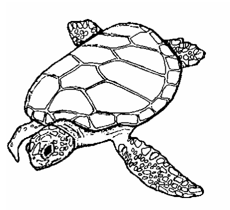
Photos by G. Myers (TNC)

Sea Turtle Biology & Conservation in the Arnavon Marine Conservation Area (AMCA) of the Solomon Islands



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September 2002

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Sea Turtle Biology & Conservation in the Arnavon Marine Conservation Area (AMCA)

EXECUTIVE SUMMARY

1. BIOLOGY OF THE TURTLES

1.1. Turtle Species.

Two species occur in the AMCA--the Critically Endangered *hawksbill (Eretmochelys imbricata)* and the Endangered *green turtle (Chelonia mydas)*. In late 1970s, ~93% of nesting turtles were hawksbills and ~7% were green turtles. The current ratio is unknown. In 1980, Vaughan estimated that the Arnavon Islands hosted approximately 27-36% of combined green turtle and hawksbill nesting in the entire Solomon Islands.

Some resident foraging hawksbills occur, but most hawksbills encountered are large or adult animals. Immature foraging green turtles are reportedly the most abundant turtles in both the AMCA region and throughout the Solomon Islands.

1.2. Regional Importance & Historical Decline.

The AMCA hosts the largest aggregation of nesting hawksbills remaining in the oceanic South Pacific. Genetic data gathered by D. Broderick indicate that hawksbills nesting in the vicinity of the AMCA constitute a unique genetic stock. Unfortunately, its numbers are much reduced, and may still be in decline. There is evidence that numbers of nesting females declined by ~50% in the 10-years from mid-1960s to mid-1970s, and by >80% in the 30-years from mid-1960s to mid-1990s.

1.3. Number of Hawksbills Nesting Annually.

In recent years, an estimated 600 egg clutches have been laid annually in the AMCA. If mortality during the nesting season is low, this represents a minimum of ~125-150 females nesting annually assuming that the average female lays 4-5 egg clutches/season. If mortality is high during the nesting season, the number of females would be greater but the outlook for the survival of the population would be worse.

1.4. Remigration Intervals & Population Size.

Few females tagged in the AMCA have been encountered during more than one nesting season. This may reflect a high rate of mortality. In recent years, however, the inter-seasonal recapture rate has increased. In the year 2000, 20%; of the 20 females encountered had been tagged in previous seasons. The remigration intervals (i.e., numbers of years separating two consecutive nesting seasons for a female) that were recorded ranged from 4 to 7 years. These long remigration intervals may partly explain the lack of inter-seasonal recaptures in the early years of the tagging programme. Unfortunately, mortality is probably also a factor because in a healthy population not subjected to high mortality the vast majority of females nesting should be experienced.

It is not possible to estimate the total size of the nesting population. But, such long remigration intervals suggest that the total nesting population may be larger than it would be if the females had shorter remigration intervals. It is possible that where the average remigration interval is longer, a smaller percentage of the total population is nesting during any one season.

1.5. Seasonal & Spatial Nesting Distribution.

Nesting Seasonality. Both green turtles and hawksbills nest year-round in the AMCA. The hawksbill nesting season peaks from May to August and again (slightly) during November to January. The peak green turtle season is reportedly September to March.

Spatial Distribution of Nesting in the AMCA. Turtles nest on four islands in the AMCA--Kerehikapo, Sikopo, Big Maleivona and Small Maleivona. In the past, some 50-65% of all recorded nesting occurred at Kerehikapo and only about 17-39% at Sikopo. In 2000, however, the proportion of turtles nesting at Sikopo increased to ~46%, while decreasing at Kerehikapo to 35%. This trend appeared to continue into the 2001 season and may be caused by erosion of the beach platform at Kerehikapo.

1.6. Turtle Migration.

Tagging data and the highly successful satellite tracking data collected in 2001-2002 indicate that female hawksbills nesting in the AMCA typically make long distance migrations to foraging grounds in Papua New Guinea and eastern and northern Australia. These long migrations, exceeding 2,000 km in some cases, are also consistent with the long remigration intervals recorded for AMCA nesting hawksbills. Genetic data gathered by Broderick indicate that most of the immature green turtles foraging in the waters of the Solomon Islands originated from distant Micronesian nesting beaches.

1.7. Growth Rates.

Preliminary data gathered by Vaughan on growth rates of immature green turtles feeding in the AMCA region indicate very slow growth -- averaging only about 0.8 cm per year.

1.8. Natural Threats to Egg Clutches.

The greatest threats to egg clutch survival include ghost crabs (*Ocypode* spp.). But since at least the year 2000 nesting season, the Purple Swamphen *(Porphyrio porphyrio)* has dug up nearly 100% of nests at Kerehikapo not protected by the COs with palm fronds. The Melanesian Megapode *(Megapodius eremita)* may also be damaging nests.

2. HISTORIC & ECONOMIC IMPORTANCE OF TURTLES

2.1. Human Threats: the Bekko Trade.

Much of the recorded population decline was caused by intense harvest of hawksbills to supply the Japanese bekko market. The hawksbill shell trade goes back to at least the 17th century. But, it became particularly intense in the Arnavon Islands in the late 1960s and early 1970s when shell from 1,000-4,000 hawksbills was exported annually to Japan from the Solomon Islands -- much of it coming from the Arnavon group. The export continued until at least 1990. The intense harvest was stimulated both by high prices paid for shell and by technological advances making it easier to catch turtles. Many reproductive females were killed. Their slaughter not only interfered with their reproduction in the year that they were killed, but it also prevented them from returning repeatedly to nest during subsequent seasons during the next 20 years of their natural life span. And not only was their own reproductive output lost to the population, but also that of the offspring they never produced.

2.2. Human Threats: Subsistence Harvest.

During 1994-96 Broderick recorded an average of ~1,068 green turtles and ~825 hawksbills harvested annually by the communities of Kia, Wagina, and Katupika combined. These turtles were taken for subsistence use only. No comparable estimates of total harvest rates have been generated in recent years.

By most accounts, although poaching still occurs in the AMCA, the situation for the turtles has improved. Nevertheless, Ramohia found evidence in 2000 that ~50 adult size hawksbills and green turtles were killed by Nikumaroro villagers, and that they may have been harvested inside the AMCA.

2.3. Protective Legislation.

Turtles are protected under the Fisheries Act. Currently the law prohibits: a) the sale and export of turtles and turtle products at all times; and b) the taking of nesting turtles or eggs during the breeding seasons--during June to August and November to January.

Such a law would be difficult to enforce in the communities. Nevertheless if the turtle populations are to survive it is critical that the harvest be kept to a minimum. To achieve this, the communities will need to decide for themselves that they want to make the necessary sacrifices to conserve their turtle populations. This end is likely to be achieved only through a programme of community awareness and education.

