

Nearshore Distribution and an Abundance Estimate for Green Sea Turtles, *Chelonia mydas*, at Rota Island, Commonwealth of the Northern Mariana Islands¹

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Abstract: Seventy-three green turtles, *Chelonia mydas* (Linnaeus, 1758), were observed in 84 sightings along 28 transects covering 67% of Rota's shoreline and outer reef perimeter in the Commonwealth of the Northern Mariana Islands. No other sea turtle species were encountered. Juvenile turtles of various sizes dominated in all surveyed environments, and observations of turtles with estimated straight carapace lengths ≤ 40 cm suggested recent and continuing recruitment at Rota. Distribution of turtles appeared temporally stable when compared with previously reported observations and data, with turtle concentrations highest along northeast, east, and southeast coasts of the island. Approximately 118 turtles were projected to inhabit nearshore habitats at Rota. Although this population may appear minor and indistinct compared with those at nearby Tinian and Saipan, continued monitoring would be useful for comparison of Mariana Islands trends. Thirty-five species of cyanophytes, algae, and a sea grass noted as green turtle forage in other world regions were identified at Rota in this and previous surveys.

THE GREEN TURTLE, *Chelonia mydas* (Linnaeus, 1758), has been reported as the principal sea turtle species in the Commonwealth of the Northern Mariana Islands (CNMI) (Wiles et al. 1989, 1990, McCoy 1997, Pultz et al. 1999, Kolinski et al. 2001, 2004, 2005). Anecdotal observations and intermittent surveys suggest that nesting greens make up a relatively small proportion of the local sea turtle population, with known numbers of

annual nests ranging to the low tens throughout the commonwealth (Pritchard 1982, Wiles et al. 1989, 1990, McCoy 1997, Pultz et al. 1999, Ilo and Manglona 2001, Kolinski et al. 2001). The preponderance of turtles in the region are found residing in nearshore reef areas of the southern arc islands (Figure 1), where identification of distributions and abundance has become critical to ascertaining turtle population status and dynamics, particularly in relation to human activities that include efforts at resource management and recovery (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998, Kolinski et al. 2001, 2004, 2005; S.P.K., unpubl. data).

In 2003, surveys of reefs throughout the Mariana Archipelago off the NOAA ship R/V *Oscar Elton Sette* included a rapid yet comprehensive assessment for turtles in nearshore marine habitats of the southernmost CNMI island, Rota. Few assessments for sea turtles in nearshore waters at Rota have been made (Wiles et al. 1990, Ilo and Manglona 2001), and published observations on turtle distributions and abundance for the island are limited (Wiles et al. 1990, Kolinski et al. 2004). Con-

