

c a y m a n
t u r t l e f a r m



Dear George Balazs,

Welcome to Grand Cayman and to the Cayman Turtle Farm's first Symposium. We are delighted that you are able to join us this week, as your participation in this project is significant. The Cayman Turtle Farm is dedicated to research and conservation and this Symposium is a reflection of this commitment. It is our intention to include programs such as this in the structure of the redevelopment of the Farm.

A complete itinerary of events is included in this welcome packet. This has been designed in order to bring perfect balance to an enjoyable working and leisure experience.

If you are not leaving on an early morning flight on your departure date, please feel free to have breakfast in Ferdinand's restaurant in the hotel and sign this charge to your room. We will be picking up this charge for you as well. Any other incidentals such as room service, mini bar, Internet and telephone charges will be your own responsibility.

Should you have any questions or concerns throughout the Symposium, please contact any of the organisation team: myself, Joe Parsons, Denise Gower or Astra Watler and one of us will be more than happy to look after your needs.

I sincerely hope that you enjoy your stay in Grand Cayman and I am looking forward to working with each of you on this globally important project.

Kind regards,



Kenneth Hydes
Managing Director

c a y m a n t u r t l e f a r m



October 18, 2003

Dear George Balazs,

Thank you for agreeing to participate in the Cayman Turtle Farm's Symposium, a think tank engineered to discuss a Population Model for the West Atlantic Green Turtle October 22 – 24, 2003.

The achievement of this model is expected to be a monumental occasion for both the Cayman Turtle Farm and the scientific community.

Your airline tickets, accommodation and meals in Grand Cayman have been arranged and paid for by the Cayman Turtle Farm. Your travel itinerary is as follows:

Date	Time	Airline	Flight Number	Destination
Mon Oct 20	1:20 pm	American Airlines	0162	Los Angeles LAX
Mon Oct 20	10:25 pm	American Airlines	0276	Miami International
Tues Oct 21	10:50 am	American Airlines	1029	Grand Cayman
Sat Oct 25	7:05 am	American Airlines	1746	Miami International
Sat Oct 25	1:15 pm	American Airlines	0297	LA (LAX)
Sat Oct 25	5:45pm	American Airlines	0251	Honolulu

Your e-tickets will be sent to you shortly.

At the Owen Roberts International Airport in Grand Cayman, take the right-hand exit out of Immigration. A Majestic Tours Representative will greet you there and provide transportation to the hotel.

The host hotel for this program is the Westin Casaurina Resort. Your confirmation number is 246838. You have been reserved in a king-bedded, non-smoking room. Please advise if you have any other special requirements.

After checking into the hotel, kindly proceed to the registration area outside of the Galleon Ballroom. You will receive your welcome package and conference information at that time.

A welcome reception is planned at the Westin Casaurina at 6:30 pm – 9:00 pm. This will be a wonderful opportunity to meet those you don't know and to catch up with old friends.

A full itinerary will be provided for you at registration. But as a quick overview: the symposium will be in full session Wednesday October 22 with a group dinner afterwards. Thursday will be a half-day session in the meeting room with a planned tour of the Cayman Turtle Farm on Thursday afternoon. Again, a group dinner is planned for Thursday evening. Friday will be another full day of meeting sessions, followed by dinner and transportation to the street party that begins the annual "Pirate's Week" Celebrations. All lunches on Wednesday, Thursday and Friday are also arranged as part of this itinerary.

October 16, 2003

We are looking forward to welcoming you to our beautiful island and are hoping that you find this trip a valuable experience professionally and personally.

Kind regards,



Kenneth Hydes
Managing Director

Workshop Title:
**Population Models for the West
 Atlantic Green Turtle**
 21-25 October 2003

 **21 October Tuesday**

Time	Event	Venue
3:00 pm - 8:30 pm	Registration	Galleon Ballroom Foyer
6:30 pm - 9:00 pm	Welcome Reception	Poolside South

 **22 October Wednesday**

Time	Event	Venue
7:30 - 8:30 am	Breakfast	Galleon Ballroom Foyer
8:30 am	Meeting begins	Galleon Ballroom B
8:30 am	Welcome and introduction of Captain Eugene Ebanks, MLA and Director of Cayman Turtle Farm (Kenneth Hydes). Welcome by Captain Eugene Ebanks and presentation by John A. Cumber primary school students. Introduction of Participants. Workshop Objectives and Agenda (Alan Bolten).	
9:45 - 10:00 am	Coffee Break	Galleon Ballroom Foyer
10:00 - 12:00 pm	Presentation: Single population model for the West Atlantic green turtle - introduction to the model (Milani Chaloupka).	
12:00 - 1:30 pm	Lunch	Galleon Ballroom Foyer
1:30 - 3:00 pm	Demonstration and discussion of the green turtle simulation model (Milani Chaloupka).	
3:00 - 3:15 pm	Coffee Break	Galleon Ballroom Foyer
3:15 - 5:00 pm	Moderated discussion: How the green turtle simulation model can be used in management decisions and identification of research priorities.	
5:00 pm	Adjourn Meeting	
7:00 pm	Meet in Lobby for transfers	
7:30 pm	Dinner	Cobalt Coast
9:30 pm	Return transfers	Westin Casarina



23 October Thursday

Time

7:30 - 8:30 am

8:30 am

8:30 - 10:00 am

10:00 - 10:15 am

10:15 - 12:30 pm

12:45 pm

1:00 pm

3:00 pm

3:15 - 5:00

5:00 - 6:00 pm

6:00 pm

8:30 pm

Event

Breakfast

Meeting Begins

Moderated discussion: Identify data gaps and actions needed to collect the data for the completion of the green turtle population model

Coffee Break

Moderated discussion: Pros and cons of developing a meta-population model for the West Atlantic green turtle populations

Meet in Lobby for transfers

Lunch

Transfers

Tour of Farm

Cocktail Reception

Dinner

Transfers back to hotel

Venue

Galleon Ballroom Foyer

Galleon Ballroom B

Galleon Ballroom Foyer

Calypso Grill

Calypso Grill

Cayman Turtle Farm

Cayman Turtle Farm

Cracked Conch

Cracked Conch

Westin Casuarina

24 October Friday

Time

7:30 - 8:30 am

8:30 am

8:30 - 9:00 am

9:00 - 10:00 am

10:00 - 10:15 am

10:15 - 12:30 pm

12:30 - 2:00 pm

2:00 - 3:00 pm

3:00 - 5:00 pm

5:00 pm

7:00 pm

7:15 - 8:15 pm

8:15 pm

10:00 pm

Event

Breakfast

Meeting Begins

General Session

Break-Outs

Plan of action for developing a green turtle meta-population model for the West Atlantic (2 breakout groups). Objectives: Identify available data, what data would be needed, and what it will take (e.g., time and money) to collect those data

Coffee Break

Continue in breakout groups

Lunch

Summary group discussions

Wrap-up

Adjourn workshop

Meet for transfers

Reception

Dinner

Transfers to Pirate's Week Street party/hotel

Venue

Galleon Ballroom Foyer

Galleon Ballroom B

Galleon Ballroom B

Galleon Ballroom A & B

Galleon Ballroom Foyer

Galleon Ballroom A & B

Galleon Ballroom Foyer

Galleon Ballroom B

Galleon Ballroom B

Lobby

Wharf

Wharf

25 October Saturday

Travel Day

Sign breakfast in restaurant to guest room

Research Needs

Spatial configuration of stocks for defining metapopulation: how many rookeries (identify a few and then combine rest in "others"?), how many foraging grounds (FG). Select on basis of relative abundance and geographic distribution. Needs to reflect biological reality of extent of demographic interactions.