SEA TURTLE BIOLOGY & CONSERVATION

1. GLOBAL IMPORTANCE OF THE ARNAVON TURTLE POPULATIONS

Archeological evidence (David Steadman, pers. comm. to J. Mortimer) indicates that hundreds of years ago, sea turtles were far more abundant throughout Oceania than they are today. This is particularly true for islands with a long history of human occupation, and may well be the case for the Solomon Islands. For at least the past three decades, levels of green turtle nesting have been low in the Solomon Islands. Whether or not this is an artefact of centuries of harvest by people is unclear.

The Arnavon Islands is home to one of the world's most important rookeries for the Critically Endangered hawksbill turtle and provide vital nesting habitat for the Endangered Green Turtle. The hawksbill turtle is listed by IUCN as a Critically Endangered species based on global population declines of >80% during the past 105 years (Mortimer & Donnelly, 2002). The Arnavon hawksbill population is the largest nesting aggregation of hawksbill turtles remaining in the oceanic South Pacific (Limpus, 1997). Unfortunately, the population has been subject to intense exploitation both for meat and for the turtle shell trade, and is still under intense harvest pressure in the Arnavon area.

Since 1991, The Nature Conservancy (TNC) has helped to preserve this important nesting habitat by working with local communities and its government partners to establish the Arnavon Marine Conservation Area (AMCA), the first such area to be designated in the South Pacific.

2. BIOLOGY OF THE TURTLES

2.1. The Complicated Life Cycle of Sea Turtles

Marine turtles have complicated life cycles. During its lifetime, a turtle may travel tens of thousands of kilometres. After hatching from the egg, young green turtles and hawksbills spend their first several years living in the open sea, near the surface of very deep water, usually among floating weeds and other debris.

Once the little turtles reach ~30 cm carapace length they move into shallow water. There they feed primarily on bottom-dwelling plants and animals. These developmental feeding grounds (where young turtles grow towards adulthood) may be hundreds or even thousands of kilometres from the nesting beaches where they were born. While growing up, the young turtles may travel from one shallow water feeding area to another. Green turtles and hawksbills grow slowly. In the Indo-Pacific, they typically take 30-40 years to reach adulthood.

When the turtle finally becomes sexually mature, it returns to the same beach where it was born. After mating and laying eggs, turtles typically go off to distant feeding grounds located hundreds or thousands of kilometres away where they remain for several years until they are ready to breed again.

2.2. Growth Rates of Green Turtles in the AMCA

Data on sea turtle growth rates are difficult to obtain. But, the Arnavon Islands provides an excellent opportunity for such a study. The recommended methodology is described in this report and also in the "*Instruction Manual for Sea Turtle Monitoring in the Arnavon Marine Conservation Area (AMCA)*" (Mortimer, 2001).

Preliminary growth rate data have already been collected at Arnavon. During 1979-80 Vaughan (1981) tagged and measured juvenile green turtles foraging in the vicinity of Kerehikapo. Twenty six (26) turtles were captured on more than one occasion. For those turtles recaptured after more than 8 months, he obtained the following data:

Table 1. Green Turtle Growth Rates Recorded in the Arnavon Islands

Starting Carapace Length (cm)	Time Interval (Years)	Growth Increment (cm)	Calculated Annual Growth Rate (cm)
45.0	1.27	1.0	***0.8***
50.8	1.00	0.2	***0.2***
45.0	1.35	0	***0***
45.0	0.81	0.5	***0.6***
47.0	0.81	1.0	***1.2***
54.5	0.76	1.7	***2.2***
45.0	1.04	1.0	***1.0***
47.0	1.03	0.5	***0.5***

These data show that the immature foraging green turtles at Arnavon grow very slowly -- an average of only ***0.8 cm*** per ***year***. The carapace length of nesting female green turtles is typically greater than 100 cm.

Since 1992, the turtle monitoring programme conducted in the AMCA has continued to collect such data (Ramohia, 2000). If the COs continue this study they will not only be collecting useful data about growth rates and habitat use. They could also ***provide*** their ***communities*** with ***first hand evidence*** that sea turtles really do ***grow slowly***.

2.3. Turtle Populations Found in the AMCA

Four categories of turtle populations are found in the AMCA. These include the following:

(a) ***Breeding adult hawksbills.*** Adult male and female hawksbills mate and lay eggs seasonally within the AMCA and also in adjacent areas. Most of these turtles were probably born in the AMCA region 30-40 or more years ago. During the nesting season, when not mating and laying eggs, these turtles live underwater at the edge of the reef, often in crevices. Tag returns indicate that during the breeding season Arnavon turtles travel outside the boundaries of the AMCA. The breeding males usually continue to feed; but breeding females generally do not feed. Once they have laid all their 3-5 egg clutches, they leave the AMCA region and return to their distant feeding grounds. There they will spend the next several years fattening up (especially the females) in preparation for their next breeding season and the long swim back to the AMCA.

(b) ***Foraging hawksbills.*** For another group of hawksbills, the AMCA provides year-round foraging habitat. Most of these turtles were probably born at nesting grounds located far away from the AMCA. When they are ready to mate and lay their own eggs, most of them will migrate back to where they were born 30-40 years earlier.

(c) ***Breeding adult green turtles.*** Adult green turtles are quite rare in the AMCA. The green turtles that mate and lay eggs within the AMCA were probably also born in the AMCA region 30-40 years (or more) earlier. Once they have laid all their egg clutches for the season, they leave the AMCA and return to their regular feeding grounds (probably far away). There they will stay for several years, fattening up to prepare for another trip back to the AMCA to lay more eggs.

(d) ***Foraging green turtles.*** Immature green turtles are relatively abundant throughout the Solomon Islands (Vaughan, 1981). These immature turtles may spend many years feeding and growing up in the Solomon Islands. The genetic data (see section *2.7 Evidence for Turtle Migration*) show that most of them were born in far off Micronesia (Broderick, 1998a). When they are ready to lay their own eggs, they will probably return to Micronesia to lay their own eggs.

2.4. Nesting Seasonality

In the Arnavon islands hawksbill nesting occurs year-round, but reportedly peaks from May to August, with another rise in November through January (McKeown, 1977; Vaughan, 1981). Table 2 presents figures calculated by Vaughan (1981) to show the average seasonal distribution of nesting activity recorded by himself and McKeown at Kerehikapo during January 1976 to July 1977, and May 1979 to January 1981.

Table 2. Average Monthly Nestings Recorded at Kerehikapo during 1976-77 and 1979-81.