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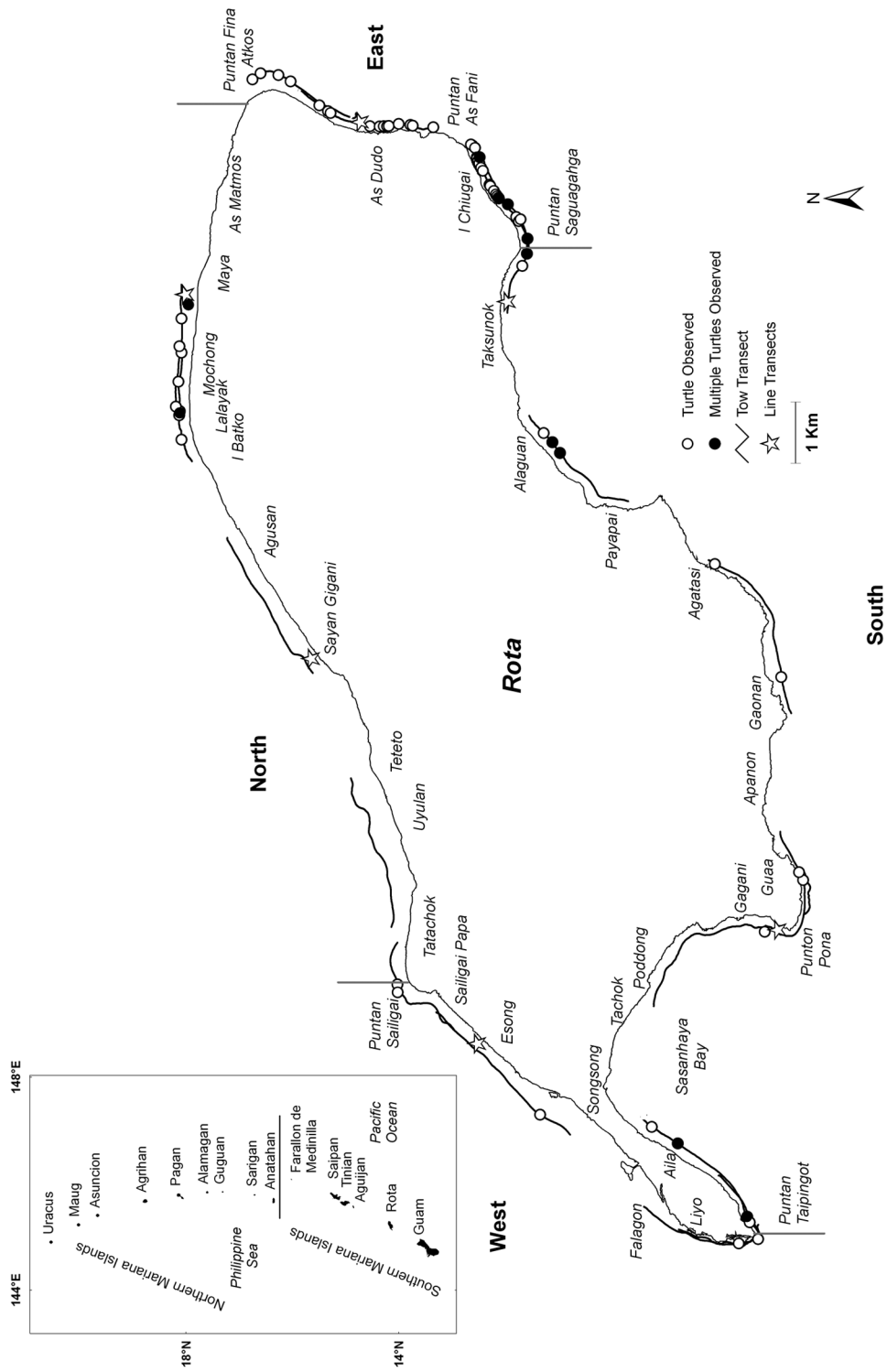


FIGURE 1. The Mariana Islands and the 2003 distribution of transects and turtles at Rota Island.

sistent with recommendations of the recovery plan for U.S. Pacific green turtle populations (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998), in this paper we present detailed information on turtle distributions, estimated size classes, projected abundance, and likely food resources for green turtles in marine habitats surrounding Rota Island.

Study Area

Rota (14° 9' N, 145° 12' E) is an 85-km² island located northeast of Guam (60 km) and southwest of Aguijan (71 km) in the southern arc of the Mariana Archipelago (Figure 1). The island consists of terraced limestone plateaus bordering two small volcanic outcrops and reaches 491 m in height (Eldredge 1983, Wells and Jenkins 1988, Wiles et al. 1990). Steep limestone cliffs, rocky shores, and intermittent benches characterize much of the eastern and southern coasts as well as the southern portion of the western peninsula. Coarse calcareous sand beaches are interspersed among rock along northern, southern, and western shores (Eldredge and Randall 1980), where sea turtle nesting has been reported as infrequent (Wiles et al. 1990, Grout 1997, McCoy 1997, Ilo and Manglona 2001). Marine habitats are diverse and include fringing reefs, shallow reef slopes, spur and groove zones, extensive pavement, boulder fields, ledges, and steep cliffs. Human development is concentrated mainly in the southwest of the island at Songsong (Figure 1). The 2000 census identified 3,283 residents (Evans et al. 2002), approximately 5% of the CNMI population. Fisheries resources at Rota are exploited by local and neighboring island residents.