- Genetic substructure
- Flipper tag returns
- Satellite telemetry

Annual probability of reproducing for both males and females

- Laparoscopy or develop other techniques

Somatic growth over a range of FG with different conditions, emphasis on >70 cm (Nicaragua, Cuba?, where else?) and oceanic stage. Needed for age class structure.

Dispersal probabilities – all stages

Density dependence

Depensatory effects

Survival probabilities – all stages

Time series for FG abundance

Time series for nesting abundance

Time series of historic harvests

Current estimates of direct and indirect takes

- oil spills
- fishery bycatch
- entanglement

Effects of habitat alteration on demography – natural and human-induced – FG & nesting beaches

- beach armoring
- changes in coastal physiognomy (e.g., mud banks, driftwood)
- catastrophic events (e.g., hurricanes)

Hatching probability over temperature range

Duration of oceanic phase (confirm Zug and Glor estimate)

Age-specific reproduction (senescence)

Relative contributions of rookeries, French Guiana?

Number of clutches per female per season

Annual variation in primary sex ratio

Improve carrying capacity estimates

Interspecific competition – food resources & nesting sites

Effects of disease, especially fibropapillomatosis, on demographic parameters

Tag Return Project – recaptures: all nesting returns, for FG > 50 km (time limit?), any rookery switches

Compilation: author will be a “group” such as Green Turtle Tag Return Group, compilation will include list of all contributors

Deadline: Submission July 2004; Published by October 2004

Define objectives

- Define spatial structure of West Atlantic green turtle metapopulation
- Compile and disseminate information on tagging (flipper, pit, carapace, living, satellite start-end points) to enhance the understanding of green turtle metapopulation spatial distribution in the Caribbean/West Atlantic/Atlantic – origin or recovery within Wider Caribbean

Getting the word out

- CTURTLE
- MTN
- WIDECAST
- Individual contacts
- Cooperative Marine Turtle Tagging Program (CMTTP)
- Identify databases that are in the hands of people who don't recognize their value
- Annual Sea Turtle Symposium

Format – Data to include –

- Provide Excel template for data reporting – option of 2 versions
- Divide reports between nesting and FG tagging programs
- **Size of turtle or at least** juvenile/adult (give guidelines)
- Location of tagging and recapture (GPS or lat/long)
- How many tagged at site (for proportion of recaptures)
- **Dates of tagging and recapture**
- **Sex (give guidelines)**
- Program
- Methods of capture and recapture

G. H. BALAZS

WORKBOOK

Cayman Islands green turtle simulation model development

October 2003, Grand Cayman

Dr Milani Chaloupka

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1.0 Stock definition

The green sea turtles resident in western Caribbean waters comprise mainly one distinct stock (Lahanas et al 1998, Bass & Witzell 2000), although the spatial configuration of the western Caribbean stock is unclear. A simple 2-substock mixed population structure is assumed for this model. The model assumes mixed substock structure in the foraging grounds but significant fidelity to the 2 primary regional rookeries — Tortuguero and the Caymans. The Tortuguero nesting substock is increasing in abundance following severe depletion due to various anthropogenic hazards (Fig 1). The Caymans nesting substock is severely depleted and apparently remains so (Aiken et al 2001). The status of other western Caribbean nesting substocks is not well known so this model comprises only these 2 substock components. The stochastic simulation model developed here is designed to explore the metapopulation dynamics of the western Caribbean stock and the risk to stock viability given exposure to various anthropogenic hazards over the last 200 years.

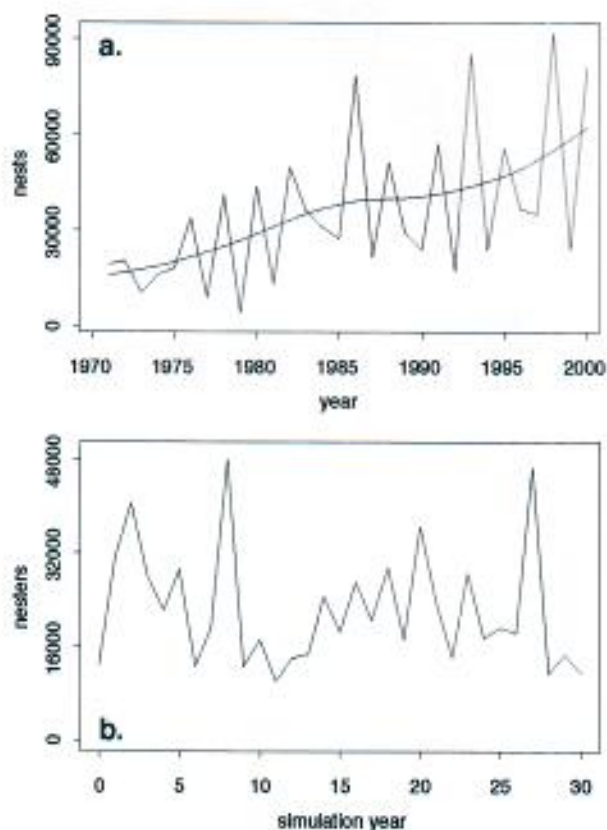


Figure 1 Panel (a) shows a time series plot of estimated number of green turtle nests laid each year (thin solid curve) at the Tortuguero rookery, Costa Rica (1971-2000) with a the long-term trend for this recovering population shown by the superimposed thick solid curve based on a stiff smoothing spline. Source: Bjorndal et al (1999) with updates in Solow et al (2002). Panel (b) shows a stochastic simulation model run for the number of nesters at the Tortuguero rookery over an arbitrary 30 year period without any anthropogenic hazards in effect.

2.0 Somatic growth behaviour

Western Caribbean greens recruit from the oceanic habitat to a neritic habitat from ca 25 cm SCL (Zug & Glor 1998, Bjorndal et al 2000). The pelagic phase duration for Caribbean greens is estimated to be ca 3-5 yr (Zug & Glor 1998). Size-at-age data for a sample of stranded Florida greens was analysed by Zug & Glor (1998) using skeletochronological

procedures. Sex-specific growth is well known for other green sea turtle stocks (Limpus & Chaloupka 1997, Chaloupka 2001b) but no comprehensive sex-specific data are available for western Caribbean greens so it is assumed in the model that males and females display similar growth. The age structure for this model was based on Zug & Glor (1998), Bjorndal et al 2000 and unpublished growth modelling of Florida greens by Kubis & Chaloupka (see Fig 3). There is a strong juvenile growth spurt ca 50-60 cm SCL that reflects developmental shifts up to ca 15 yrs of age. The age structure given these considerations is summarised in Table 1.