Month	Average nestings per month	Average nestings per day	Percent of Annual Nesting
Jan	15	0.48	8.2
Feb	12.5	0.45	6.9
Mar	10.5	0.33	5.8
Apr	10.5	0.35	5.8
May	17	0.55	9.3
Jun	21.5	0.72	11.8
Jul	23.5	0.76	12.9
Aug	18	0.58	9.9
Sep	12	0.40	6.6
Oct	12.5	0.40	6.9
Nov	15	0.50	8.2
Dec	14	0.45	7.7
Total:	182		100%

2.5. Spatial Distribution of Nesting in the AMCA

Turtles nest on four islands in the AMCA. These include: Kerehikapo, Sikopo, Big Maleivona and Small Maleivona. Since 1991, the official methodology for monitoring turtles in the AMCA during peak nesting season includes daily beach surveys at Kerehikapo and weekly surveys at each of the other islands (Ramohia, 2000). The elements of this programme are very good. But in practice, monitoring effort is sometimes uneven making interpretation of the data more difficult.

Table 3 shows the spatial distribution of nests recorded in the AMCA during surveys conducted between 1979 and 2000:

Table 3. Distribution by Island of Nests Recorded in the AMCA.

Year	Kerehikapo		Sikopo		Big Maleivona		Small Maleivona		Total Nest Sample
	# nests	% total	# nests	% total	# nests	% total	# nests	% total	
1979	39	52 %	19	25 %	17	23 %	--	--	75
1980	72	63 %	22	19 %	19	17 %	--	--	113
1991	19	65 %	5	17 %	4	14 %	1	3 %	29
1992	89	56 %	52	33 %	14	9 %	3	2 %	158
1993	105	51 %	79	39 %	18	9 %	3	1 %	205
1994	63	63 %	24	24 %	9	9 %	4	4 %	100
1995	66	54 %	35	28 %	21	17 %	1	1 %	123
2000	65	35 %	85	46 %	29	16 %	8	4 %	187
1979 - 1995		*51-65 %*		*17-39 %*		*9-23 %*		*1-4 %*	
2000		*35 %*		*46 %*		*16 %*		*4 %*	

Ramohia & Pita (1996) reported that nesting densities at Sikopo are not as high as those on Kerehikapo, and the data reflect this. During the period between 1979 and 1995, Kerehikapo accounted for 51 - 65 % of all egg clutches laid in the AMCA (see Table 3).

During my visit to the AMCA in 2001, however, my impression was that a higher proportion of nesting was occurring on the remote islands -- especially at Sikopo. This may reflect a trend that was detected by Ramohia (2000) during the 2000 season. During the year 2000, only 35% of nesting occurred at Kerehikapo, and almost half occurred at Sikopo. During my visit in 2001, during a single nesting beach survey, more than 30 old tracks were visible in sectors SI-03 and SI-04 on the southwest coast of Sikopo (Victor Tooa Tebaubau, pers. comm. to J. Mortimer). This reflects a higher concentration of nesting than what occurred at Kerehikapo during the same period.

In 2001 the condition of the nesting beach at Kerehikapo appeared to be rather degraded, while that of many of the beaches at Sikopo and Maleivona seemed to be in better condition. This may have caused the turtles to nest in greater numbers at the more remote islands. Data showing that individual turtles moved between Kerehikapo and Sikopo were reported by Ramohia and Pita (1996).

These observations reinforce the importance of monitoring the remote islands on a more regular basis than has been done at times in the past (including during the 2001 season). In the words of Ramohia (2000): *"All the islands in the Arnavon Group should be treated equally when studying nesting ground."*

2.6. Egg Clutch Survival

Predation and incidental damage to egg clutches is caused by the following:

(a) ***Ghost Crabs (Ocypode spp.)*** dug into 19% of the 341 nests examined by Vaughan at Kerehikapo island (Vaughan, 1981).

(b) ***Hermit Crabs (Coenobita spp.)*** tended to attack egg clutches near the surface and shortly after they were laid (Vaughan, 1981).

(c) ***Rats*** were reported by Vaughan (1981) to prey heavily on egg clutches at ***Sikopo***, especially in the first week after the clutch was laid.

(d) ***Birds***. Vaughan (1981) reported damage from birds only as "incidental". But during my own visit in 2001, birds did extensive damage to those egg clutches laid on Kerehikapo unless the COs covered the nests with palm fronds.

- **Purple Swamphen *(Porphyrio porphyrio)*.** In 2000, Ramohia (2001) reported that 22 nests or (11.8%) were predated by Purple Swamphen. This included 11 nests on Kerehikapo, 10 nests on Sikopo, and 1 on Maleivona. The problem seems to have worsened, because by 2001, the birds were digging up virtually every unprotected egg clutch laid on Kerehikapo island. Such damage may be a relatively new phenomenon because Vaughan (1981) did not report damage caused by this species.

- **Melanesian Megapode (*Megapodius eremita*).** Whether or not the Melanesian Megapode plays a roll in damaging turtle nests needs further investigation. But, notably Vaughan (1981) reported 3 of 341 nests on Kerehikapo to have been "dug into by nesting megapodes". In support of this assertion he also reports having excavated a hatched nest on Sikopo and finding a megapode egg amongst the turtle shell cases!

2.7. Evidence for Turtle Migration

Three types of data have been collected on AMCA turtles demonstrating long distance migration:

- Tag return data;
- Genetic data; and
- Satellite telemetry data.

2.7.1. Tag Return Data

Turtles tagged while nesting in the Arnavons have been recovered from both long and short distances away.

(a) ***Long distance recoveries*** include the following:

- Tagged nesting at Kerehikapo on 5 December 1976; Killed Fisherman's Island, Central Province, PNG, February 1979; Distance travelled ***>1,200 km;*** Time interval ≥ 3 years (Vaughan, 1981).

- Tagged foraging at Sakeman Reef, Torres Strait, Australia, on 31 March 1979; Nested 16 February 1980 at Kerehikapo; Distance travelled ***>2,200 km;*** Time interval >10 months (Vaughan, 1981).

- Other records of tagged turtles moving between their nesting ground in the Solomon Islands / Papua New Guinea region and feeding grounds in eastern Australia are shown in Figure 2 (Limpus et al., 2001).

These records indicate that many adult female hawksbills that nest in the Solomon Islands region migrate westward to foraging grounds in eastern Australia.

(b) ***Shorter distance recoveries*** include the following:

- Tagged nesting at Kerehikapo on 19 December 1976; Killed at Kia, Santa Ysabel, 3 June 1977; Distance travelled ***50 km;*** Time interval >5 months (Vaughan, 1981).

- Tagged at Wagina, on 3 February 1977; Killed on north shore of Choiseul between April and June 1979; Distance travelled ***30 km***; Time interval ≥ 2 years (Vaughan, 1981).

These shorter distance recoveries might indicate that some nesting turtles remain in the vicinity of the AMCA. More likely, however, these shorter distance recoveries involve nesting turtles killed in the vicinity of their nesting grounds during the periods between nesting emergences.

2.7.2. Genetic Data

Genetic information can be used to understand turtle migrations. The procedures used are basically the following (here highly over-simplified):

1. Identify the genetic characteristics of each nesting population in the region by analysing tissue from a representative sample of nesting turtles at each site.