MATERIALS AND METHODS

Assessments for turtles at Rota were conducted on 19 and 20 September 2003, off the NOAA ship R/V *Oscar Elton Sette*. Two survey methods were employed. Towed-diver surveys (Kenyon et al. in press) consisted of two scuba divers per boat being towed parallel to shore by each of two boats at depths

ranging from 3 to approximately 30 m. On one of the boats, when a turtle was sighted its approximate position was signaled to boat personnel via a magnetic-switch telegraph and recorded on a geographic positioning system (GPS) (Garmin 76S). On the other boat turtle positions were estimated by matching observation times with points collected every 5 sec on a GPS set to record tow tracks. Observation time, species, size (visually estimated straight carapace length [SCL] made in comparison with 1-m-wide tow-boards delineated with 10-cm markings), sex (when discernable), activity, and habitat characteristics were recorded by underwater observers. Individual tows typically lasted 1 hr and occurred at spatial intervals that allowed for characterization of all major (i.e., north, east, south, and west) coastlines (Figure 1). The second method consisted of dive surveys made between depths of 12 and 22 m by eight scientific divers who collected data on turtles while assessing fish, invertebrate, and algal communities along three 25-m transects at each of six locations around the island. The dive survey data are presented to reflect consistency in observations of turtle distributions. However, they were not included in abundance estimates because most likely were resightings of turtles counted in tow surveys that overlapped these short transects. In all surveys, benthic habitats and the water column were assessed for turtles within ranges of visibility (typically 15 to >40 m). Surface waters also were searched by support boat personnel, with pertinent information on turtle sightings (as previously described) being recorded.

Turtle maturity status was not directly measured for any individual. Visual SCL estimates were used to grossly categorize turtles as juveniles (≤ 70 cm), juvenile/adults (> 70 and ≤ 90 cm), and presumed adults (> 90 cm). The range for "presumed adults" may appear liberal but was based on the average of mean SCL nesting sizes presented for Pacific turtles by Hirth (1997), rounded to the nearest decimeter. Estimated turtle numbers were adjusted for each transect by removing resightings of the same individual based on size, distinguishing features, time, and specific locations and/or routes. Such methods are

Taksumok	9/19	1:25	Dive survey	0	0	0	0	0	0	0	0	*0.0
Alaguan to Payapai	9/19	0:56	Single tow	6	1	3	2	6	2	6	2.6	2.6
Agatasi to Gaonan	9/19	1:00	Single tow	2	2	0	0	2	0	2	0.7	0.7
Guaa to Gagani South Puntan	9/19 9/20	1:00 0:30	Single tow Single tow	1 1	1 *1	0 0	0 0	1 *1	0 0	1 *1	0.4 *1.1	0.4 *1.1
Pona West Puntan	9/19	1:26	Dive survey	0	0	0	0	0	0	0	*0.0	*0.0
Pona Puntan Pona to Poddong	9/19	1:01	Single tow	1	0	1	0	1	0	1	0.4	0.4
Ala to Puntan Taipingot	9/20	0:58	Single tow	3	3	0	0	3	0	3	1.1	1.1
Taipingot to Puntan Taipingot	9/19	0:23	Single tow	3	2	0	0	2	0	2	1.6	1.6
Subtotal West Rota		9:07		21	10	7	2	19	2	19	(Mean ± SE) 1.4 ± 0.4	1.4 ± 0.4
Puntan Taipingot to Liyo	9/19	0:38	Single tow	2	1	1	0	2	0	2	1.4	1.4
Puntan Taipingot to Falagon	9/20	0:51	Single tow	0	0	0	0	0	0	0	0.0	0.0
Songsong to Saligai Papa	9/20	1:01	Single tow	1	1	0	0	1	0	1	0.3	0.3
Esong Saligai Papa to Puntan Saligai	9/20 9/20	1:35 0:44	Dive survey Single tow	0 2	0 2	0 0	0 0	0 2	0 0	0 2	*0.0 1.4	*0.0 1.4
Subtotal		4:49		5	4	1	0	5	0	5	(Mean ± SE) 0.8 ± 0.4	0.8 ± 0.4
Totals		24:40		84	43	22	8	73	8	73	(Grand mean ± SE) 2.3 ± 0.7	2.3 ± 0.7