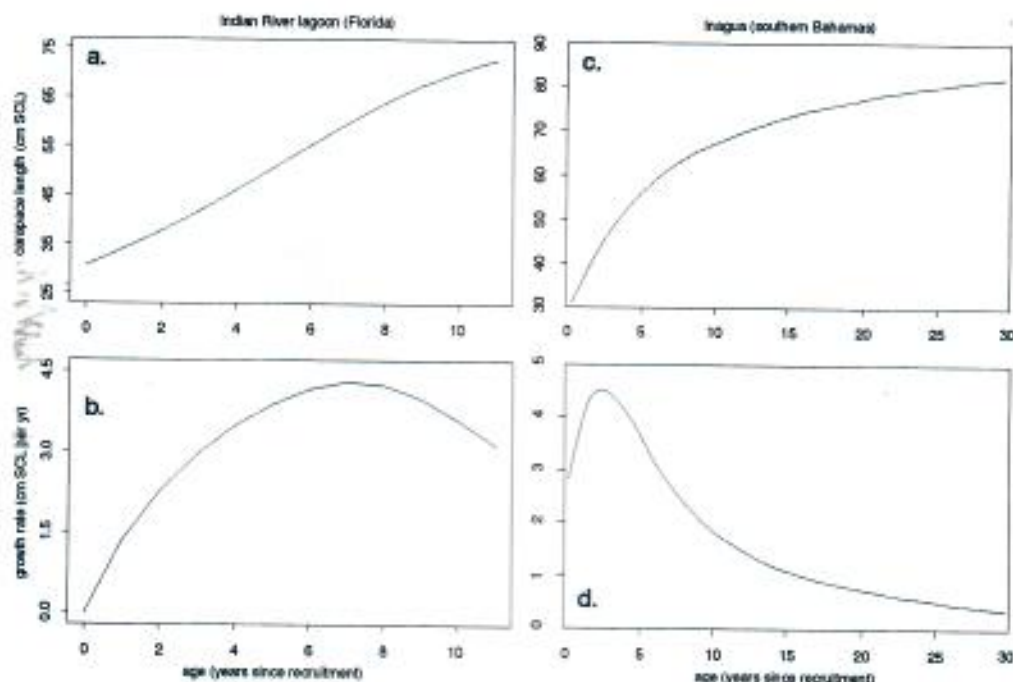


Figure 2 Estimated somatic growth functions for green turtles resident in foraging grounds in (a-b) Indian River lagoon (Florida) and (c-d) Inagua in the southern Bahamas. All functions based on nonparametric regression models (see Limpus & Chaloupka 1997, Bjorndal et al 2000). Panels (a,c) the expected size-at-age (age ~ years-at-large since recruitment) functions for each population, which were derived by numerical integration of size-specific growth functions. Panels (b,d) show age-specific growth functions for each population derived by numerical differentiation of the curves shown in (a,c). Source: Kubis & Chaloupka (unpubl) for Florida greens and Bjorndal et al (2000) for Bahamas greens.

Table 1 Summary of ageclass structure and ageclass-specific survival estimates and sampling probability density functions included in the stochastic simulation model of Cayman green turtle population dynamics. Ageclass structure based on growth functions in Fig 2 and Zug & Glor (1998); survival probability functions based on Chaloupka & Limpus (2002) and Bjorndal et al (2003) for ageclass-specific survival probabilities for green sea turtle populations.

ageclass	stage	mode	comment
0	hatchling	multiple	predation, poaching/harvest, erosion/wash-over, beach temperature
1	neonate	0.25	derived parameter including egg and hatchling survival, ev pdf
2-5	pelagic juvenile	0.60	derived parameter, logistic pdf
3-15	benthic juvenile	0.80	incidental drowning and other hazards, derived parameter, logistic pdf
15-25	immature	0.85	incidental drowning and other hazards, empirical basis, logistic pdf
25-40	subadult	0.90	right skewed extreme value pdf, empirical basis, multiple hazards
40+	adult	0.95	left skewed ev pdf, empirical basis, multiple hazards



Figure 3 Developmental phase- and reproductive-status based lifecycle graph or causal loop model for Caribbean green turtles. This is the demographic structure and feedback mechanisms included in the stochastic simulation model to explore Cayman green turtle population dynamics that is subject to various hazards (eg., nesting beach erosion, nest inundation by wave washover, egg and turtle harvesting, or incidental capture and drowning in coastal or pelagic fisheries).

3.0 Age-size-sex-spatial structure

Given the age-specific findings in Zug & Glor (1998) and the size- and age-specific findings in Fig 2, it is apparent that Caribbean greens are ca 25-40 yr old at maturity, which is consistent with estimates for the sGBR and Hawaiian green turtle metapopulations (Chaloupka et al 2003, Balazs & Chaloupka in press). The derived ageclass structure for the simulation model given these considerations is summarised in Table 1, which includes the distributed recruitment from 3-5 years from the oceanic phase to the neritic juvenile phase.

The model comprises 2-subpopulations reflecting the Totyuguero and Cayman nesting substocks. The substock structure is based on the observations that (1) there is strong foraging ground fidelity and (2) little immature dispersal between foraging. Once recruited to a substock, it is assumed that there is ageclass-specific dispersal behaviour to reflect the mixed haploptype composition found for the western Caribbean greens (Lahanas et al 1998, Bass & Witzell 2000). The oceanic juveniles recruit as neritic juveniles from ca 3-5 yrs (see Zug & Glor 1998). The function for oceanic juveniles recruiting to the coastal habitat for each substock is assumed to be an age-specific function (probabilities are changeable in the model using interactive slider devices —

- probability of a 3 yr old pelagic juvenile recruiting as a 4 yr old benthic juvenile = 0.25
- probability of a 4 yr old pelagic juvenile recruiting as a 5 yr old benthic juvenile = 0.75
- probability of a 5 yr old pelagic juvenile recruiting as a 6 yr old benthic juvenile = 1.00

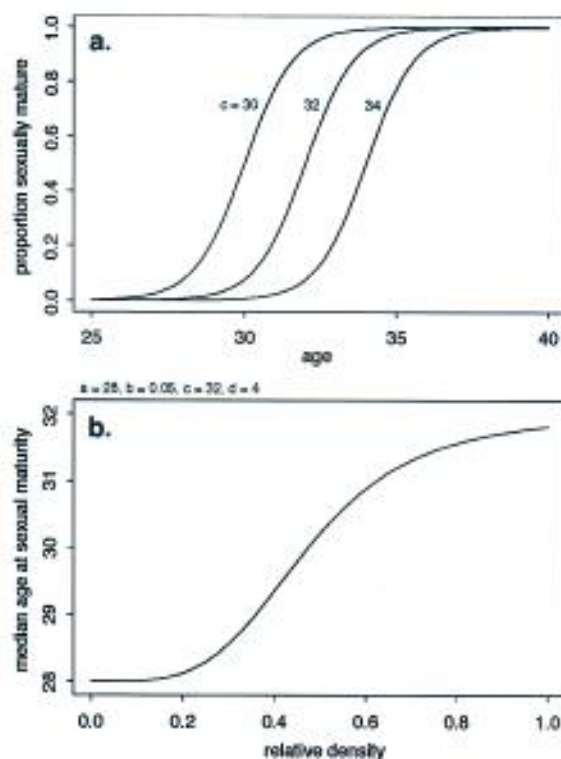


Figure 4 Panel (a) shows various forms of the logistic age-specific maturity function [$y = 1/(1+\exp(-a(\text{age}-b)))^c$], which is adjustable by using an interactive slider device. Here the 'b' parameter is varied to show some of the age-specific maturity functions that can be applied in the model to evaluate model sensitivity. The 'b' parameter = median age at maturity when the 'c' parameter = 1, if 'c' < 1 then 'b' > median while if 'c' > 1 then 'b' < median age at maturity. Panel (b) shows the 'c' parameter as a Morgan-Mercer-Flodin function of relative benthic substock density used here to invoke density-dependence in the age-at-maturity function shown in (a).

