south, though many were also growing throughout the northern and southern rocky formations. The elevation of these large *Porites* heads ranged from within inches (0.10 meter) of mean low water to well below the 12-foot (4-meter) survey limit.

2.2.2.1.2 All Coral Species

Table 15 lists all of the coral species identified in the quadrat surveys at Green Beach. Density values provide the average number of colonies per square meter of reef. The total number of species observed in the quadrat survey is 22 species.

Table 15. Green Beach Coral Species Densities from All Quadrats

Species*	***Density (avg. # colonies/m^2)***	***Count***
Favia matthaii	3.00	30
Favia pallida	1.50	15
Galaxea fascicularis	1.50	15
Acanthastrea brevis	1.00	10
Goniastrea edwardsi	1.00	10
Pocillopora meandrina	1.00	10
Acanthastrea echinata	0.90	9
Goniastrea retiformis	0.90	9
Leptoria phrygia	0.60	6
Pavona clavus	0.60	6
Pavona maldivensis	0.60	6
Gardineroseris planulata	0.50	5
Cyphastrea serailia	0.30	3
Platygyra daedalea	0.30	3
Favia favus	0.20	2
Montastrea curta	0.20	2
Pavona varians	0.20	2
Platygyra pini	0.20	2
Acropora tenuis	0.10	1
Favia stelligera	0.10	1
Pavona minuta	0.10	1
Pocillopora ankeli	0.10	1

Notes: * In order by abundance; aggregate for the whole beach.
Legend: T = threatened; sp. = unknown species – identified only to genus.

Figure 17 shows the cumulative representation of the coral community at Green Beach as measured by the quadrat method. The most abundant species was *Favia matthaii,* which makes up 20% of the coral counts at Green Beach. The first five species in Table 15 comprise 54% of the coral colonies counted in quadrats, while the other 17 species comprise the remaining 46% of the coral colonies at Green Beach.

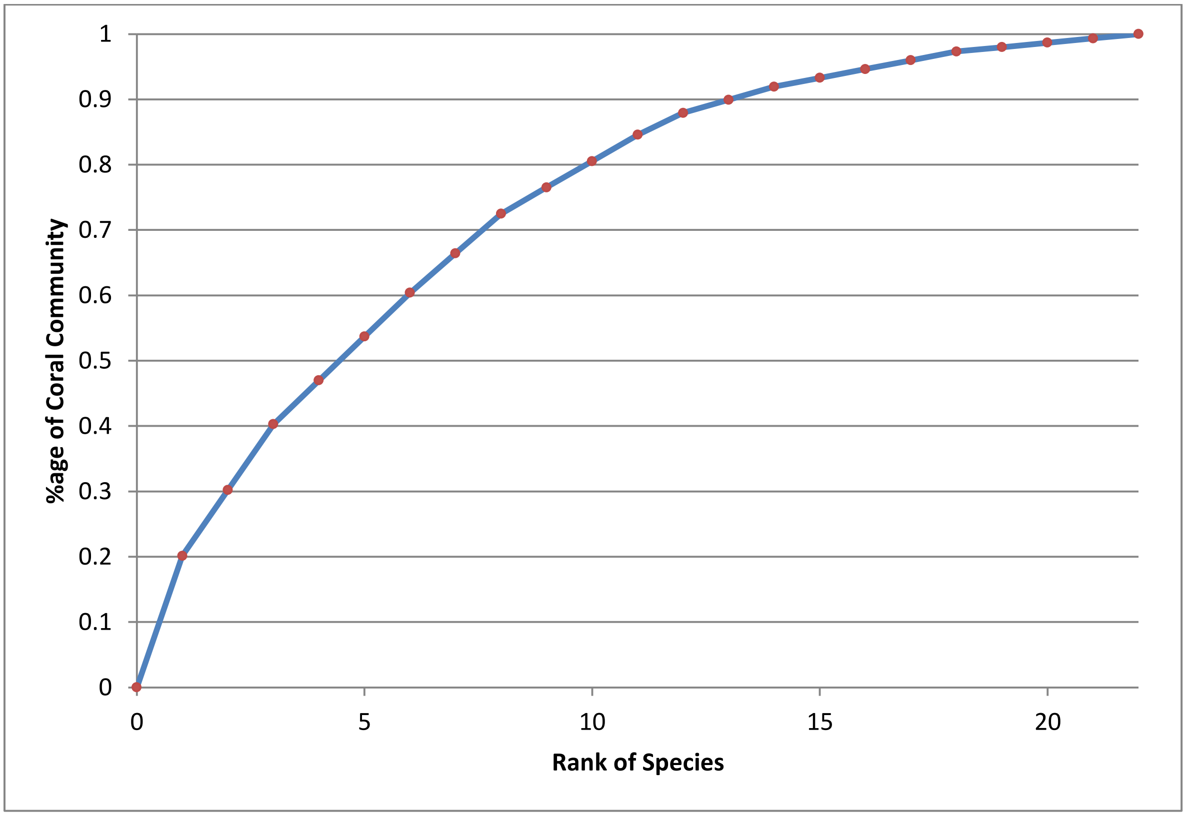


Figure 17. Green Beach Cumulative Coral Species Representation Based on Quadrat Colony Counts

Figure 18 shows the abundance of each species of coral at Green Beach as a percentage of the coral population plotted against its rank from most plentiful species to least plentiful species. Most of the species fall close to the line. The row of values at the right end of the graph is for all of the species for which only one colony was seen in the quadrats at Green Beach.

Figure 19 shows the distribution of sizes for the most plentiful colonies. There is still an abundance of colonies that are in the 2-4 inches (5-10 centimeters) diameter range and few colonies that are in the larger size classes.