*, Number not included in total because likely noted in repetitive area surveys; **, transect length overlap not included in totals.

open, however, to potentially counting some individuals twice, particularly those observed at distance and lacking distinguishing features. Regional turtle abundance in Rota's nearshore waters was projected by multiplying the mean number of turtles per kilometer from surveyed transects by total kilometers in each region. Total abundance was determined using the mean of islandwide samples. No correction factor for single tows was used because the mean percentage increase in turtle numbers with double tows was zero (Kolinowski et al. 2004). Upper boundaries of 95% confidence intervals were calculated for each region as well as islandwide using *t* distributions.

Field identifications of algal and sea-grass species were conducted by P.S.V. using the algal sampling protocol described by Preskitt et al. (2004). The results were collated with those reported in the literature, and a species list of potential green turtle forage for Rota was compiled along with locations and references. Hirth (1997) and additional sources (Agastheesapillai and Thiagarajan 1979, Balazs 1980, 1985, Mortimer 1981, Mendonca 1983, Balazs et al. 1987, 1995, 2005, Burke et al. 1991, Limpus et al. 1994, 2005, Forbes 1996, Russell and Balazs 2000, Read and Limpus 2002, Seminoff et al. 2002, Calvo et al. 2003, Ferreira et al. 2003, Lopez-Mendilaharsu et al. 2003, 2005, Russell et al. 2003, Searle 2003, Andre et al. 2005, Holloway-Adkins and Ehrhart 2005, Sanchez and Quiroga 2005, Sara et al. 2005, Uzcategui et al. 2005, Makowski et al. 2006) were used for guidance in listing only those species identified as turtle forage in other parts of the world.

RESULTS

Seventy-three individual green turtles were observed via 84 sightings along 28 transects covering 67% of Rota's 51 km of outer reef perimeter (Table 1, Figure 1). No other turtle species were encountered. Fifty-nine percent (43 turtles) of the turtles were juveniles, 30% (22 turtles) were classified as juvenile/adult, and 11% (8 turtles) were categorized as presumed adults. Juveniles were the domi-

nant size class on all coastlines. Presumed adults were observed in east- and south-coast habitats (Figure 2) and included four probable females (SCL \geq 100 cm) and three males. Four turtles had estimated SCLs \leq 40 cm, suggesting relatively recent recruitment to the resident population.

Twelve percent (9 turtles) of the turtles were observed in habitats on the north side of the island, 55% (40 turtles) on the east, 26% (19 turtles) at south-coast sites, and 7% (5 turtles) along the west coast. Projected numbers and average densities of turtles for the entire perimeter of each coastal region are shown in Table 2. The average projected density of turtles on the east coast was 4.4 and 4.7 times that of the north and south coasts, respectively, and 8.3 times that of the west coast. Turtle concentrations were highest along northeastern, eastern, and southeastern shorelines from Lalayak to Alaguan (Figure 1). The total number of green turtles inhabiting Rota's nearshore environments was projected to be approximately 118, with an upper estimate of 191 (95% confidence interval) (Table 2).