The neritic or benthic juvenile phase (3-15 yrs old, Table 2) is assumed to last ca 12 yr given findings for the Inagua population in the southern Bahamas (Bjorndal et al 2000) The immature duration is estimated ca 10 yrs (15-25 yrs old, Table 2). The subadult or maturing adult duration is estimated ca 15 yrs (25-40 yrs old, Table 2) with the assumed age-specific maturation functions shown in Fig 4b, which were derived from size-specific maturation data for male and female greens in Hawaiian and GBR waters (Balazs & Chaloupka in press, Chaloupka et al 2003), which is also assumed to be density-dependent (Fig 4b). A common age-specific maturity function is the default in the model although sex-specific maturity is accommodated by parameter adjustments to the maturity functions using interactive sliders devices. Adults are 40+ years old with 100% sexual maturity assumed. The ageclass/stage structure in the model is summarised in Fig 3 (Table 2), which includes the major sources of mortality risk and the key environmentally influenced demographic processes. The major environmental effects in the model are concerned with breeding behaviour (Fig 7a) and temperature dependent hatching probability (Fig 6a).

Hatchling sex ratio is also temperature dependent (Fig 6b) and implemented in the model given a stochastic beach temperature generator based on nest temperature assuming a 2:1 sex ratio (Spotila et al 1987). While the model is sex structured, its default setting is for sex-specific differences in breeding probability functions but no sex-specific differences in maturation or survival probability functions. However, all settings are readily changed in the model using interactive slider devices.

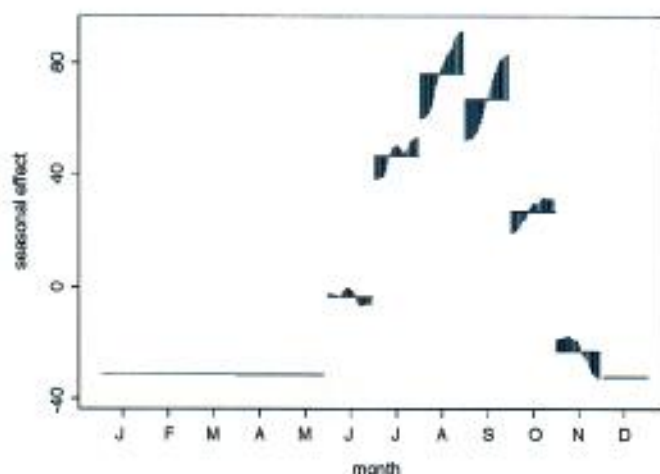


Figure 5 Seasonal cycle monthly subseries plot of the estimated number of green turtle nests laid each month over a 30-yr period (1971-2000) at the Tortuguero rookery, Costa Rica. The plot shows the fitted seasonal component from an STL analysis (Fig 13d) that provides an assessment of the historical seasonal pattern as well as the temporal behaviour of each monthly subseries over the 30 yr. The horizontal line is the fitted mid-mean value of the seasonal component for each month. The fitted values for each year (ends of the vertical lines) associated with each midmean show the pattern of interannual variation of the monthly subseries. Nesting is highly seasonal (June-November) with peak nesting during August and September, with significantly increased nesting during these 2 months over the 30 yr period.

4.0 Fecundity

The simulation model is based on an annual cycle with no internal seasonal structure — the model simulates annual sex- and ageclass-specific abundance for the Cayman green turtle population. Many sea turtle populations nest year-round but there is usually a strong seasonal cycle (Fig 5), so modelling annual rather than monthly abundance is justified for the purposes of this model. The seasonal nesting cycle is apparent for the Tortuguero green nesting population (Bjørndal et al 1999), further justifying use of an annual rather than a monthly period model. The expected primary sex ratio ($PSR = 0.67$) was sourced from Godfrey et al (1996) and is consistent with estimates for many other green turtle populations (Chaloupka & Limpus 2001). Expected eggs per clutch or clutch size ($EPC = 112$) was sourced from Bjørndal & Carr (1989) and is consistent with estimates for other green turtle stocks (Mortimer & Carr 1987, see Chaloupka 2002). This was sampled in the model as a Poisson random variate with $\mu = 112$, which provides a pmf that is consistent with the graphical summaries for Atlantic green nesting populations (Mortimer & Carr 1987, Bjørndal & Carr 1989).

There is some evidence for seasonal variation in clutch size at other rookeries but the effect is limited (Mortimer & Carr 1987, Bjørndal & Carr 1989) and no such effect is apparent at the Hawaiian or Great Barrier Reef stocks rookery. There is some evidence for increasing clutch size with age at the Tortuguero rookery in Costa Rica (Bjørndal & Carr 1989) but any such effect has limited demographic impact when discounted for the survival of ageing females (Chaloupka 2002). Expected number of clutches laid per season (expected $CPS = 3$, $max = 8$) was sourced from Johnson & Ehrhart (1996), which is also consistent with estimates for the Ascension Island green nesting population (Mortimer & Carr 1987). This parameter was sampled in the model as a binomial random variate [$bin[p = 0.30, n = 8]$], which provides a pmf consistent with the graphical summary information presented in Mortimer & Carr (1987).

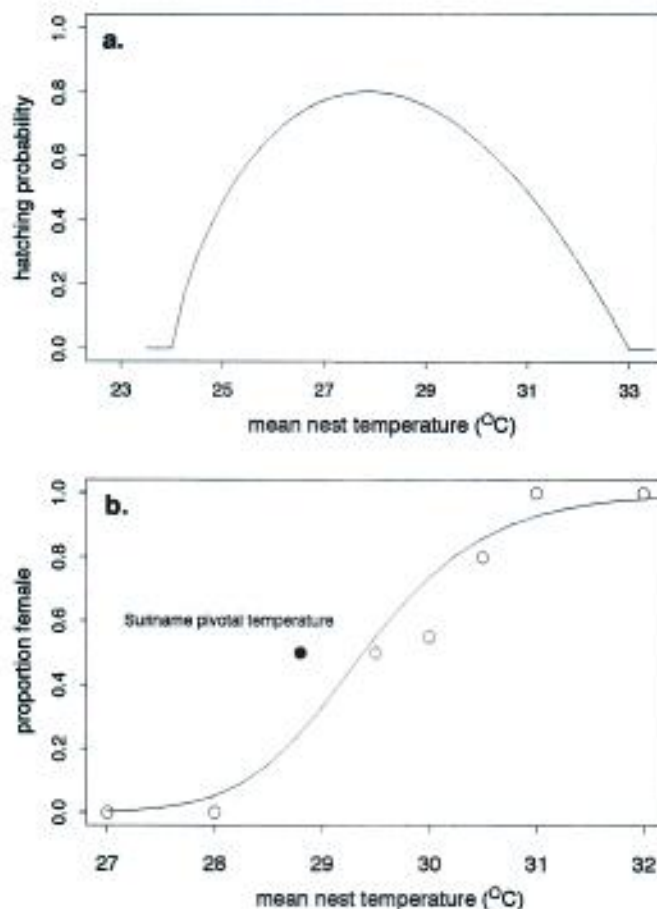


Figure 6 Functional form assumed in model for temperature-dependent (a) hatching probability and (b) hatchling sex determination for the Tortuguero rookery. Panel (a) shows a Thornley-type model fit for hatching probabilities known for other green turtle populations. Panel (b) shows a generalised logistic function fit (solid curve) for hatchling sex determination probabilities derived from data in Spotila et al (1987) for the Tortuguero rookery (open dots). Pivotal temperature for a Suriname rookery shown by solid dot (Godfrey et al 1996).