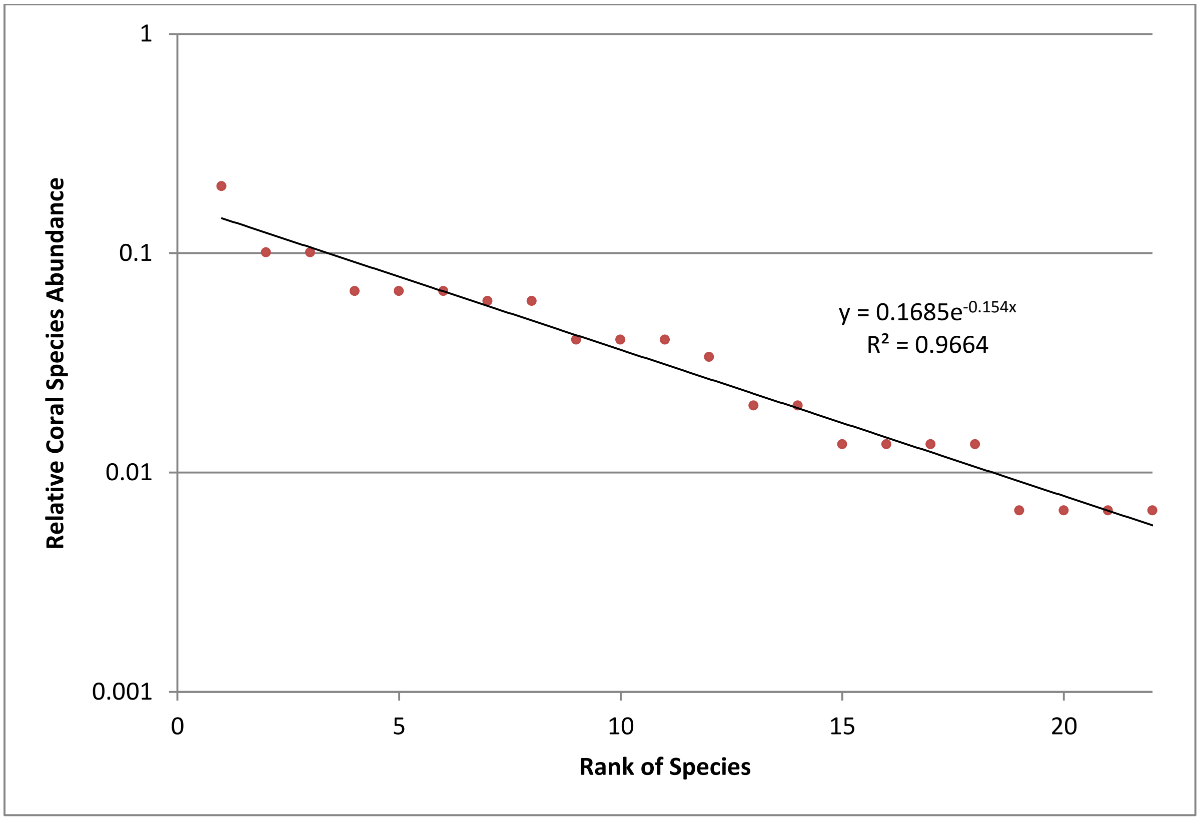
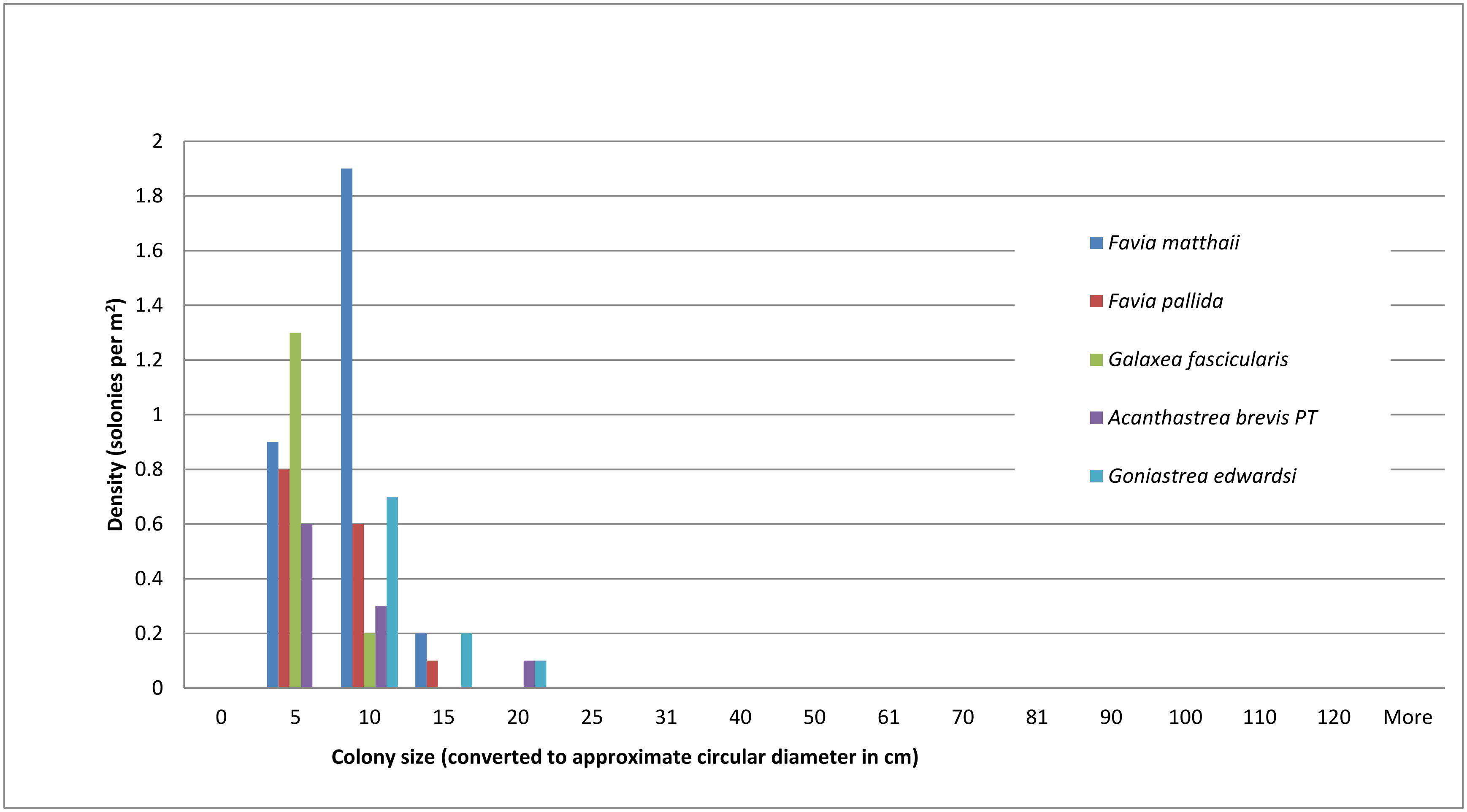


Figure 18. Green Beach Relative Abundance of Coral Species Based on Quadrat Colony Counts



Note: Five species make up the top 50th percentile at Green Beach. *Legend:* PT = ESA proposed threatened.

Figure 19. Green Beach Size-Frequency Histogram of the Most Abundant Coral Species