The compilation of data from marine plant and algae surveys indicated the presence of at least 35 species of cyanophytes, algae, and a sea grass identified as green turtle forage in other parts of the world (Table 3). Three (9%) of the species were cyanophytes, 11 (31%) were chlorophytes, 8 (23%) were phaeophytes, 12 (34%) were rhodophytes, and one (3%) was an anthophyte. Twenty-five (71%) of the species were located at north-coast sites, 5 (14%) along the east coast (only one site surveyed), 24 (69%) on the south coast, and 25 (71%) at west-coast sites. Additional Rota genera (Tsuda 2003, this study) that may be utilized by turtles include *Calothrix*, *Microcystis*, *Avrainvillea*, *Chaetomorpha*, *Microdictyon*, *Udotea*, *Valonia*, *Dictyopteris*, *Rosenvingia*, *Amphiroa*, *Ceramium*, *Galaxaura*, *Gelidium*, *Hypoglossum*, *Laurencia*, *Liagora*, and *Polysiphonia*.

DISCUSSION

The distribution of sea turtles at Rota was similar to that described in Wiles et al.

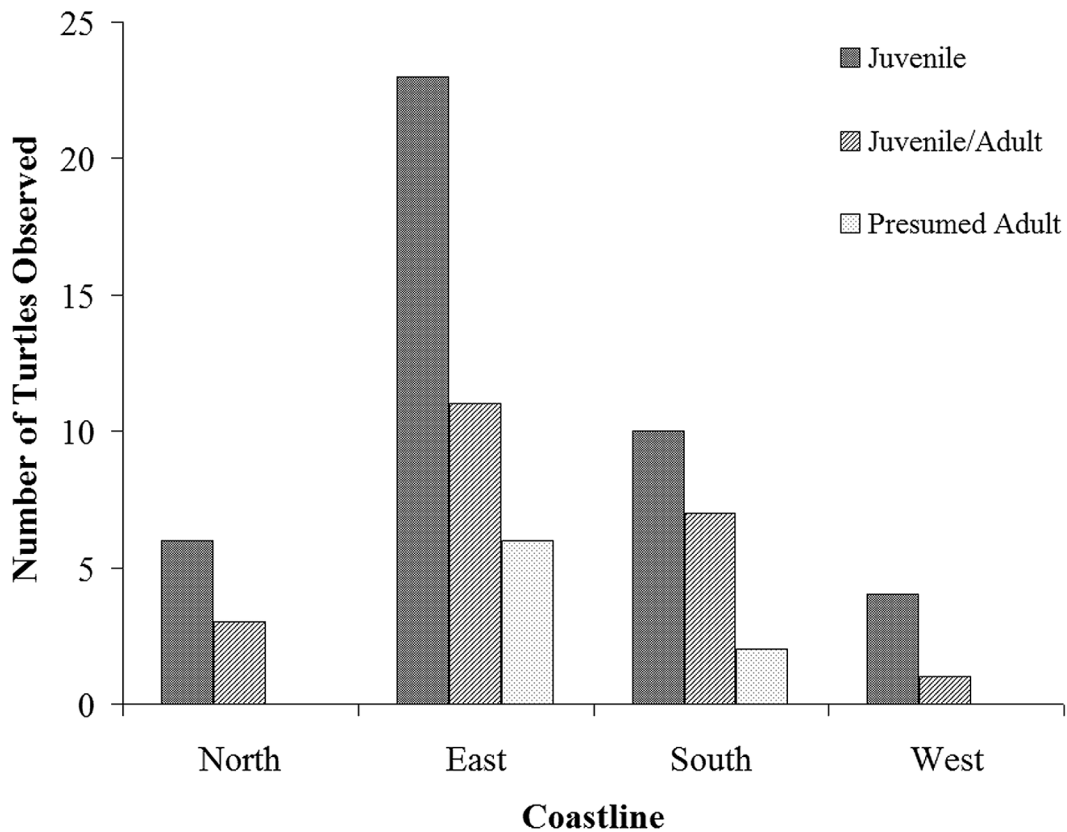


FIGURE 2. Estimated number of green turtles observed at Rota Island categorized by size and location.