5.0 Temperature-dependent hatching probability and sex determination

Green turtle sex ratio and hatching probability are assumed to be a direct function of the nesting temperature during incubation (Limpus & Reed 1985, Wibbels et al 1993, Godfrey et al 1998). There are no reliable hatching probability function data for Caribbean green turtle populations so the functional form was based on a Thornley-type nonlinear model fitted to data for other green turtle populations (Fig 6a). This function is consistent with data for the southern Great Barrier Reef green turtle stock. Spotila et al (1987) provided some experimental data for the Tortuguero rookery that were used to derive the temperature-dependent hatchling sex ratio process for the model. The functional form that best fits these data was a generalised logistic function (Fig 6b). The simulation model then uses a stochastic beach temperature generator to derive annual nest temperature that is consistent with seasonal nest temperatures recorded at the Tortuguero rookery and an expected female hatchling fraction ca 0.67 (Spotila et al 1987). The simulated nest temperature for each season forms the basis for deriving the expected female hatchling fraction and hatching probability for that simulation year. The 2 forms shown in Fig 6 are generic for a Caribbean green turtle population and the functional forms are readily adjustable by using interactive slider devices.

6.0 Expected breeding behaviour

There is only very limited remigration interval information for the any Caribbean green turtle population (Carr et al 1978, Mortimer & Carr 1987) so this model uses data from the better studied Hawaiian green turtle population. Balazs (unpubl 2002) provided data comprising 1847 records of the remigration interval for female greens nesting on East Island, French Frigate Shoals rookery (see Fig 7a). These data were used to derive the expected probability of Cayman female breeding each year, which was based on fitting various probability density functions to the reciprocal of the data in Fig 7a. This function is consistent with remigration data for the Ascension Island rookery (Mortimer & Carr 1987) and with data provided for the Tortuguero rookery (Carr et al 1978). The best fit probability density function (pdf) to the derived annual proportion of Hawaiian females breeding was an extreme value pdf (Fig 7b, solid curve). The expected male breeding probability function (Fig 7b, dashed curve) was derived by offsetting the estimated female pdf given the assumptions in Balazs (1980) that Hawaiian males have a shorter remigration interval than females — a view that is consistent with males from other green turtle stocks (Limpus 1993, Limpus et al 1994). The assumed sex-specific breeding functions for a Caribbean population result in significant inter-annual fluctuations in the number of females that nest each year due to the fluctuations in the assumed annual breeding behaviour (Fig 7b). Such fluctuations in nesting are characteristic of the Tortuguero rookery (Bjorndal et al 1999, Solow et al 2002; see Fig 1). The fluctuations in breeding behaviour (environmental stochasticity) are assumed implicitly in the model to be a function of fluctuating food supply effecting accumulation of body fat needed for vitellogenesis and migration (Kwan 1994).

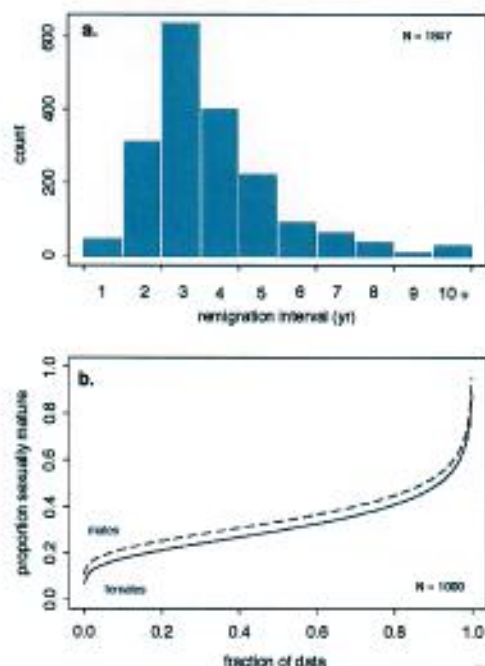


Figure 7 Panel (a) shows estimated remigration interval (years) for females nesting on East Island (French Frigate Shoals) from 1973-2001. Panel (b) is a quantile plot based on a right skewed extreme value pdf showing the derived proportion of females preparing to breed each year (solid curve) - based on Balazs (1980), it is assumed that males have a higher probability of preparing to breed function (dashed curve).

7.0 Ageclass-specific survival probabilities

There are few reliable ageclass-specific estimates of green sea turtle survival probabilities (see review in Chaloupka & Limpus 2001b). The following estimates were derived from various sources (Gyuris 1994, Chaloupka & Limpus 2001b, Chaloupka 2002, Bjorndal et al 2003). Most of these estimates and assumed pdfs are also consistent with robust estimates derived using long-term mark-recapture studies for green turtles resident in sGBR waters (see Chaloupka & Limpus 2001a,b) and in Baja California waters (Seminoff et al in press). Some ageclass-specific estimates were derived using model tuning (Table 1). There are no apparent sex-specific difference in green sea turtle survival (Chaloupka & Limpus 1998, Chaloupka 2002) although the model includes sex-specific survival probability functions should such information become available. Fig 8 shows the range of ageclass-specific survival probability density functions (pdfs) assumed in the Caribbean green turtle metapopulation model.

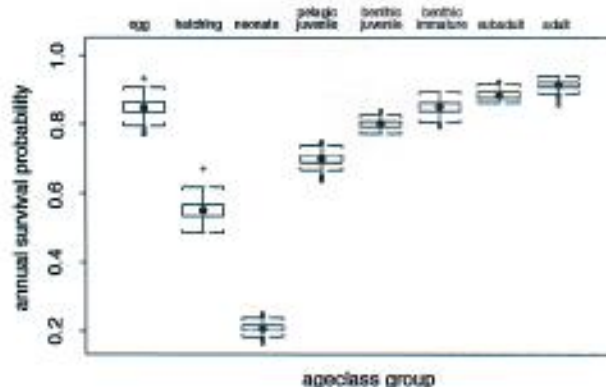


Figure 8 Boxplot summaries of the ageclass- and stage-specific annual survival probabilities from 1000 model runs of the stochastic simulation model of the Hawaiian green turtle metapopulation dynamics, which is assumed to be similar for the Caribbean stock (see also Table 1). Pelagic juvenile survival probabilities were derived here by model tuning as there are no empirical estimates for this ageclass. All ageclass-specific survival probability functions are readily adjustable in the model using interactive slider devices.