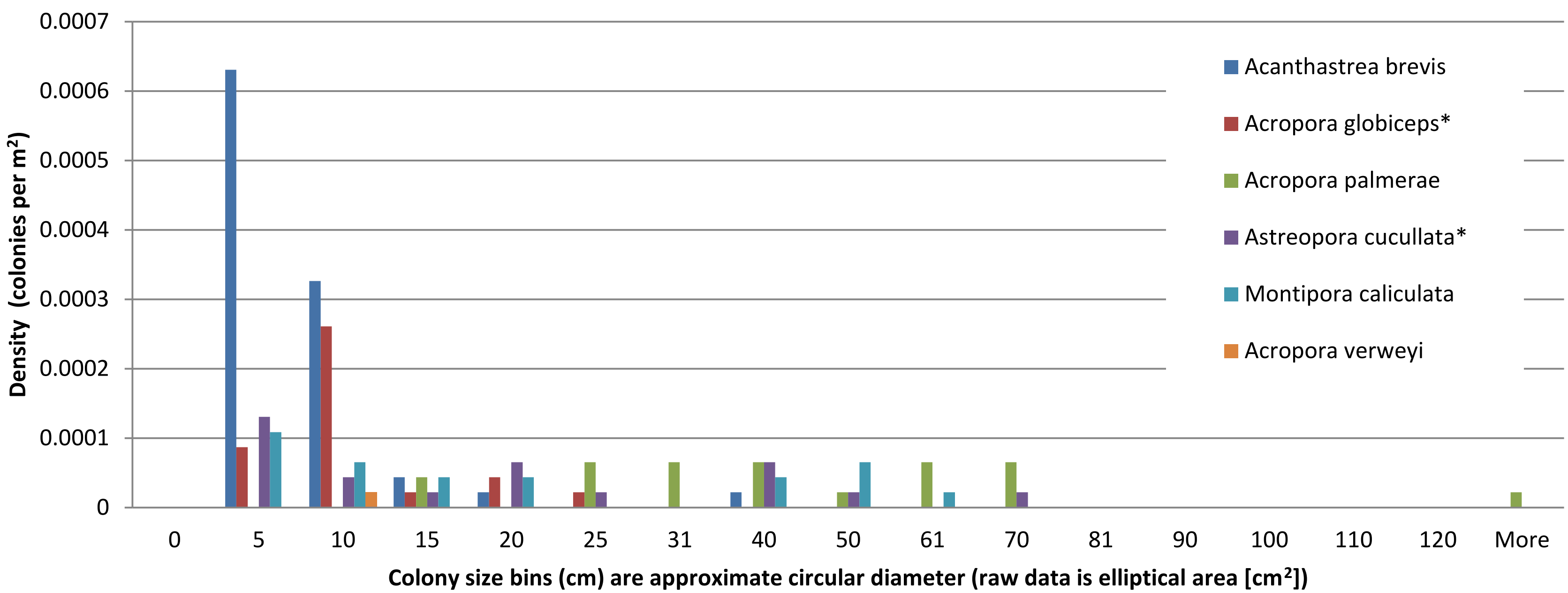
2.2.2.1.3 Special-Status Coral Species

Table 16 shows the ESA corals at Green Beach (*Acropora globiceps*). Corals at Green Beach are concentrated in the patch reefs to the north and south sides, and there were no ESA corals found in the middle of the beach shallower than 12 feet (4 meters) (DoN 2014). Figure 20 shows the size frequency distribution for ESA species. As can be seen from the figure, there is fair representation throughout all size classes, though densities are highest in the 2-4 inches (5-10 centimeters) class range.

Table 16. Green Beach Coral Colony Populations of ESA Species from All Surveys

Species	*Density*	*Count*	*Size (cm^2)*				
			Minimum	*Maximum*	*Average*	*Mode*	*Median*
Acropora globiceps	0.0004	20	8	471	106	79	79

Legend: cm^2 = square centimeter; T = threatened.



Note: All six previously proposed threatened species in this sample are displayed, though Acropora verweyi is represented by a single colony. The densities (y-axis) are two orders of magnitude smaller than all other sites.

Figure 20. Green Beach Size-Frequency Histogram of ESA Coral Species from All Surveys

2.2.2.2 Red Beach

2.2.2.2.1 Overview

Most of the area surveyed at Red Beach showed low topographic complexity, zero coral cover, and high sand cover. No ESA corals were recorded from the beachfront area shallower than 12 feet (4 meters). There were no portions of Red Beach seafloor that were high complexity and none that were moderate or high coral cover. Among the 90 coral species recorded, 84 were positively identified, including 1 ESA-threatened species (DoN 2014; NOAA 2014).

2.2.2.2.2 All Coral Species

Table 17 lists all of the coral species identified in the quadrat surveys at Red Beach. Density values provide the average number of colonies per square meter of reef. The total number of species observed in the quadrat survey is 61 species.

Table 17. Red Beach Coral Species Densities from All Quadrats

*Species**	*Density (avg. # colonies/m^2)*	*Count*
Leptastrea purpurea	3.51	151
Psammocora profundacella	1.67	72
Pavona varians	1.40	60
Favia pallida	1.35	58
Astreopora myriophthalma	1.28	55
Astreopora randalli	1.21	52
Cyphastrea serailia	0.91	39
Favia matthaii	0.84	36
Porites sp.	0.77	33
Pocillopora meandrina	0.70	30
Cyphastrea chalcidicum	0.60	26
Stylocoeniella guentheri	0.56	24
Porites solida	0.53	23
Astreopora cucullata	0.37	16
Pocillopora sp.	0.35	15
Astreopora gracilis	0.33	14
Montipora foveolata	0.26	11
Montipora verrucosa	0.23	10
Pocillopora eydouxi	0.21	9
Goniastrea edwardsi	0.19	8
Galaxea fascicularis	0.16	7
Pocillopora verrucosa	0.16	7
Astreopora elliptica	0.14	6
Leptastrea transversa	0.14	6
Pavona chiriquensis	0.14	6
Leptoseris incrustans	0.12	5
Montastrea cf. valenciennesi	0.12	5
Montipora sp.	0.12	5
Turbinaria reniformis	0.12	5
Acanthastrea brevis	0.09	4
Echinophyllia aspera	0.09	4

Table 17. Red Beach Coral Species Densities from All Quadrats

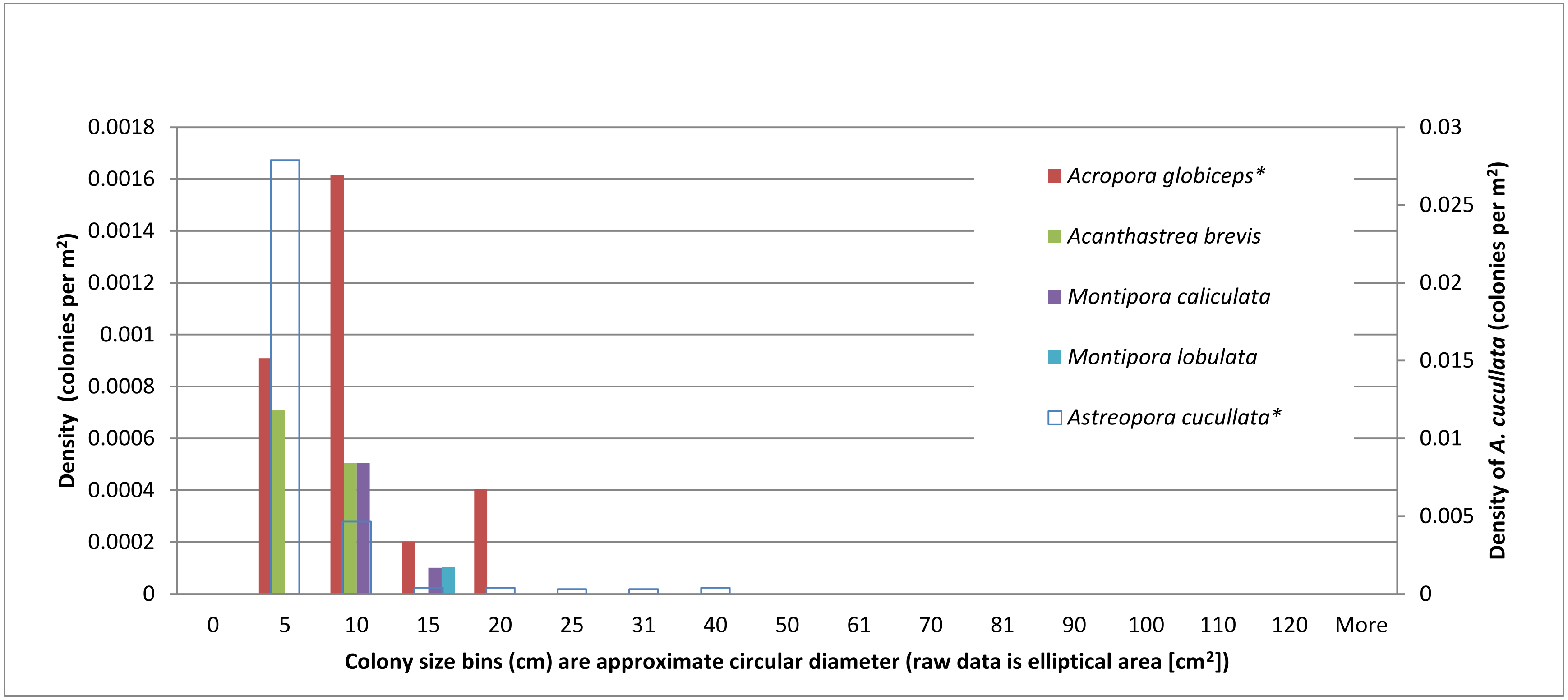
*Species**	*Density (avg. # colonies/m²)*	*Count*
Favia favus	0.09	4
Favia rotumana	0.09	4
Favia stelligera	0.07	3
Goniopora minor	0.07	3
Goniopora sp. 'long tentacles'	0.07	3
Montipora hoffmeisteri	0.07	3
Pavona venosa	0.07	3
Porites lutea	0.07	3
Acropora tenuis	0.05	2
Coscinaraea wellsi	0.05	2
Cyphastrea microphthalma	0.05	2
Goniastrea retiformis	0.05	2
Goniopora fruticosa	0.05	2
Montastrea curta	0.05	2
Platygyra pini	0.05	2
Plesiastrea versipora	0.05	2
*Acropora globiceps * T*	0.02	1
Astreopora listeri	0.02	1
Cyphastrea sp.	0.02	1
Favia sp.	0.02	1
Fungia scabra	0.02	1
Goniastrea pectinata	0.02	1
Leptoseris mycetoseroides	0.02	1
Millepora platyphylla	0.02	1
Montipora cf. planiscula	0.02	1
Montipora ehrenbergii	0.02	1
Montipora grisea	0.02	1
Pocillopora damicornis	0.02	1
Porites rus	0.02	1