TABLE 2

Projected Green Turtle Abundance by Region and Islandwide for Rota

Region	Total Perimeter (km)	Perimeter Surveyed (%)	Average No. Turtles/km (\pm SE)	Projected No. of Turtles	Upper 95% Confidence Interval Boundary
North	15.2	58.4	1.5 ± 0.8	23	54
East	6.3	82.7	6.6 ± 2.5	41	92
South	22.1	64.3	1.4 ± 0.4	32	55
West	7.7	78.7	0.8 ± 0.4	6	15
Islandwide	51.3	67.0	2.3 ± 0.7	118	191

(1990), with concentrations highest along the northeastern, eastern, and southeastern coasts of the island. Similarly, the distribution appeared consistent with observations and data provided by Ilo and Manglona (2001) in areas where survey overlap occurred. Temporal

consistency in the general distribution suggests stability in Rota's habitat availability and utilization by turtles but also may reflect illegal harvesting pressure, with limited access for poaching along trade-wind coasts. Similar distributions favoring east-coast habitats have

TABLE 3

Rota Marine Algae Listed by Hirth (1997) and Additional Sources (See Text) as Green Turtle Forage

Classification	Location and Reference
Cyanophyta	
<i>Hormothamnium entermorphoides</i> Grunow	Uyulan ⁹ , North Rota; Gaonan ¹ , Apanon, Gagani ⁸ , South Rota; Puntan Sailigai, Falagon ¹ , West Rota
<i>Microcoleus lyngbyaceus</i> (Kutzing) Anagnostidis & Komarek	Teteto area ¹ , North Rota; Gaonan, Sasanhaya Bay ¹ , Apanon ⁸ , South Rota; Puntan Sailigai ¹ , Falagon ¹ , West Rota
<i>Schizothrix calcicola</i> (C. Agardh) Gomont	Teteto area, Tatachok ¹ , Mochon-As Matmos area ⁶ , North Rota; Gaonan, Sasanhaya Bay ¹ , Apanon, Gagani ⁸ , South Rota; Puntan Sailigai ¹ , West Rota
Chlorophyta	
<i>Bryopsis pennata</i> Lamouroux	Uyulan ⁹ , Teteto area ¹ , Mochong-As Matmos area ⁶ , North Rota; West Puntan Pona ¹² , South Rota; Puntan Sailigai ¹ , West Rota
<i>Caulerpa cupressoides</i> (West) C. Agassiz	Uyulan ⁹ , North Rota; Gagani ⁸ , South Rota; Falagon ¹ , Puntan Sailigai ¹ , West Rota
<i>Caulerpa racemosa</i> (Forsskål) J. Agassiz	Tatachok ^{1,4} , Uyulan ⁹ , Teteto area ¹ , Mochong-As Matmos area ⁶ , North Rota; Apanon, Gagani ⁸ , Sasanhaya Bay ¹⁰ , South Rota; Falagon ^{1,2} , Puntan Sailigai ¹ , West Rota
<i>Caulerpa serrulata</i> (Forsskål) J. Agardh	Teteto area ¹ , Mochong-As Matmos area ⁵ , North Rota; Puntan Sailigai ¹ , West Rota
<i>Caulerpa urvilliana</i> Montagne	Sayan Gigani, Mochong ¹² , North Rota; As Dudo ¹² , East Rota; Falagon, Songsong ¹ , West Rota