2. Genetically analyse tissue from a large sample of foraging turtles in a particular area. Match the genetic characteristics of those foraging animals to the genetic characteristics of known nesting populations in the region (obtained by step 1.). This will often demonstrate from which nesting population the foraging turtles did (or did not) originate. The data can be inconclusive, however, if not enough nesting populations have been analysed.

Broderick (1998b) did a ***genetic survey*** of turtle populations in the AMCA region. He examined both nesting and foraging hawksbills and also foraging green turtles. His results indicate the following:

(a) ***Hawksbills.*** Hawksbills that nest in the vicinity of the Arnavon islands constitute a unique genetic stock that does not interbreed with other large stocks in the region (Broderick & Moritz, 1996). This means that hawksbill ***nesting*** populations in the AMCA region, if depleted, will not be colonised from other populations.

Unfortunately, the genetic data do not yet provide conclusive evidence telling us at which beach the ***foraging*** hawksbills were born (Broderick 1998b).

(b) ***Green turtles.*** Genetic analysis indicates that ***foraging*** green turtles in the AMCA come primarily from distant rookeries in ***Micronesia,*** rather than in (relatively) nearby Australia (Broderick 1998b).

No data were presented for ***nesting*** green turtles.

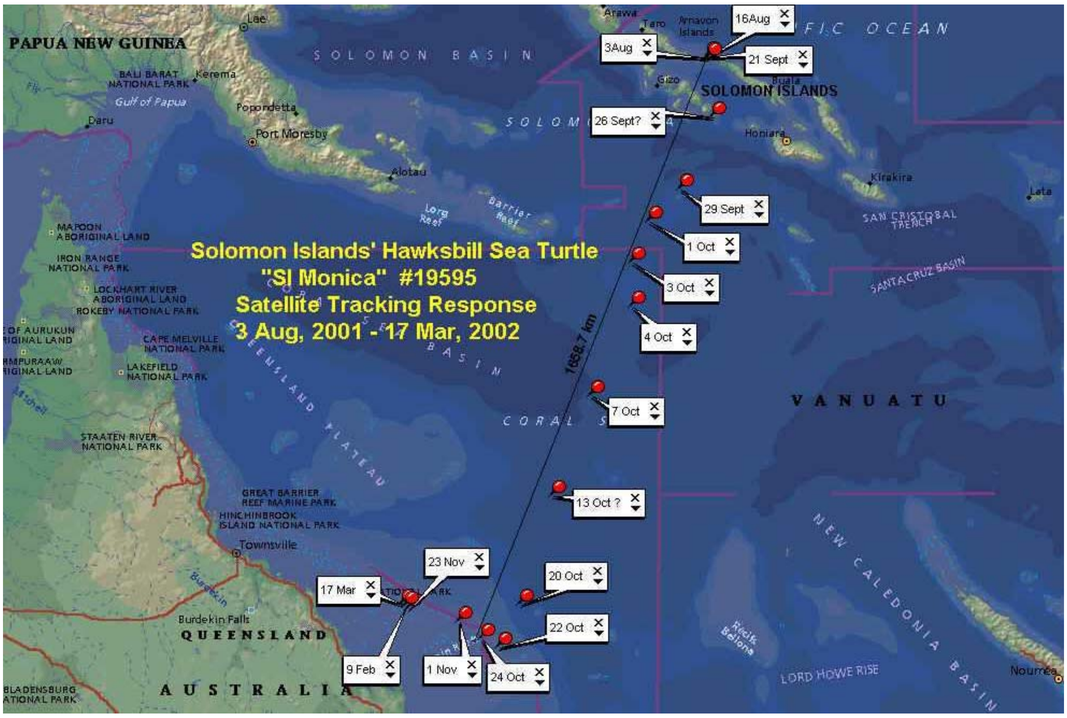
2.7.3. Satellite Tracking Data

In late July/early August 2001, two nesting female hawksbills were deployed with satellite transmitters. The tracking study was highly successful. The results are presented in Figure 1, and demonstrate the following patterns of post-nesting migration:

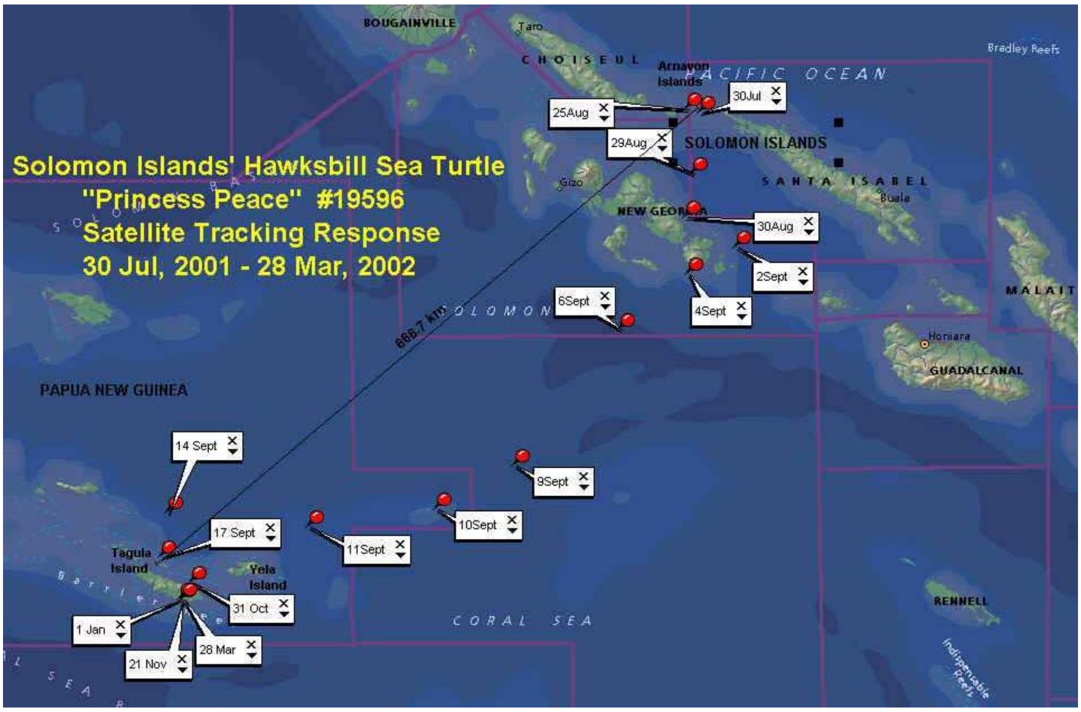
(a) ***S.I. Monica***. Travelled from Kerehikapo island to the southern end of the Great Barrier Reef in Australia. Distance travelled ***>1700 km***; Travel time interval ***33 days.***

(b) ***Princess Peace.*** Travelled from Kerehikapo island to Tagula Island in eastern Papua New Guinea. Distance travelled, ***~700-800 km***; Travel time interval ***23 days.***

Figure 1. Maps showing post nesting migrations of two hawksbills tracked from the Arnavon Islands. Maps were produced by George Myers of The Nature Conservancy (Honiara Office).



a) SI Monica. Travelled from Arnavon Islands to the southern end of the Great Barrier Reef of Australia.



b) Princess Peace. Travelled from Kerehikapo Island to Tagula Island in eastern Papua New Guinea.