Notes: *In order by abundance; aggregate for the whole beach.
Legend: sp. = unknown species – identified only to genus; T = Threatened.

The most abundant species was *Leptastrea purpurea*, which is not an ESA coral species. The coral assemblage in the shallowest 16 feet (5 meter) of the breakwater footprint was distinctly different than the deeper habitat, which is consistent with its exposure to high-energy water motion. In both shallow and deep areas, small colonies were abundant and large colonies were uncommon (DoN 2014).

2.2.2.2.3 Special-Status Coral Species

Table 18 shows the ESA coral species at Red Beach (*Acropora globiceps*). Figure 21 shows the distribution of sizes for *Acropora globiceps* and the most plentiful previously proposed coral species at Red Beach. None of these species coral species were observed directly in front of the sandy beach, at depths shallower than 12 feet (4 meters). Some of these species were observed near the headlands to the north and south, but these headlands seem unlikely to be exposed to the proposed activities (DoN 2014).



Note: All five previously proposed threatened species in this sample are displayed. Astreopora cucullata is displayed on the secondary y-axis (at right) because its abundance is approximately one order of magnitude greater than all other previously proposed coral species in this location.

Figure 21. Red Beach Size-Frequency Histogram of ESA Coral Species from All Surveys

Table 18. Red Beach Coral Colony Populations of ESA Threatened Species from All Surveys

Species*	Density	Count	Size (cm^2)				
			Minimum	Maximum	Average	Mode	Median
Acropora globiceps	0.0004	20	8	471	106	79	79

Legend: cm^2 = square centimeter; *T = threatened.*

2.2.2.3 Blue Beach

2.2.2.3.1 Overview

Blue Beach is in a semi-protected embayment on the northwest coast of Pagan and is not fronted by a shallow reef flat. Most of the area surveyed at Blue Beach has low topographic complexity, no coral cover, and high sand cover. No ESA-proposed corals were recorded from the beachfront area shallower than 12 feet (4 meters) (DoN 2014). Among the 108 coral species recorded, 103 were positively identified and include 1 ESA coral species. Blue Beach has no ESA coral colonies directly in front of the sandy beach, at depths shallower than 12 feet (4 meters). The headlands to the north and south have ESA corals (DoN 2014).

2.2.2.3.2 All Coral Species

Among the 119 coral species recorded, 96 were positively identified. The identity of 23 species could not be resolved positively beyond genus. There were no portions of the Blue Beach seafloor that were high complexity and none that were moderate or high coral cover within the survey area. The bottom substrate is coarse-grain igneous sand and cobble. Where corals occur, the dominant substrate is igneous and there is no evidence of carbonate framework buildup (DoN 2014).

2.2.2.3.3 Special-Status Coral Species

Among the 96 positively identified coral species was 1 ESA coral species. Blue Beach has zero ESA-proposed coral colonies directly in front of the sandy beach at depths shallower than 12 feet (4 meters). The headlands to the north and south have ESA-proposed corals (DoN 2014).

2.2.2.4 South Beach

2.2.2.4.1 Overview

Most of the area surveyed at South Beach had low to moderate topographic complexity, low to moderate coral cover, and low to high sand cover in various locations. The reef area was physically complex, with narrow regular groves in the shallow fore reef, transitioning rapidly to deep fore reef morphology of low-relief relict spurs punctuated by enormous massive *Porites* colonies (typically 10-20 feet [3-6 meters] diameter). Among the 101 recorded coral species, 94 were positively identified coral species, including 1 ESA coral species.

The bottom substrate is limestone, and no igneous substrate or clasts were visible. The bases of grooves shallower than 16 feet (5 meters) often had polished surfaces and polished cobble-sized clasts, indicating high-energy sediment transport and erosion. The shoreline of South Beach is a shore-attached fringing reef crest with karst characteristics (chemically weathered limestone).

Shallower than 10 feet (3 meters), the South Beach fringing reef is homogenous. An exception is the prominent sand channel running from offshore to inshore just east of the center of South Beach. This sand channel is about 330 feet (100 meters) wide and runs up to the exposed shore-attached fringing reef crest with karst characteristics.

2.2.2.4.2 All Coral Species

Table 19 shows the 66 coral species and their densities from the sampled quadrats. *Favia pallida* and *Gioniastrea retiformis* were the two most abundant species.

Table 19. South Beach Coral Species Densities from All Quadrats

*Species**	*Density*	*Count*
Favia pallida	3.70	255
Goniastrea retiformis	3.29	227
Acanthastrea brevis	2.07	143
Leptoria phrygia	2.04	141
Galaxea fascicularis	1.96	135
Favia matthaii	1.74	120
Favia stelligera	1.35	93
Pavona varians	1.23	85
Acanthastrea echinata	0.97	67
Montastrea curta	0.70	48
Platygyra pini	0.67	46
Goniastrea edwardsi	0.54	37
Porites rus	0.39	27
Pocillopora verrucosa	0.38	26
Cyphastrea microphthalma	0.33	23
Cyphastrea chalcidicum	0.30	21
Pavona chiriquensis	0.28	19
Cyphastrea serailia	0.25	17
Pocillopora meandrina	0.20	14
Favia favus	0.19	13
Pavona species 1 (high, narrow collines, tentacle tips always visible)	0.17	12
Pocillopora sp.	0.16	11
Acropora ocellata	0.09	6
Acropora surculosa	0.09	6
Leptastrea purpurea	0.09	6
Pavona clavus	0.09	6
Pavona duerdeni	0.09	6
Pocillopora eydouxi	0.09	6
Pocillopora setchelli	0.09	6
Porites solida	0.09	6
Acropora globiceps T	0.07	5
Acropora verweyi	0.07	5
Cyphastrea sp.	0.07	5
Hydnophora microconos	0.07	5
Montastrea cf. *valenciennesi*	0.07	5
Montipora sp.	0.07	5
Platygyra daedalea	0.07	5