8.0 Compensatory effects

The expected sex-specific breeding probability was also assumed in the model to be a density-dependent function. Bjorndal et al (2000) have shown evidence of density-dependent effects on green turtle growth that were assumed to be related to declining per capita food availability as the population increased. It is reasonable to assume that food availability might also have an effect on loggerhead breeding behaviour. Moreover, many marine vertebrate populations do recover from significant levels of harvesting but this recovery can take a long time for sea turtles so that any density-dependent effects in the model need to be readily amended in light of new information. Hence, the model includes a switch to turn on or off any density-dependent functions to evaluate the effect of including density-dependence and the assumed functional form of that dependence on model performance and sensitivity.

The assumed sex-specific functional forms are shown in Fig 9, which was based on a Morgan-Mercer-Flodin function where $y = (a \cdot b + c \cdot X^d) / (b + X^d)$ and (a-d) are estimable or adjustable parameters, y = expected proportion preparing to breed each year and X = (1 - relative density). The Morgan-Mercer-Flodin function is flexible with good statistical fitting properties and is adjusted in the model to correct for new information or to evaluate the effect

of different functional forms on model performance and sensitivity. Special cases of the Morgan-Mercer-Flodin function include the rectangular hyperbola, the Michaelis-Menten-Monod, the Holling Types I-III and the Hill functions that are used to reflect growth, nutrient uptake, predator consumption or density-dependent demographic functions.

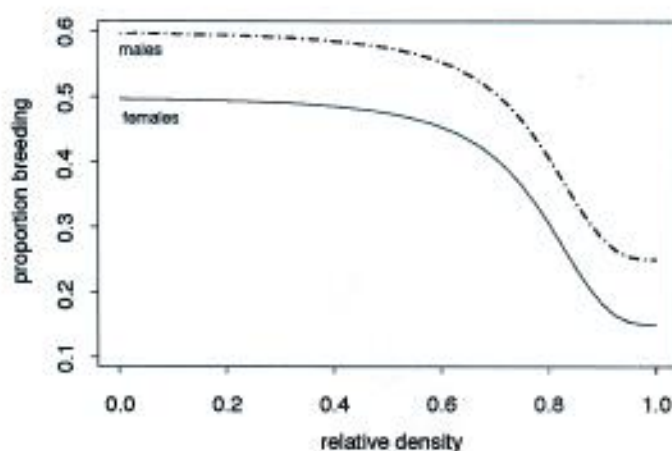


Figure 9 Density-dependent sex-specific probability of breeding functions for Cayman greens. Solid curve shows female annual breeding probability function as a function of the relative benthic substock density. Dashed curve = male breeding probability function. The assumed functional forms are easily changed in the model using interactive parameter slider devices. The functional form used here is based on the Morgan-Mercer-Flodin function that includes other common functional forms as special cases.

9. Depensatory effects

The actual number of females breeding and then nesting depends not only on preparing to breed and migrating to the regional rookery but also the probability of actually finding at least 1 male to mate with in the courtship grounds. For instance, if many females are ready to mate but there are too few males then many potential pregnancies will not be realised due to the male shortage. This is a form of depensatory density-dependence known as an Allee effect (Dennis 1989) that is an important process affecting the recovery or rebound capacity of populations exposed to perturbations such as harvesting or a run of ecological catastrophes. The mating success probability function used in the model was based on a Morgan-Mercer-Flodin function (Fig 10), where: $y = (a \cdot b + c \cdot X^d) / (b + X^d)$, (a-d) are adjustable parameters, y = probability of a female in the courtship grounds finding and mating with at least 1 male and X = relative density of mature males assuming they migrated to the courtship grounds.

This form based on relative density is adopted here mainly to implement sex-biased harvesting or loss potential in the model and assumes that it is the relative abundance of females to males that effects the probability of encountering a mate in the courtship grounds. It is also assumed here that there is some form of competition between females for mates. It is important to note that the functional form in the model shown in Fig 10 is generic and not based on empirical data for the Cayman green stock. Nonetheless, the function is readily adjusted to reflect other forms if necessary and to evaluate the effect of various forms on model performance and sensitivity.

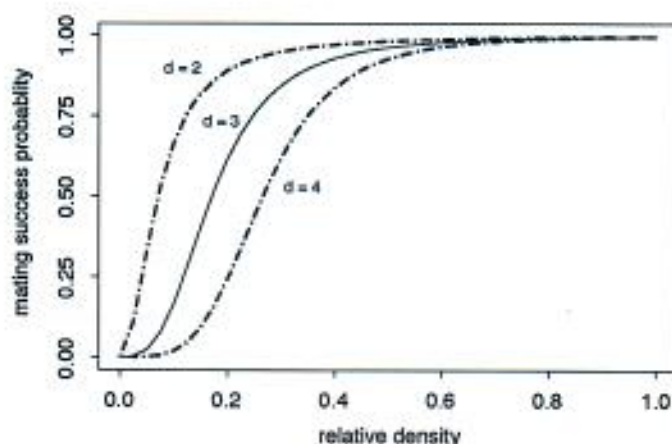


Figure 10 Density-dependent female mating success function (probability of a Cayman female green turtle finding and mating with at least 1 male given relative density of breeding males and females in the courtship grounds. Solid curve shows function setting in model while the 2 dashed curves show other forms possible in model by simple changes to a specific parameter setting.