2.8. Remigration Intervals

2.8.1. Interval Length

The "Remigration Interval" is the number of years separating two consecutive nesting seasons of an individual turtle. Ramohia and Pita (1996) reported that by 1996, although 146 nesting hawksbills had been tagged in the Arnavon group during the previous five nesting seasons, no inter-seasonal recaptures had been recorded. Ramohia and Pita expressed concern that this reflected high mortality of nesting turtles from hunting pressure in areas adjacent to the AMCA.

During the year ***2000*** nesting season, however, Ramohia (2000) reported that at least ***four*** (i.e., ***20%***) of 20 turtles intercepted at Kerehikapo had been tagged during previous seasons. For these four turtles, the following remigration intervals were recorded:

a) ***7 years***. Nesting turtle tagged in 1993, returned to nest in 2000.
b) ***5 years***. Nesting turtle tagged in 1995, returned to nest in 2000.
c) ***4 (?) years***. Two nesting turtles probably tagged in 1996, returned to nest in 2000.

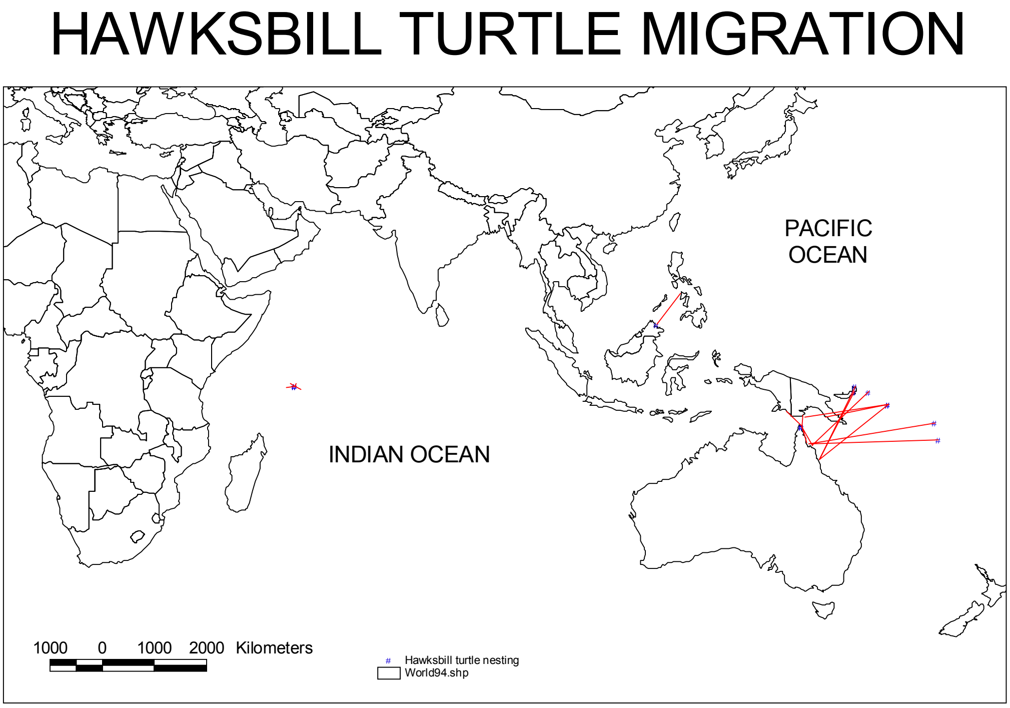
During my visit in 2001 another nesting turtle was re-captured after an interval ***>5 years*** (Ramohia, pers. comm. to J. Mortimer). These data suggest that ***long*** remigration ***intervals*** may be ***typical*** for the Arnavon population.

2.8.1. Relationship between Distances Travelled & Interval Length

Data gathered from a number of nesting populations around the world suggest that greater distance travelled between nesting and foraging habitats correlates with longer remigration intervals. Data collected in the Arnavon Islands reflect this correlation. Long distance migrations >1000 km between nesting and feeding grounds appear to be typical for the Arnavon hawksbill nesting population (see section *2.7. Evidence for Turtle Migration*). It follows that long remigration intervals (4 to 7 years) would be consistent with such long distance migrations.

In contrast, the predominant remigration interval recorded for hawksbill turtles nesting in Seychelles is only two to three years (2-3 yrs) (Mortimer & Bresson, 1999); and satellite tracking has demonstrated that post-nesting migration is typically <200 km (Mortimer & Balazs, 2000). Figure 2 compares migrations recorded for hawksbills in Seychelles with those recorded in the region of Australia-Solomon Islands.

Figure 2. Patterns of hawkbill migration recorded in the Indian Ocean and western Pacific (from Limpus et al., 2001).



2.9. How Many Turtles are There?

2.9.1. In the Solomon Islands

In 1979-80, Peter Vaughn (1981) did a survey of the turtles of the Solomon Islands. He visited Santa Ysabel, Choiseul, New Georgia, Shortlands, and Makira. (No surveys were conducted in Guadalcanal, Malaita, and Eastern Outer Islands.)

He found low density turtle nesting throughout the country. Table 4 summarises all the results of his survey. His major findings were the following:

(a) Santa Ysabel and Choiseul (***hawksbills*** and ***green turtles*** combined)

- Total approximately ~1,000-1,400 nests / yr
- Relative abundance: ~7 % Green Turtles and ~93 % Hawksbills
- Most important sites: at Arnavon Islands (~600 nests); at Ramos Island (~50-100 nests)

(b) Shortlands had the highest proportion of ***green turtles***

- ~ 50% green turtles: of 500-600 nests / yr)

(c) Santa Ysabel and Choiseul (***leatherbacks***)

- 300-600 nests / yr

Vaughan (1981) reported immature foraging green turtles as "numerous" throughout the country, but nesting green turtles as scarce (Vaughan, 1981).

Systematic turtle surveys are needed to determine the current status of marine turtles throughout the Solomon Islands.