Table 19. South Beach Coral Species Densities from All Quadrats

Species*	***Density***	***Count***
Acropora tenuis	0.06	4
Porites sp.	0.06	4
Stylocoeniella armata	0.06	4
Acropora abrotanoides	0.04	3
Favites flexuosa	0.04	3
Goniastrea sp.	0.04	3
Montipora grisea	0.04	3
Porites lutea	0.04	3
Psammocora digitata	0.04	3
Acropora palmerae	0.03	2
Acropora sp.	0.03	2
Echinopora aff. lamellosa	0.03	2
Goniopora somaliensis	0.03	2
Montipora verrucosa	0.03	2
Porites annae	0.03	2
Porites lobata	0.03	2
Stylocoeniella guentheri	0.03	2
Acropora wardii	0.01	1
Cyphastrea agassizi	0.01	1
Favites sp.	0.01	1
Gardineroseris planulata	0.01	1
Heliopora coerulea	0.01	1
Millepora tuberosa	0.01	1
Montastrea annuligera	0.01	1
Pavona maldivensis	0.01	1
Pocillopora ankeli	0.01	1
Pocillopora cf. *ligulata*	0.01	1
Pocillopora elegans	0.01	1
Scolymia australis	0.01	1

Note: *In order by abundance; aggregate for the whole beach.
Legend: sp. = unknown species – identified only to genus; T = Threatened.

Figure 22 shows the cumulative representation of the coral community at South Beach as measured by the quadrat method. The two most abundant species were *Favia pallida* and *Goniastrea retiformis*, which together make up 28% of the coral counts at South Beach. The first six species in Table 19 comprise 59% of the coral colonies counted in quadrats, while the other 60 species comprise the remaining 42% of the coral colonies at South Beach.

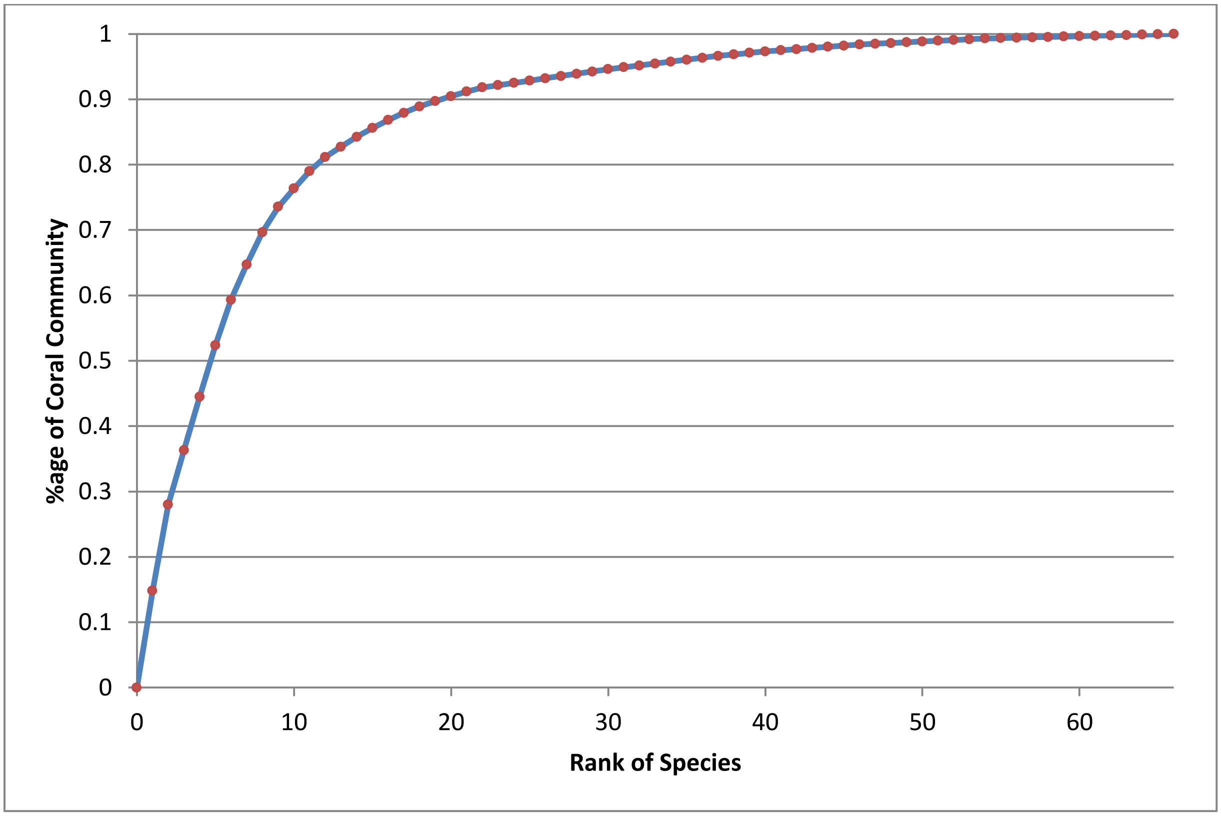


Figure 22. South Beach Cumulative Coral Species Representation Based on Quadrat Colony Counts

Figure 23 shows the abundance of each species of coral at South Beach as a percentage of the coral population plotted against its rank from most plentiful species to least plentiful species. With the exception of the most abundant species shown at the far left, the remaining species fall close to the line. The row of values at the right end of the graph is for all of the species for which only one colony was seen in the quadrats at South Beach.

Figure 24 shows the distribution of sizes for the most plentiful colonies. The majority of the colonies are within the 2-4 inches (5-10 centimeters) diameter range; however, there was a wide variety of densities into the larger colony sizes.