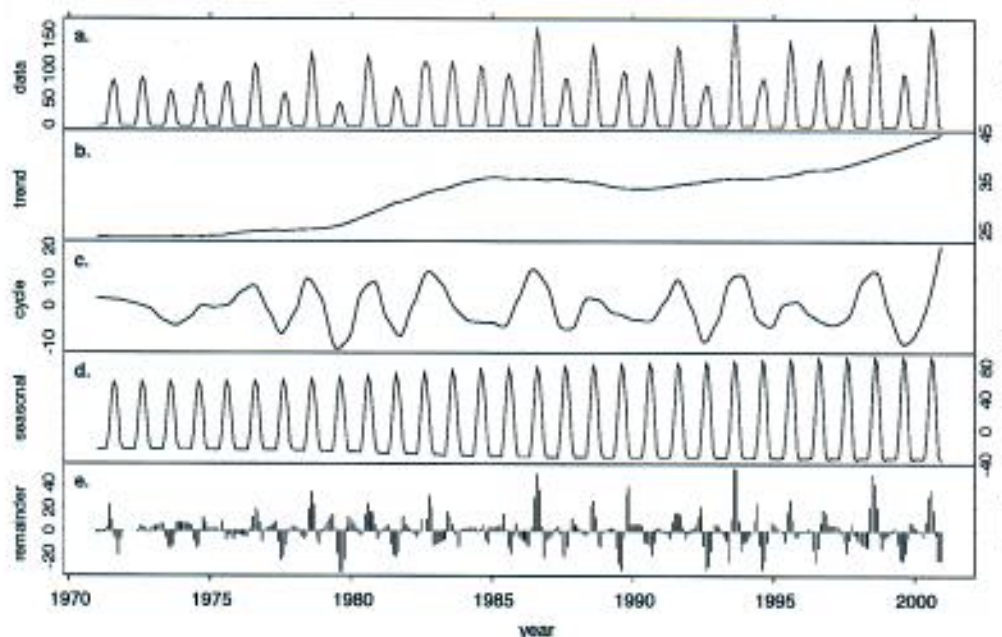


Figure 11 STL decomposition plot of the estimated number of green turtle nests laid each month at the Tortuguero rookery (1971-2000) — note square root scale for data series. Panel (a) estimated annual nests laid series. Panel (b) fitted long-term trend or low-frequency variation in estimated number of nests laid (bandwidth of trend filter = 9 yr). Panel (c) fitted 2-3 year quasi-periodic trend or high-frequency variation in estimated nests laid (bandwidth of trend filter = 4 yr). Panel (d) residual component remaining after the trend (panel b) and quasi-periodicity (panel c) components have been fitted to the series. The 3 components shown in panels (b to d) sum exactly to the series shown in panel (a). The panel scales are not the same so the vertical bar at the right of each panel indicates relative variation in scaling amongst the components and original series. Hence the seasonal and residual are substantial components of the original realisation shown in (a). Note also that the magnitude of the seasonal component (d) increased significantly over the 30-yr period. See Chaloupka (2001) for details of time series decomposition methods based on robust nonparametric regression modelling such as STL, which uses less smoothing methods (Cleveland et al 1990).

10. Population trends

Population trends can be a useful measure of stock status and condition when used cautiously (Bjorndal et al 1999, Chaloupka & Limpus 2001a). Trends also provide one basis for simulation model evaluation by serving as an empirical benchmark to assessment model performance. Bjorndal et al (unpubl) estimated the ageclass-specific abundance of green turtles in 2 foraging ground populations around the Bahamas. These estimates were derived using a Horwitz-Thompson type estimator based on CJS estimates of ageclass-specific recapture probabilities (see Bjorndal et al 2003). These estimates provide a basis for deriving some initial density estimates and a some basis for estimating of the overall metapopulation abundance — useful for initialising the simulation model. Bjorndal et al (1999) provide a nesting time series for the Tortuguero nesting substock while Aiken et al (2001) show that the Cayman nesting substock remains seriously depleted. A time series decomposition analysis of the Tortuguero nesting data is shown in Fig 11 using a robust nonparametric procedure (Chaloupka 2001a). The most important feature of these data is (1) the long term increase and (2) the quasi 3 year periodicity in nester abundance (Fig 11d). The use of nesting beach (Bjorndal et al 1999) and foraging ground abundance trends (Bjorndal et al in prep) are used in this project to evaluate model performance and model calibration.

11. Environmental and demographic stochasticity

The variability in remigration intervals or probability of breeding and nesting variability is assumed to be due to fluctuations in environmental factors such as SST, food and so on that effect survival or breeding behaviour. Environmental stochasticity is included in the model by sampling various demographic parameters from specified pdfs that reflect both measurement error and environmental stochasticity. The model does not explicitly account for what are the factors driving the environmental stochasticity, except for beach temperature. Chaloupka (2001a) has shown that regionally synchronised nesting fluctuations for southeast Asian green sea turtle populations (hence interannual variability in breeding probability) was most likely due to fluctuations in SST and hence ENSO events. This may also be correct for Cayman greens but there is no empirical basis for this view so no attempt has been made here to explicitly link breeding behaviour to ENSO events, although this has been done elsewhere (Chaloupka 2002). The model also includes demographic stochasticity (see Engen et al 1998). For instance, the expected number of clutches was also subject to demographic stochasticity by using a binomial sampling approach (Akçakaya 1991) with expected clutch size and expected number of nesting females. The actual number of hatchlings was subject to demographic stochasticity by sampling expected number of clutches, clutch frequency and egg survival probabilities using Poisson sampling (Brillinger 1986, Gustafsson 2000). The hatchling sex ratio in the simulation model is subject to demographic stochasticity using binomial sampling (Akçakaya 1991), as suggested by Brook et al (2000).

12. Other competing risks included in model

It was important to model simultaneously all anthropogenic hazards because of the problem of competing risks. The point is that a turtle cannot be killed twice and so mortality risks are not additive making it difficult to quantify cause-specific effects in the presence of competing risks. The model includes the capacity to account for cause-specific mortality using a multiplicative competing risks approach (see Chiang 1991). Two forms of harvest strategy or

loss functions that might be attributable to incidental drowning in coastal fisheries or minor losses due to boat strikes are explicitly accounted for in the model —

- constant rate or loss (Getz & Haight 1989)
- constant offtake or loss (Getz & Haight 1989)

Threshold-based including pure and proportional forms of harvesting of subadult and/or adult loggerhead turtles with or without stock assessment uncertainty (Lande et al 1997) have been included in other similar models but not for this particular model.

Other hazards to long-term Cayman green stock viability that are include in this model are —

- coastal fisheries
- subsistence harvesting
- egg harvest, poaching and nesting habitat loss

References

- Aiken JJ, Godley BJ, Broderick AC, Austin T, Ebanks-Petrie G, Hays GC (2001) Two hundred years after a commercial marine turtle fishery: the current status of marine nesting in the Cayman Islands. *Oryx* 35: 145-151 (see also Aiken et al 2001 in MTN 95: 13 for updates)
- Akçakaya H, Raphael M (1998) Assessing human impact despite uncertainty: viability of the northern spotted owl metapopulation in the northwestern USA. *Biodiversity Conserv* 7: 875-894
- Bass A, Witzell W (2000) Demographic composition of immature green turtles (*Chelonia mydas*) from the east central Florida coast: evidence from mtDNA markers. *Herpetologica* 56: 357-367
- Bjorndal K, Carr, A (1989) Variation in clutch size and egg size in the green turtle nesting population at Tortuguero, Costa Rica. *Herpetologica* 45, 181-189.
- Bjorndal K, Bolten A, Chaloupka M (2000) Green turtle somatic growth model: evidence for density-dependence. *Ecol Applic* 10: 269-282
- Bjorndal K, Bolten A, Chaloupka M (2003) Survival probability estimates for immature green turtles, *Chelonia mydas*, in the Bahamas. *Mar Ecol Prog Ser* 252: 273-281
- Bjorndal K, Bolten A, Chaloupka M (in prep) Evaluating green sea turtle abundance in the Bahamas.
- Bjorndal K, Wetherall J, Bolten A, Mortimer J (1999) Twenty-six years of green turtle nesting at Tortuguero, Costa Rica: an encouraging trend. *Conserv Biol* 13: 126-134
- Bolten A (2003) Variation in sea turtle life history patterns: neritic versus oceanic developmental stages. In: Lutz P, Musick J, Wyneken J (eds) *The biology of sea turtles*, volume 2. CRC Press, Boca Raton, FL, p 243-257
- Bowen B, Meylan A, Ross J, Limpus C, Balazs G, Avise J (1992) Global population structure and natural history of the green turtle (*Chelonia mydas*) in terms of matriarchal phylogeny. *Evol* 46: 865-881
- Brillinger DR (1986) The natural variability of vital rates and associated statistics. *Biometrics* 42: 693-734
- Brook B, Burgman M, Frankham R (2000) Differences and congruencies between PVA packages: importance of sex ratio for predictions of extinction risk. *Conserv Ecol* 4: pp 17
- Carr A, Carr M, Meylan A (1978) The ecology and migrations of sea turtles, 7. The west Caribbean green turtle colony. *Bull Am Mus Nat Hist* 162: 1-46