Table 4. Estimates of Turtle Nesting in Solomon Islands in 1979-80 (Vaughan, 1981)

(not including Guadalcanal, Malaita, and Eastern Outer Islands)

Island Group	Hawksbills	Green Turtles	Hawksbills & Green Turtles (combined)		Leatherbacks		
	Number of Beaches	Number of Beaches	Number of Nests		Number of Beaches	Number of Nests	
			min	max		min	max
Santa Ysabel	38	10	800	950	20	150	250
Choiseul	38	11	230	450	27	110	220
New Goergia	17	4	120	175	13	60	150
Shortlands	25	21	500	600	1	0	1
Makira			35	50	0	0	0
Totals for Entire (surveyed) Country	*118*	*46*	*1,685*	*2,225*	*61*	*320*	*621*

Arnavon Islands: Contribution to the above figures	Hawksbills & Green Turtles (combined)		
	Number of Nests		
	min	max	
	600	600	
% of Total:	36%	27%	27-36% of total combined Hawksbill & Green turtle nesting in the country

Hawksbill nests = 560 nests (92.6% of AMCA total)

Green Turtle nests = 45 nests (7.4% of AMCA total)

2.9.2. In the Arnavon Islands

Considered together, all the areas surveyed in 1980 by Vaughan (1981) produced an estimated 1,685-2,225 combined hawksbill and green turtle nests. The Arnavon islands accounted for 27-36% of this total -- approximately one-third.

Vaughan estimated that during ***1979-80*** about ***600*** egg clutches were laid each year in the Arnavon Islands -- ~45 by Green turtles (7.4 %) and ~ 560 by Hawksbills (92.6 %). During ***1976-77***, McKeown (1977) had also estimated ***~600*** egg clutches laid annually.

Leary and Laumani (1989) conducted a turtle survey for Isabel Province, based largely on interviews, in November 1989. They concluded that only ***120-200*** egg clutches were laid in the Arnavons during ***1989***. This represented a drastic decline in nesting activity in the Arnavons since 1980 (Vaughan, 1981). However, the authors attributed much of this decline to loss of suitable nesting beach from storm surge wave action caused by cyclone Namu in 1986. They noted that many parts of the Arnavon beaches were less than a fifth of the size that appears in aerial photos in Vaughan's (1981) report. They suggest that in 1989 'Arnavon turtles' had travelled to lay eggs at less-damaged beaches elsewhere in the surveyed region. This idea was supported by their data which showed the absolute numbers of nestings outside the Arnavons (but in the Isabel Province) to have increased by an average of 23-28 % between 1980 and 1989 (from 211-341 in 1980 (Vaughan, 1981) to 259-438 in 1989 (Leary and Laumani, 1989).

Since 1991, turtle surveys have been conducted in the Arnavon Islands, focussed primarily at Kerehikapo island, and mostly during the peak nesting season from June to late August. The data collected during these survey periods each year are extrapolated for the entire year in an effort to assess approximate annual levels of nesting activity. Although this method is likely to over-estimate the population it at least provides an index of nesting activity.

Table 5. Assessment of Turtle Nesting Activity in the Arnavon Islands.

Year	Estimated Number of Nests per Year	Number of Days Surveyed during peak period (Jun - Aug)	Average number of Nests/Day (during survey period)	Source
1976 - 1977	~600	--	--	McKeown, 1977
1979 - 1980	~600	--	--	Vaughan, 1981
1989	120 - 200	Based on interviews	--	Leary & Laumani, 1989
1991	161	66	0.27	Leary and Holthus, 1993
1992	679	84	1.88	Leary and Holthus, 1993; Ramohia & Pita, 1996
1993	--	90	2.1	Ramohia & Pita, 1996
1994	--	84	1.33	Ramohia & Pita, 1996
1995	599	75	1.64	Ramohia & Pita, 1996
2000	? (Tables missing)	87	? (Tables missing)	Ramohia, 2000

More data, especially systematic track counts conducted at all islands in the AMCA are needed to accurately assess the size of the nesting population. Ideally, surveys should be conducted regularly throughout the year although financial constraints may preclude doing this at all islands. Suggested methodologies for such surveys are described in detail in this report and also in "*Instruction Manual for Sea Turtle Monitoring in the Arnavon Marine Conservation Area (AMCA)*" (Mortimer, 2001).

2.9.3. Interpreting the Arnavon Nest Counts

2.9.3.1. *Annual Numbers of Nesting Females in the AMCA*

Efforts have been made to calculate the numbers of females nesting annually in the AMCA by dividing the estimated number of total clutches by estimates of the average number of clutches laid per female per season. Unfortunately, the accuracy of such an estimate will depend on a number of factors including the following:

(a) ***How many egg clutches*** is the ***average*** female ***able to lay*** during a single nesting season? This figure varies from one population to another, and needs to be assessed for each population. It is a difficult figure to assess because it requires that during a nesting season most females are intercepted by the taggers during most of their nesting emergences. This is probably not possible to do in the AMCA.

The natural situation. Data from the Caribbean and the Indian Ocean indicate that when nesting turtles are protected from human harvest the average female lays 4 to 5 clutches per nesting season (Mortimer & Bresson, 1999). If AMCA females are able to lay 4-5 egg clutches per season, then the annual nesting population could be fewer than 125 females.

(b) ***Do females survive*** the entire nesting season? If many female turtles are ***killed*** during the nesting season before they finish laying all their egg clutches, then the average turtle will lay ***fewer*** egg ***clutches***.

In such a case, there is good news and bad news:

- The good news is that there are more turtles in the population. But,
- The bad news is that most of them are killed before the end of the season!

Leary and Holthus (1993) reported that females laid "approximately 2.9 clutches per season." Not clear, however, is whether 2.9 was the average number of egg clutches recorded for all tagged turtles, or whether 2.9 was the average number of clutches recorded for those turtles that laid more than one clutch.

More data are ***needed*** to produce a reliable population estimate for the Arnavon Islands.

2.9.3.2. *The Arnavon Green Turtle Nesting Population.*

Vaughan reported that Green Turtles accounted for approximately 7.4 % of all egg clutches laid in the Arnavon Islands. During the period since 1991, however, relatively fewer green turtles have been encountered. Ramohia and Pita (1996) report only 1.3 % (13 out of 600) nestings involved green turtles.

It is possible that there has been a disproportionate decline in numbers of green turtles nesting in the AMCA. It is also likely, however, that the peak green turtle nesting season does not coincide with that of the hawksbills during which monitoring activities are focussed (i.e. during the months of June to August). In fact, Vaughan (1981) reported that the peak nesting season for green turtles is during the months of September through March.

A turtle monitoring programme that includes year round tracks counts (at least on Kerehikapo island) would provide the data necessary to properly assess the status of the green turtle population.

2.9.4. Estimating Total Population Size

Accurate estimates of the total size of the nesting population are impossible to make because there are too many unknown parameters, including the following:

(a) How many females nest each year (See section *2.9.3.1. Annual Numbers of Nesting Females in the AMCA*).
(b) The sex ratio of males to females
(c) Remigration intervals for both male and female turtles (See section *2.8. Remigration Intervals*)
(d) The likelihood that a nesting females will return to nest in a future season
(e) Survival rate of adult turtles

Relationship to Remigration Interval Lengths. Longer remigration intervals may reflect a relatively larger population of nesting females. In other words, if individual females return to Solomon Islands to nest at less frequent intervals, there may be more of them overall. For example, if all turtles returned exactly on a three-year cycle, then approximately 1/3 of mature animals would nest each year. If, on the other hand, all turtles returned exactly on a five-year cycle, then approximately 1/5 of mature animals would nest each year. (This is a crude model to illustrate this point.)