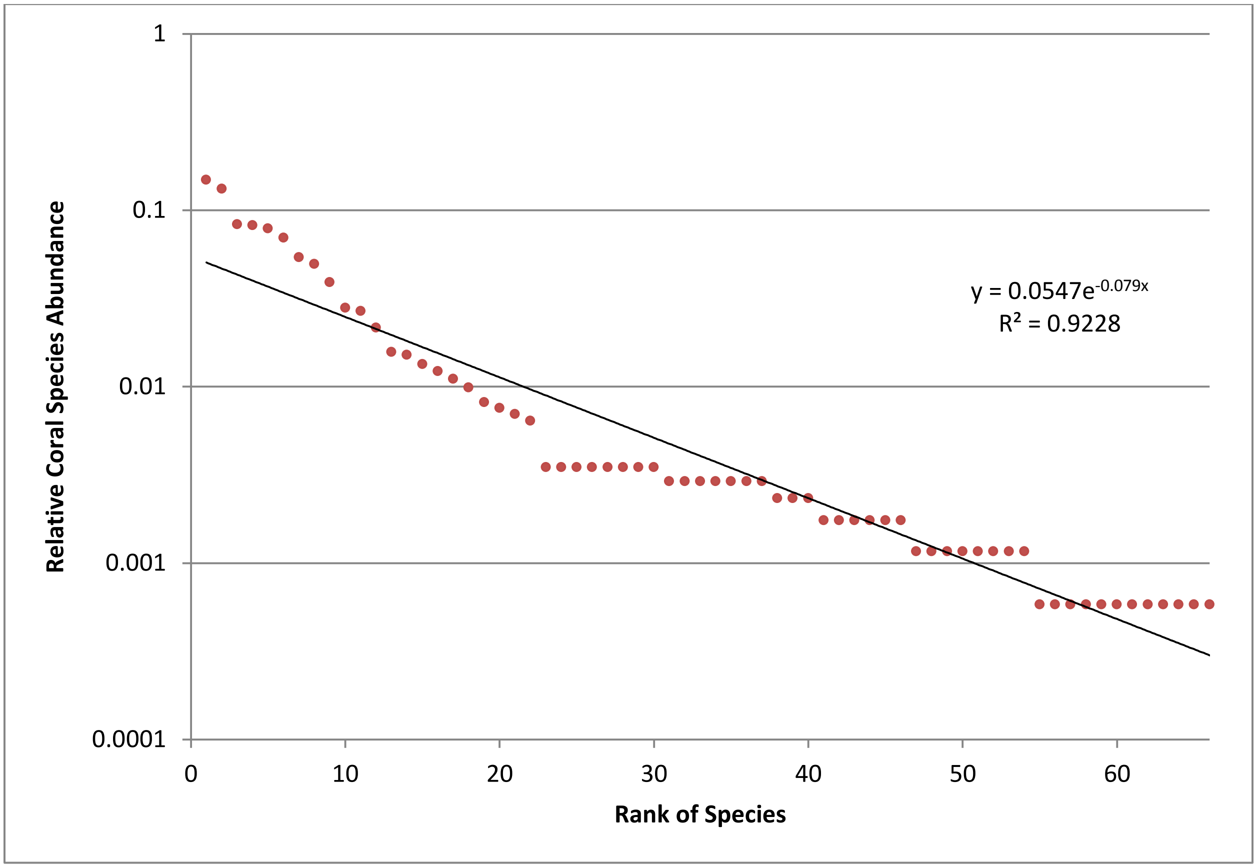
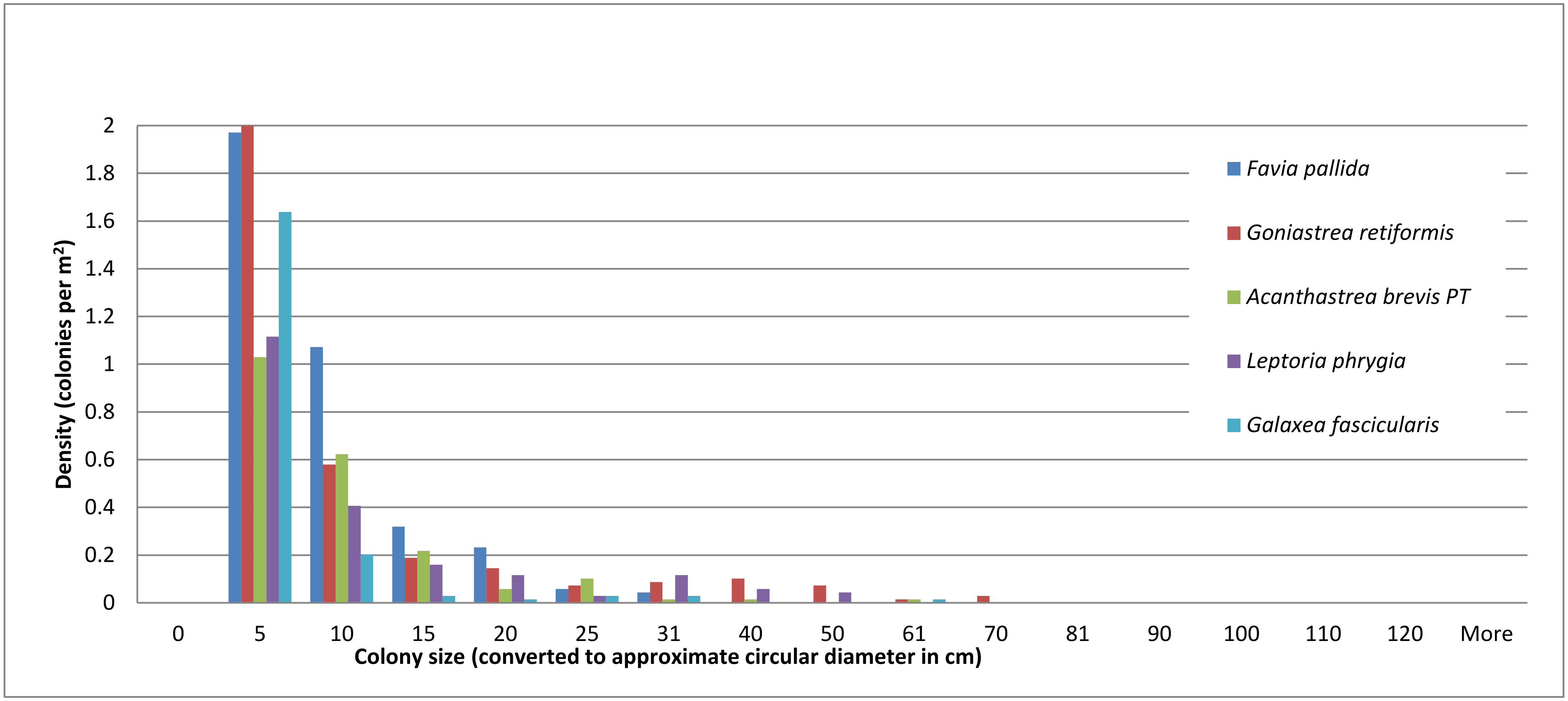


Figure 23. South Beach Relative Abundance of Coral Species Based on Quadrat Colony Counts



Note: Five species make up the top 50th percentile at South Beach. *Legend:* PT = ESA-proposed threatened.

Figure 24. South Beach Size-Frequency Histogram of the Most Abundant Coral Species

2.2.2.4.3 Special-Status Coral Species

Table 20 shows the ESA coral species at South Beach (*Acropora globiceps*). Figure 25 shows the distribution of sizes for *Acropora globiceps* and the most plentiful previously proposed coral species at South Beach. South Beach contains ESA corals in front of the sandy beach because, unlike the leeward beaches, the entire beach has a shore-attached fringing reef. As shown, densities are fairly evenly represented.

Table 20. South Beach Coral Colony Densities for ESA-Proposed Threatened Species from All Samples

Species	*Density*	*Count*	*Minimum Size (cm^2)*	*Maximum Size (cm^2)*	*Average Size (cm^2)*	*Mode Size (cm^2)*	*Median Size (cm^2)*
*Acropora globiceps**	0.07	5	39	471	196	79	79

Legend: cm^2 = square centimeter.