<i>Chlorodesmis fastigiata</i> (C. Agardh) Ducker	Mochong-As Matmos area ⁶ , North Rota
<i>Cladophoropsis sundanensis</i> Reinbold	Tatachok ¹ , North Rota; Puntan Sailigai ¹ , West Rota
<i>Dictyosphaeria cavernosa</i> (Forsskål) Borgesen	Tatachok, Teteto area ¹ , Mochong ¹² , Mochong-As Matmos area ⁶ , North Rota; As Dudo ¹² , East Rota; Taksunok ¹² , Gaonan ¹ , Apanon ⁸ , Sasanhaya Bay ¹ , South Rota; Puntan Sailigai ¹ , West Rota
<i>Dictyosphaeria versluysii</i> Weber van Bosse	Teteto area ¹ , Sayan Gigani, Mochong ¹² , North Rota; As Dudo ¹² , East Rota; Taksunok, West Puntan Pona ¹² , South Rota; Falagon ¹ , Esong ¹² , West Rota
<i>Halimeda opuntia</i> (L.) Lamouroux	Tatachok, Teteto area ¹ , Mochong, Sayan Gigani ¹² , Mochong-As Matmos ⁶ , North Rota; As Dudo ¹² , East Rota; Sasanhaya Bay ¹ , Apanon ⁸ , South Rota
<i>Ulva lactuca</i> L.	Sasanhaya Bay ¹⁰ , South Rota
Phaeophyta	
<i>Chnoospora implexa</i> Hering	Falagon ¹ , West Rota
<i>Dictyota bartayresiana</i> Lamouroux	Teteto area ¹ , North Rota; Falagon ¹ , West Rota
<i>Dictyota friabilis</i> Setchel	Tatachok ¹ , North Rota
<i>Lobophora variegata</i> (Lamouroux) Womersley ex Oliveira	Tatachok ¹ , North Rota; Sasanhaya Bay ¹ , South Rota; Falagon, Songsong, Puntan Sailigai ¹ , West Rota
<i>Padina minor</i> Yamada	Tatachok ¹ , Mochong-As Matmos area ⁶ , North Rota; Gaonan ¹ , South Rota; Falagon ^{1,2} , West Rota
<i>Sargassum cristaefolium</i> C. Agardh (formerly <i>S. duplicatum</i>)	Sasanhaya Bay ¹ , South Rota; Songsong ⁷ , West Rota
<i>Sphaecularia tribuloides</i> Meneghini	Tatachok ¹ , North Rota; Sasanhaya Bay ¹ , South Rota; Falagon ¹ , Apanon ⁸ , West Rota
<i>Turbinaria ornata</i> (Turner) J. Agassiz	Tatachok ^{1,4} , Uyulan ⁹ , Sayan Gigani ¹² , Mochong-As Matmos area ⁶ , North Rota; As Dudo ¹² , East Rota; Apanon ⁸ , West Puntan Pona ¹² , Gagani ⁸ , Sasanhaya Bay ^{1,10} , South Rota; Esong ¹² , Puntan Sailigai ¹ , West Rota
Rhodophyta	
<i>Acanthophora spicifera</i> (Vahl) Borgesen	Uyulan ⁹ , North Rota; Gaonan ¹ , Apanon ⁸ , South Rota
<i>Botryocladia skottsbergii</i> (J. Agardh) Kylin	Mochong ¹² , North Rota
<i>Centroceras clavulatum</i> (C. Agassiz) Montagne	Tatachok ¹ , North Rota; Gaonan ¹ , Apanon ⁸ , Sasanhaya Bay ¹ , South Rota
<i>Champia parvula</i> (Agassiz) Harvey	Puntan Sailigai ¹ , West Rota
<i>Gelidium acerosa</i> (Forsskål) Feldmann & Hamel	Uyulan ⁹ , Mochong-As Matmos area ⁶ , North Rota; Apanon ⁸ , South Rota; Puntan Sailigai ¹ , West Rota