2.9.5. Population Trends

2.9.5.1. *Historical Estimates of Population Size*

Given that the trade in turtle shell in the Solomon Islands goes back to the late 17th century (see section *3.1. The Tortoiseshell Bekko Trade*), it is very likely that hawksbill populations in the Solomons have been in decline during the past few centuries. But there is no doubt that the hawksbill nesting populations in the Arnavon Islands have declined dramatically during the past 40 years. McKeown estimated that during the 1960s there was a peak of ~100 nests per week in the Arnavons (Vaughan, 1981). At Sikopo, in 1963, one hunting party took 20 hawksbills off one beach in two nights. By 1974, one man spent a full month on Sikopo and caught only 16 turtles (Vaughan, 1981).

If we assume that 25-30% of McKeown's estimated '100 nests per week' were at Sikopo (see Table 3), then there would have been some 25-30 nests per week at Sikopo alone in the 1960's. This is not inconsistent with the report of a hunting party taking 20 hawksbills off Sikopo in two nights in 1963. These data indicate that the size of the Arnavon nesting population declined significantly during the 10-year period between the mid-1960s and the mid-1970s -- perhaps by as much as 50%.

Another way to look at the rate of decline would be to compare estimates of average numbers of nests per night. McKeown's figure of 100 nests per week is equivalent to ~14 nests per night during peak season in the 1960s. In contrast, Table 5 indicates that during a typical nesting season during 1992-1995 there was an average of 1.33-2.1 nests per night (Ramohia and Pita, 1996). This represents a decline of >80% in numbers of nests during a period of only 30 years between the mid-1960s and mid-1990s.

2.9.5.2. *Continuing High Rates of Harvest for Subsistence*

Unfortunately, there is evidence that the rates of turtle harvest in the communities surrounding the AMCA have remained high even in recent years and that a significant amount of the harvest may occur within the AMCA. (See section *3. Historic & Economic Importance of Turtles.*)

2.9.5.3. *Interpreting Low Rates of Inter-seasonal Tag Returns*

Throughout most of the years of the tagging programme begun in 1992, there was a very low rate of Inter-seasonal tag return. By 1996, after five years during which 146 nesting turtles had been tagged, none had been intercepted during more than one nesting season (Ramohia and Pita, 1996). High rates of mortality caused by over-harvest of turtles in the region were certainly at least partly responsible for this.

Another factor to consider, however, is that long remigration intervals may be typical for the Arnavon population, and if so, they would account (at least in part) for the lack of inter-seasonal recaptures during the early years of the tagging study (see section *2.8. Remigration Intervals*).

During ***1994-96***, Broderick (1998a, 1998b) found that ***fewer than 10%*** of nesting hawksbills slaughtered in the communities were experienced nesters (See section *3.2. Subsistence Hunting*). He based this estimate on his observations of the gonads of butchered turtles.

During the 2000 nesting season, however, ***20%*** of the nesting turtles encountered (i.e., 4 of 20 turtles) had been tagged in previous nesting seasons. This indicates that at least 20% of the turtles were experienced nesters -- a figure twice as high as that reported by Broderick (1998a, 1999b) in his study.

These data offer some cause for optimism regarding the status of the Arnavon population. Nevertheless, they need to be interpreted cautiously. Following are two of the possible conclusions one might draw:

- Mortality rates have generally ***declined*** since 1996; **or**
- Mortality rates in general have ***not declined*** since 1996. Maybe mortality has always been lower for those females nesting inside the boundaries of the AMCA. This would not necessarily have been reflected in Broderick's data which were gathered from the three communities (rather than inside the AMCA itself).

Nevertheless, in a healthy population of turtles one would expect a higher percentage of experienced nesters -- approaching 50-60% (Limpus, pers. comm.). It follows that a figure of 20% is low, and the Arnavon population most still be considered ***critically endangered*** and under continuing threat.

3. HISTORIC & ECONOMIC IMPORTANCE OF TURTLES

Historically in the Solomon Islands, green turtles have been harvested for their meat and hawksbills primarily for their shell.

3.1. The Tortoiseshell (Bekko) Trade

From the late 17th Century, Solomon Islanders traded hawksbill shell to Europeans and later to the Japanese. McKinnon (1975) linked the trade in turtle shell to the origin of head-hunting raids directed against the people of West Solomon Islands by people of New Georgia. Shell was exchanged for weapons which were used to extend and maintain control over turtle hunting grounds. Head-hunting raids had ceased by the early 1900's, and by the end of 1992 export of turtle shell also stopped.

But, between the late 1980s and 1992 (when international trade in bekko became illegal), Solomon Islands provided much of the turtle shell (bekko) imported annually into Japan (Table 6). For example, in 1989 Japan imported a reported total of 25,513 kg of bekko, of which 3,709 kg (15 %) came from the Solomon Islands (Official Japanese Government Statistics).

Table 6. Export of Hawksbill Shell from Solomon Islands reported both as Kg of shell and in "Turtle Equivalents." Conversion to Turtle Equivalents is based on data for Oceania from Milliken & Tokunaga (1987).

Year	Trade in Tortoiseshell (kg)			Turtle Equivalents: 1 turtle = 0.88 kg shell (Milliken & Tokunaga, 1987)	Village Price (SI $)
	Source: McKeown, 1977; Vaughan, 1981	Source: Mack & Duplaix, 1979	Source: Official Japanese Government Statistics		
1966		63		72	
1967		901		1,023	
1968		1,233		1,401	
1969		1,213		1,378	
1970	1,136	1,469	1,469	1,290 - 1,669	
1971	1,636	816	816	927 - 1,859	
1972	3,181	1,590	1,590	3,615 - 1,807	0.90
1973	1,818	378	378	430 - 2,066	1.00
1974	3,818	657	657	746 -4,338	1.70
1975	--	846	846	961	1.60
1976	--	873	873	992	3.50
1977	1,363	756	756	859 -1,548	3.50
1978	1,181	528	528	600 - 1,342	6.50
1979	1,363	799	924	907 - 1,548	6.50
1980			704	800	7.00
1981			336	381	
1982			1,206	1,370	
1983			992	1,127	
1984			1,127	1,280	
1985			1,556	1,768	
1986			1,793	2,037	
1987			4,833	5,492	
1988			3,911	4,444	
1989			3,709	4,214	
1990 (Jan-Jul)			1,985	2,255	

The period when the greatest amounts of shell were exported was in the late 1960s and early 1970s (see Table 6). Large amounts of shell were also reported in the late 1980s. Some of this shell may have been 'laundered' by reporting it as coming from the Solomons during a period when many other countries had already made it illegal to export turtle shell.