2.2.2.5 North Beach

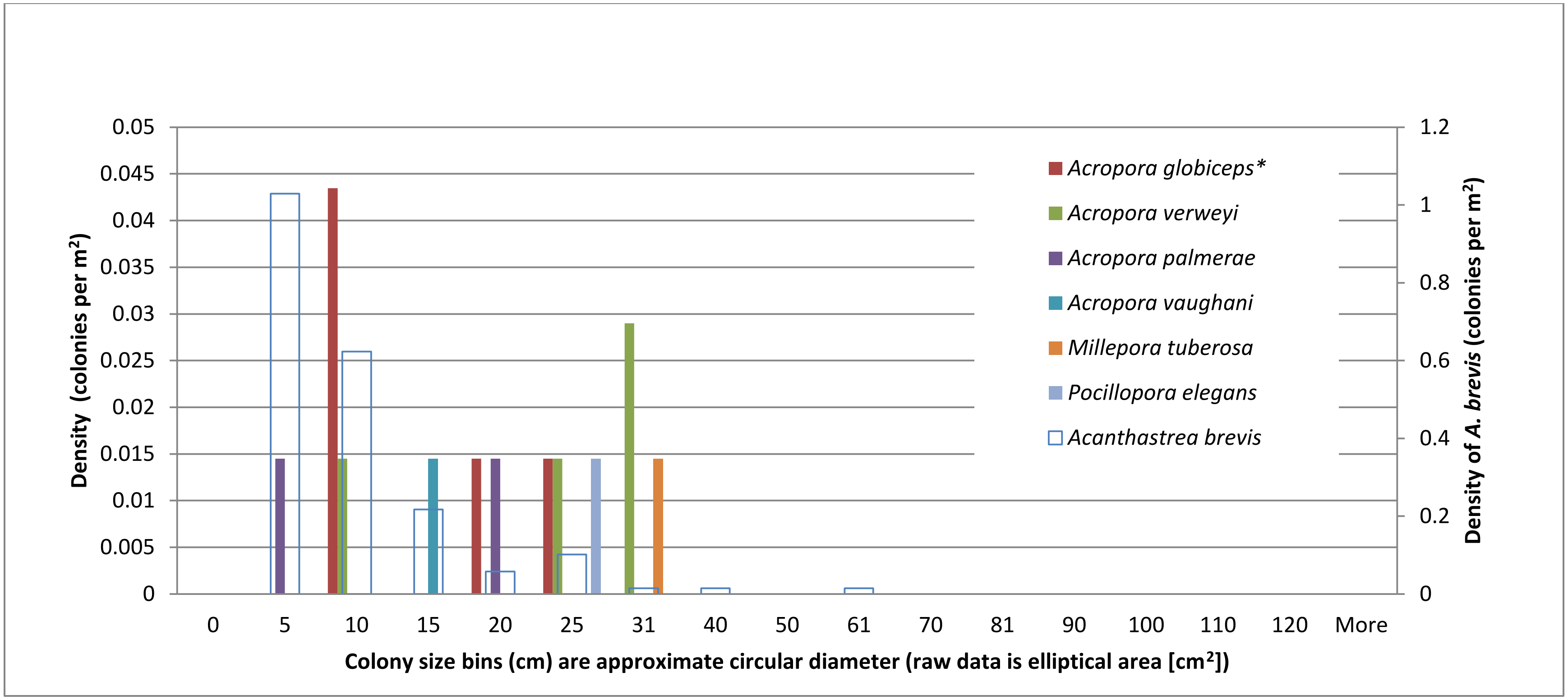
The shoreline of North Beach is a shore-attached fringing reef crest with karst characteristics (chemically-weathered limestone). Grooves are relatively regular, narrow, and deep. Other narrow grooves run diagonally to the shore-normal spur and groove pattern, and these have the physical characteristics of cracks or fissures. Many of the spurs are deeply undercut, and fracturing seems likely in this geologically active setting (Riegl and Dodge 2008). The bases of grooves often have polished surfaces indicating high-energy sediment transport and erosion.

During the summer 2013 coral marine surveys (DoN 2014), broad-scale habitat mapping, coral demographics, and ESA coral demographics were not conducted at North Beach. However, 33 coral species were recorded and 30 were positively identified, including 1 ESA coral species, based on past surveys. North Beach has a low coral assemblage relative to other sites on Pagan (DoN 2014).

2.2.2.6 Gold Beach

Gold Beach has moderate topographic complexity, high coral cover, and low or no sand cover. The reef area was highly physically complex, with deep irregular groves and fractures. The shoreline of Gold Beach is a shore-attached fringing reef crest with karst characteristics (chemically-weathered limestone). Gold Beach is located at the end of an irregularly shaped, cliff-lined cove. The bottom substrate is limestone, and away from the adjacent cliffs no igneous substrate or clasts were visible. The bases of grooves often had polished surfaces, indicating high-energy sediment transport and erosion. The cliff walls and steep fringing reef reflected incoming waves from several directions, resulting in steep and confused seas on a calm day, and dangerous standing waves on a typical condition day. This exaggerated water motion likely transports much of the sand to deeper water as would be expected. Because of these rough conditions, most survey efforts could not be safely conducted in the shallows of Gold Beach. Even on an atypically calm day, conditions shallower than 12 feet (4 meters) were too rough for surveys, and habitats shallower than 6 feet (2 meters) were inaccessible (DoN 2014).

Among the 92 coral species recorded at Gold Beach, 82 were positively identified coral species, including 1 ESA coral species.



Notes: All seven previously proposed threatened species in this sample are displayed. Acanthastrea brevis is displayed on the secondary y-axis (at right) because its abundance is approximately one order of magnitude greater than all other previously proposed coral species in this location.
*Acropora globiceps (Wallace 1999; Veron 2000) = Acropora humilis (Randall and Myers 1983).

Figure 25. South Beach Size-Frequency Histogram of ESA Coral Species from All Samples and Surveys

2.3 COMPARISON OF SURVEY DATA

2.3.1 Population Metrics Overview

Different metrics are necessary in order to draw conclusions between the various beaches surveyed and to assist in establishing baseline conditions of coral communities. Below are descriptions of species richness, the diversity index used, and species evenness. These parameters allow a more developed understanding of the coral community as a whole.

2.3.1.1 Species Richness

Species richness is the scientific term for the number of different species represented in an ecological community or region. Methods for evaluating the diversity of species at locations of concern is important because biodiversity are an important aspect of community ecology contributing to the resilience and robustness of naturally communities.

Species richness is simply a count of species; it does not take into account the abundances of the species, which is a relative measure of how plentiful individual species are.

2.3.1.2 Diversity Indices

Species richness is just one way to quantify the diversity of a community or area. A diversity index is another method for quantifying diversity that takes into account more information than just the number of species present. This statistic incorporates a measure of how common each species is into a measure of diversity. A regularly used diversity measure is the Shannon index which is represented by *H*. The statistic is calculated by: $H = -\sum_1^i p_i \, log_x p_i$, where *i* is the index of the species, p_i is the proportion of the total count of coral colonies that are represented by species *i*, and *x* is the base of the logarithm used to calculate the diversity index. For this study, the diversity values were calculated using two different logarithmic bases: base 10 ($\log_{10}$) and base e ($\log_e$) (where e = 2.718281828). These are common bases used when performing the calculations.

Since the index is calculated using logarithms, *H* can take on values from very small, such as 0.05 for a community that is virtually dominated by a single species, up to the log of the number of different species for a community that has an even representation of all species in the community. The actual value of *H* is less important than the relationship of the number to the value of *H* calculated for other communities and the maximum value possible. Since the scale that numbers are considered on is logarithmic, differences in numbers can seem small. For example, in log base 10, $\log_{10}30 = 1.477$ and $\log_{10}300 = 2.477$, so the log scale being used should be kept in mind when comparing numbers.

2.3.1.3 Species Evenness

To make the diversity measures more intuitive, another measure called evenness or equitability (represented as *J*), can be calculated that gives a sense of how evenly the species within a community are represented. The statistic is calculated by: $J = H/\log_x S$, where *H* is the diversity index, *S* is the total count of coral species, and *x* is the base of the logarithm used to calculate the diversity index. Evenness or equitability can take on values between a low 0 and a high of 1. A value of 1 represents a completely evenly distributed community.