TABLE 3 (continued)

Classification	Location and Reference
<i>Gracilaria crassa</i> Harvey	Gaonan ¹ , South Rota
<i>Gracilaria salicornia</i> (C. Agardh) Dawson	Gaonan ⁵ , South Rota
<i>Hypnea musciformis</i> (Wulfen) Lamouroux	Teteto ^{1,11} , North Rota; Sasanhaya Bay ^{1,11} , South Rota; Songsong, Puntan Sailigai ^{1,11} , West Rota
<i>Hypnea pannosa</i> J. Agardh	Puntan Sailigai ¹ , West Rota
<i>Hypnea spinella</i> (C. Agardh) Kutzin	Esong ¹² , West Rota
<i>Jania capillacea</i> Harvey	Mochon-As Matmos area ⁶ , North Rota; Apanon ⁸ , South Rota
<i>Tolypocladia glomerulata</i> (Agassiz) Schmitz	Gaonan ¹ , South Rota; Falagon ¹ , West Rota
Anthophyta	
<i>Enhalus acoroides</i> (L.f) Royle	Apanon ⁸ , South Rota; Falagon ³ , West Rota

References for locations: 1, Tsuda 1969; 2, U.S. Fish and Wildlife Service 1980; 3, Eldredge and Randall 1980; 4, Ellis-Neill and Neill 1985; 5, Meneses and Abbott 1987; 6, Randall and Smith 1988; 7, Tsuda 1988; 8, Wylie 1989; 9, Randall 1997; 10, Winzler and Kelly Consulting Engineers 2002; 11, Tsuda 2003; 12, this study.

been reported for other human-inhabited CNMI southern arc islands (Kolinski et al. 2001, 2004), all of which are large in size. Long-term fidelity to nearby resting and foraging areas is known for green turtles in the Pacific (Balazs 1980, Balazs et al. 1987, Limpus et al. 1994, Musick and Limpus 1997). Although potential food resources appear on all major coasts (Table 3), food abundance and its proximity to resting habitats at Rota remain unknown. Additional studies examining habitat specificity and usage in high turtle density areas may be warranted, because identification and protection of important marine habitats is considered critical to the maintenance and recovery of sea turtle populations (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998).

The projection of 118 turtles for Rota's nearshore reefs was similar to the estimate of 92 turtles generated for 2001 (Kolinski et al. 2004) using snorkel-tow and land-based survey data (Ilo and Manglona 2001). The closeness of the estimates over the 3-yr period suggests general consistency among the methodologies as well as short-term stability in turtle abundance at Rota. Frequent long-term monitoring and estimates of uncertainty will be needed to fully elucidate stability or trends in population status (see Bjorndal et al. 2005). Confidence intervals on future abundance estimates may be gained through incorporation of distance sampling (Buckland et al. 1993) in the towed-diver monitor-

ing protocol. However, additional nearshore mapping of CNMI benthic depths will be necessary because accurate estimates on habitat area are lacking and will influence distance sampling analysis results.

United States recovery criteria for regional green turtle stocks require demonstration of statistically significant population increases in key foraging areas (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1998). Although stock identifications have yet to be made for turtles foraging in Rota and other CNMI waters, there is some question as to whether Rota is "key" with regard to turtle utilization of regional nearshore habitats. Between 1,000 and 2,000 green turtles are believed to inhabit island reef areas in the southern arc of the CNMI. Approximately 92% of these turtles are located along the coasts of Tinian (54%) and Saipan (38%). Rota habitats appear to support 6% of turtles in CNMI southern arc waters (Kolinski et al. 2004), despite an island-reef perimeter similar in size to that of neighboring Tinian. There is no conspicuous distribution differentiation based on turtle size or maturity between Rota, Tinian, and Saipan (Kolinski et al. 2004, this study). Although observations of turtles ≤ 40 cm SCL indicate relatively recent and perhaps direct recruitment of pelagic transitioning juveniles at Rota (Hirth 1997, Musick and Limpus 1997, but see Limpus and Chaloupka 1997, Zug et al. 2002, Balazs and Chaloupka 2004, Chaloupka et al. 2004), Rota's relative contri-

bution to supporting regional foraging turtles currently appears minor and indistinct.

The relevance of Rota to regional turtle monitoring may be in comparing Mariana Islands trends, because the capacity for increasing turtle numbers may be great where they are least abundant, assuming that appropriate habitat is available. Poaching in the Mariana Islands occurs (Wiles et al. 1990, McCoy 1997; Jay Gutierrez, Guam Division of Aquatic and Wildlife Resources, pers. comm.), but its influence on turtle populations remains unknown, highlighting a need for investigation and analysis. Future research should also focus on the genetic identification of green turtle stocks and the geographic extent of their dispersal (FitzSimmons et al. 1999, Kinan 2002), because foraging population demographics in the Marianas may depend primarily on impacts and processes that occur across international boundaries (Koliniski 1995, Gutierrez 2004).

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