Nevertheless, it is possible that the figures presented in Table 6 are real. Of the turtle shell exported from Solomon Islands in 1990, the origin of 2,089.29 kg of shell was reported to the Fisheries Division. Of all the shell reported, 47% originated from the Waghena area of Western Province (now Choiseul Province) and a further 9% from the Kia area (Leary & Holthus, 1993). In other words, 1,179 kg (56% of all the turtle shell for which the origin of capture was reported) came from the vicinity of the Arnavon Group of islands and surrounding areas. This represents some 1,300 individual turtles using a value of 0.88 kg per turtle (Milliken & Tokunaga, 1987).

According to local reports, between the late 1960s and 1992 harvest was so intense in the Arnavons that very few female hawksbills were able to lay eggs before they were killed (Chris Ribua Taniana, pers. comm. to J. Mortimer). In 1980, Vaughan (1981) also reported that most of the shell exported from the Solomon Islands was believed to have come from the Arnavon Islands.

3.2. Subsistence Hunting

During 1994-96, Broderick studied subsistence use of turtles by communities located near (within 50 km of) the AMCA. He estimated that annually the villages of Kia, Wagina and Katupika together consumed an average of ~1,068 green turtles and ~825 hawksbills (Broderick, 1998a; 1998b). An estimated 40% (~353) of those hawksbills were adult females.

The hunting methods employed by the communities varied. For Kia, free diving at night along the reef edge was the dominant capture method (63%). For Wagina, most of the turtles (70%) were captured incidentally while engaged in other fishing activities (usually crayfish hunting) generally during night dives. For Katupika, most of the turtles (67%) were speared on full moon nights over the reef flats, and this explains why most of the turtles captured for Katupika were green turtles rather than hawksbills.

Broderick found that although the meat of green turtles was preferred over that of hawksbills, the hunters also biased their catch towards larger animals. In the village of Wagina, which was located closest to the Arnavon islands, more hawksbills than green turtles were harvested annually (~450 hawksbills vs. ~201 green turtles), and most of those hawksbills were adult females in reproductive condition. This is probably because, near the AMCA, most of the green turtles encountered are immature and most of the hawksbills are adult.

Broderick 1998b reported that at least 13% of hawksbills and 5% of green turtles tagged in his feeding ground study were subsequently harvested by villagers. This suggests that a large proportion of the available turtle resource was being harvested. Likewise, Leary & Holthus (1993) reported that nine (9) of the 27 nesting turtles tagged in 1992 (one third) were known to have been killed by fishermen.

Broderick's figures are also disturbing because they indicate high harvest rates of adult hawksbill turtles even after the shell trade had ceased. Broderick found that <10% of hawksbills nesting in the study area were experienced breeders (Broderick, 1998a; 1998b)(see discussion of this in section *2.9.5.3. Interpreting Low Rates of Inter-seasonal Tag Returns*). This provides further evidence that past levels of exploitation were very high. (In populations where mortality is low, the vast majority of females nesting in any one season are experienced (Limpus et al., 1998).

Broderick (1998b) was unable to know the relative extent to which the low proportion of experienced breeders could be blamed on recent subsistence exploitation, and to what extent on the earlier intense harvest for bekko. By 1998, approximately 400 nesting hawksbill turtles had been tagged in the Arnavon Islands since the monitoring programme began; but only two turtles had ever been recorded nesting for a second season (Peter Ramohia, pers. comm. to D. Broderick, as reported in Broderick 1998b). In recent years the proportion of remigrant turtles has risen somewhat (see section *2.9.5.3. Interpreting Low Rates of Inter-seasonal Tag Returns)*.

3.3. The Situation in Recent Years

Although some poaching reportedly still occurs in the AMCA, by most accounts, the situation for turtles has improved. The perceived improvement in recent years may reflect enhanced respect for the AMCA by members of the local communities. Tagging data gathered in recent years indicates increasing numbers of records of tagged turtles laying two or more egg clutches both within and between nesting seasons (Thomas, 2000; AMCA unpublished data). There are also reports of an increasing number of daylight nesting turtles (Thomas, 2000).

Nevertheless, as recently as 2000, Ramohia (2000) estimated that ~50 adult size hawksbills and green turtles were killed in Nikumaroro village during peak turtle season in June, July, and August 2000. Additional information he obtained from reliable sources indicate that these turtles were harvested inside the AMCA.

Given the decades-long history of intense over-harvest at the Arnavon rookery, it is critical that present-day harvest be kept to a minimum in order to conserve and protect what remains of the Arnavon nesting population. Of particular concern is the relative lack of reproduction that occurred during the period from the late 1960s to 1992. During those years, few young turtles would have been added to the population. Thus, old females now remaining in the population must be allowed to lay eggs and produce as many new offspring as possible in order to make up for that "lost generation".

Over-harvest of hawksbills in the AMCA region will have its greatest long-term impact on the local nesting population. Over-harvest of foraging green turtles is likely to impact both the foraging populations in the Solomon Islands as well as the nesting populations in Micronesia.

3.4. Protective Legislation

Amendments to the Fisheries Act were made in March 1993. The law bans the sale and export of turtles and turtle products at all times. It prohibits the taking of nesting turtles or eggs during breeding seasons -- during June to August and November to January.

Unfortunately this law is very difficult to enforce in the communities.

During my visit to Honiara in July-August 2001 significant amounts of hawksbill shell items were openly on sale in the tourist shops despite the fact that such sale was illegal. The law should be easier to enforce in Honiara.

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ACKNOWLEDGEMENTS

This study was made possible by The Nature Conservancy's Coastal Marine Program for the Asia Pacific Region and the AMCA Management Committee. Special thanks are due Dr. Rodney V. Salm (Honolulu Office), Dr. Peter Thomas (New Zealand Office), and George Myers (Honiara Office) all of whom made the work possible. John Pita and Peter Ramohia provided invaluable information and insight, logistical support, and good company. The AMCA Conservation Officers (COs) were a delight to work with. Special thanks go to Victor Tooa Tebaubau, Dickson Motui, 'Danny' Michael Danibea, Arnold Pitakaka, Chris Ribua Taniana, and Nelson Kokonava who participated enthusiastically in the turtle programme. John Ribaua was very helpful during my visit to Wagina. Victor, Dickson, and John translated to their local languages, the oral presentations/slide shows that I gave in their communities.

Shari Walker, Martha McManus, Robyn Curham, George Teleki, and Willie Ake provided administrative and logistical assistance. The US-NMFS made the satellite transmitters available to the Solomon Islands, and the enthusiasm and willingness of George Balazs to share his extensive knowledge ensured that the tracking study was a success. Marydele Donnelly provided me with Bekko trade statistics.

I am grateful for the warm hospitality afforded me by many people in Honolulu, Honiara, Kia, and Wagina. Special thanks go to Rod, Susan, Lauren, and Josephine Salm who brought me into their home in Honolulu; to Chris Ribua Taniana and his family with whom I stayed in Wagina; and to George Myers and Martha McManus for their friendship and assistance.