2.3.2 Tinian

2.3.2.1 Species Richness

In the case of Tinian, species richness is considered for the coral reef community from the landward edge of the reef flat to the reef slope directly in front of the four beaches proposed for training. Methods for collecting the coral data presented in this appendix are found in the *Coral Marine Resources Survey Report* (DoN 2014). Previous surveys by Randall (1995) reported 40 genera and 141 species of coral collected on Tinian. The work done by Minton et al*.* (2009) provided detailed information for Unai Chulu, Unai Babui, and Unai Dankulo (north of Unai Masalok on the windward side of Tinian). Data are limited for Unai Lam Lam and Unai Masalok, which were not included in Minton et al. (2009).

In December 2012, the NMFS proposed the listing of 59 Indo-Pacific coral species as threatened or endangered under the ESA (NMFS 2013). Based on a review of past data, 36 species of corals that are proposed for listing under the ESA could occur on Tinian reefs in the regions of influence of the proposed action. Past surveys confirmed 11 ESA-proposed coral species (10 proposed threatened and 1 proposed endangered) on Tinian reefs in the region of influence (Minton et al. 2009).

Table 21 lists the species richness for the four proposed training beaches and Unai Dankulo (just north of Unai Masalok and not proposed for training under the proposed action) on Tinian as measured by the DoN coral surveys conducted in July 2013. The total species richness is the combined number of species identified by all methods of coral surveying conducted in 2013 (DoN 2014).

Table 21. Coral Species Richness at Tinian Beaches

	Unai Chulu	***Unai Babui***	***Unai Lam Lam***	***Unai Masalok***	***Unai Dankulo[(1)]***	***Cumulative (n=5 Sites)***
Total Species Richness[(2)]	121	107	108	113	119	164
Total Irresolvable Identification[(3)]	10	9	6	5	4	12
Total ESA-Proposed Species	8	7	7	9	11	12

Notes: [(1)]Unai Dankulo included deeper fore reef habitat than the other sites (to 66 feet [20 meters]).
[(2)]Total species richness includes all identifications.
[(3)]Irresolvable includes those identified only to genus and not species. All other identifications represent species that are positively identified, or are likely to become positive with additional field collections, taxonomic work, or definition of potential novel species.

Only 1 ESA species was identified on the reefs associated with the Tinian beaches proposed for use under the proposed action. These observations are primarily for the coral community down to 12 feet (3.6 meters) depth. More species and different species could occur on reefs at depths greater than 12 feet (3.6 meters).

The values in Table 21 indicate that the beaches on Tinian have a relatively similar number of species at all of the beaches that were surveyed. The two larger beaches, Unai Chulu and Unai Dankulo, have the highest species counts. This could be a result of the fact that the larger area provides more habitat for even a single example of a species to occur. Clearly, not all species occur at all sites, because the cumulative number of species is larger than the number of species seen at any single beach.

2.3.2.2 Diversity Index and Evenness

Shannon diversity indices and evenness values calculated from quadrat sampling performed at the proposed beaches on Tinian during the 2013 surveys (DoN 2014) are presented in Table 22. Data from the quadrat sampling method applied during these surveys were used to calculate the statistics because that sampling method was applied at every beach; therefore, the data between beaches is comparable because it was taken using a consistent method. Not all species that were observed during the summer 2013 studies were observed within quadrats, so the diversity and evenness statistics are applicable only to the data from the quadrats, but are considered representative of each beach.

Table 22. Diversity Indices and Evenness at Tinian Beaches

Beach	*# of Species*	*H'(log_e)*	*Max possible H'(log_e)*	*H'(log_{10})*	*Max possible H'(log_{10})*	*Evenness*
Unai Babui	54	3.088	3.989	1.341	1.732	0.774
Unai Chulu	68	3.159	4.220	1.372	1.833	0.749
Unai Lam Lam	52	3.201	3.951	1.390	1.716	0.810
Unai Masalok	43	3.327	3.761	1.445	1.633	0.884

The difference between diversity values in Table 22 is small. It is notable that the diversity values for Unai Lam Lam and Unai Masalok are greater than Unai Chulu and Unai Babui, even though fewer species were seen in the quadrats at Unai Lam Lam and Unai Masalok. This is because species are more evenly represented at Unai Lam Lam and Unai Masalok, as evidenced by the higher evenness values for those beaches and the fact that the calculated value of *H* comes closer to the maximum value. This result is somewhat intuitive, because a community of species will be a more robust representation of biodiversity if the species are represented more evenly instead of having a large number of species that are represented by just a few token examples.

2.3.3 Pagan

2.3.3.1 Species Richness

For Pagan, species richness is considered for the coral reef community from the landward edge of the reef flat to the reef slope directly in front of the four beaches proposed for training. The exception is a deeper section of reef area in front of Red Beach where a proposed pier and breakwater may be constructed. Table 23 lists the species richness for the four proposed training beaches at Pagan from recent surveys and past survey data. Of note is that the proposed construction area of Red Beach has the greatest species richness, and is substantially higher than the other beaches surveyed.

Table 23. Coral Species Richness at Pagan Beaches

	Green Beach	*Red Beach(1)*	*Red Beach Potential Construction Area*	*Blue Beach*	*North Beach*	*South Beach*	*Cumulative (n=7 Sites)*
Total Species Richness[2]	70	90	128	108	33	101	160
Total Irresolvable Identification[3]	2	6	11	5	3	7	11
Total ESA-Proposed Species	8	8	10	11	3	7	12

Notes: [1]Red Beach is not inclusive of the potential construction area.
[2]Total species richness includes all identifications.
[3]Irresolvable includes those identified only to genus and not species. All other identifications represent species that are positively identified, or are likely to become positive with additional field collections, taxonomic work, or definition of potential novel species.

2.3.3.2 Diversity Index and Evenness

Table 24 lists Shannon diversity values and evenness values calculated from quadrat sampling performed at the proposed beaches on Pagan. Data from the quadrat sampling method applied in the 2013 Summer surveys (DoN 2014) were used to calculate the statistics because that sampling method was applied at every beach; therefore, the data between beaches is comparable because it was taken using a consistent method. Not all species that were observed during the 2013 Summer surveys were observed within quadrats, so the diversity and evenness statistics are applicable only to the data from the quadrats, but are considered representative of each beach. North Beach and Blue Beach were not assessed with the quadrat method; therefore, diversity and evenness measures were not calculated for those beaches.

Table 24. Diversity Indices and Evenness at Pagan Beaches

Beach	*# of Species*	*H'(log_e)*	*H'(log_{10})*	*Evenness*
Green	22	2.693	1.170	0.871
Red – potential construction area shallow	9	1.824	0.792	0.830
Red – potential construction area deep	58	3.144	1.365	0.774
South	66	3.037	1.319	0.725

As was done for Tinian, the diversity values were calculated using two different logarithmic bases: base 10 (log_{10}) and the natural log (log_e). The difference in diversity values between beaches is greater on Pagan than at Tinian. This is probably because the nearshore environment is more variable in character around Pagan than Tinian and thus supports different coral assemblages. The diversity indices for the deep part of the Red Beach construction area and South Beach are similar to the beaches on Tinian, while Green Beach and the shallow part of the Red Beach construction area have much lower species richness than the Tinian beaches and therefore have lower diversity indices. Notably, the evenness of the less rich Pagan beaches is higher than the more species-rich Pagan beaches.

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3.1.2 Coral

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