- Chaloupka M (2001a) Historical trends, seasonality and spatial synchrony in green turtle egg production. *Biological Conservation* 101: 263-279
- Chaloupka M (2001b) System-of-equations growth function for southern Great Barrier Reef green sea turtles. *Chelonian Conserv Biol* 4: 88-93
- Chaloupka M (2002) Stochastic simulation modelling of southern Great Barrier Reef green turtle population dynamics. *Ecol Modelling* 148: 79-109
- Chaloupka M (2003) Stochastic simulation modeling of loggerhead sea turtle population dynamics given exposed to competing mortality risks in the western South Pacific region. In: Bolten A, Witherington B (eds) *The biology and conservation of loggerhead sea turtles*. Smithsonian Institution Press, Washington DC, p 274-295
- Chaloupka M (2004) Exploring the metapopulation dynamics of the southern Great Barrier Reef green sea turtle genetic stock and the possible consequences of sex-biased local harvesting. In: Akçakaya H, Burgman M, Kindvall O, Wood C, Sjogren-Gulve P, Hattfield J, McCarthy M (eds) *Species conservation and management: case studies*. Oxford University Press Inc, New York
- Chaloupka M, Limpus C (2001a) Trends in the abundance of sea turtles resident in southern Great Barrier Reef waters. *Biol Conserv* 102: 235-249
- Chaloupka M, Limpus C (2001b) Estimates of survival probabilities for the endangered loggerhead sea turtle resident in southern Great Barrier Reef waters. *Marine Biology* 140: 267-277
- Chaloupka M, Limpus C, Miller J (2003) Sea turtle growth dynamics in a spatially structured metapopulation. *Coral Reefs*
- Chiang CL (1991) Competing risks in mortality analysis. *Ann Rev Pub Health* 12: 281-307
- Cleveland R, Cleveland W, McRae J, Terpenning P (1990) STL: a seasonal-trend decomposition procedure based on Loess. *Journal of Official Statistics* 6: 3-73
- Dennis B (1989) Allee effects: population growth, critical density and the chance of extinction. *Nat Res Modeling* 3: 481-538
- Engen S, Bakke O, Islam A (1998) Demographic and environmental stochasticity - concepts and definitions. *Biometrics* 54: 39-45
- Getz W, Haight R (1989) Population harvesting: demographic models of fish, forests and animal resources. *Monographs in Population Biology* 27, Princeton University Press, Princeton, New Jersey
- Godfrey M, Barreto R, Mrosovsky N (1996) Estimating past and present sex ratios of sea turtles in Suriname. *Can J Zool* 74: 267-277
- Gustafsson L (2000) Poisson simulation - a method for generating stochastic variations in continuous system simulations. *Simulation* 74: 264-274
- Gyuris E (1994) The rate of predation by fishes on hatchlings of the green turtle (*Chelonia mydas*). *Coral Reefs* 13: 137-144
- Johnson S, Ehrhart L (1996) Reproductive ecology of the Florida green turtle: clutch frequency. *J Herpetol* 30: 407-410
- Kwan D (1994) Fat reserves and reproduction in the green turtle, *Chelonia mydas*. *Wildl Res* 21: 257-266
- Lahanas P, Bjorndal K, Bolten A, Encalada S, Miyamoto M, Valverde R, Bowen B (1998) Genetic composition of a green turtle (*Chelonia mydas*) feeding ground population: evidence for multiple origins. *Mar Biol* 130:345-352

- Lande R, Saether B, Engen S (1997) Threshold harvesting for sustainability of fluctuating resources. *Ecology* 78: 1341-1350
- Limpus CJ (1993) The green turtle, *Chelonia mydas*, in Queensland: breeding males in the southern Great Barrier Reef. *Wildl Res* 20: 513-523
- Limpus C, Couper P, Read M (1994) The green turtle, *Chelonia mydas*, in Queensland: population structure in a warm temperate feeding area. *Mem Queensland Mus* 35: 139-154
- Limpus C, Reed P (1985) The green turtle, *Chelonia mydas*, in Queensland: a preliminary description of the population structure in a coral reef feeding ground. In: Grigg G, Shine R, Ehmann H (eds) *Biology of Australasian Frogs and Reptiles*. Royal Society of New South Wales, Sydney, p 47-52
- Macey R, Oster G, Zahnley T (2000) *Berkeley Madonna User's Guide*. Version 8.0. University of California, Berkeley
- Mortimer J, Carr A (1987) Reproduction and migrations of the Ascension Island green turtle (*Chelonia mydas*). *Copeia* 1987, 103-113
- Parsons JJ (1962) *The Green Turtle and Man*. University of Florida Press, Gainesville
- Seminoff J, Jones T, Resendiz A, Nichols W, Chaloupka M (in press) Status of green turtles (*Chelonia mydas*) at Bahía de los Angeles, Baja California, México: are human impacts preventing recovery at this historically exploited foraging area? *J Mar Biol Assoc UK*
- Solow A, Bjorndal K, Bolten A (2002) Annual variation in nesting numbers of marine turtles: the effect of sea surface temperature on re-migration intervals. *Ecology Letters* 5: 742-746
- Spotila J, Standora E, Morreale S, Ruiz G (1987) *Herpetologica* 43: 74
- Wibbels T, Balazs G, Owens D, Amoss M (1993) Sex ratios of immature green turtles inhabiting the Hawaiian Archipelago. *J Herpetol* 27: 327-329
- Witzell W (1994) The origin, evolution and demise of the US sea turtle fisheries. *Mar Fish Rev* 56: 8-23
- Zug G, Glor R (1998) Estimates of age and growth in a population of green sea turtles (*Chelonia mydas*) from the Indian River lagoon system, Florida: a skeletochronological analysis. *Can J Zool* 76: 1497-1506

Certificate of Participation

CAYMAN
turtle farm



George Balazs

Participated in the

Cayman Turtle Farm Western Atlantic Green Turtle Population Model Symposium

October 22- 24, 2003

A handwritten signature in cursive script, appearing to read "Milani Chaloupka".

Chaired by: Dr. Milani Chaloupka

A handwritten signature in cursive script, appearing to read "Alan Bolten".

Dr. Alan Bolten



A new start



Turtles are a hands-on experience

After the wrath of Hurricane Michelle, Cayman Turtle Farm is looking towards a bright new future. CAROL GRAY reports

No-one who was near the Cayman Turtle Farm when Hurricane Michelle unleashed her fury on Grand Cayman's northwest point will easily forget the destruction and devastation of that day. "The date is imprinted on my brain," says Turtle Farm managing director Kenneth Hydes. "I might occasionally forget my wedding anniversary. But I'll never forget that Sunday, November 4 2001!"

The storm had been hovering around the Caribbean for some time. Grand Cayman was calm, however. The omens were good. On the Friday evening, the winds shifted slightly. The Turtle Farm staff were advised of a potential problem. The following day, wind speeds were still low. The farm staff, nevertheless, began taking the sort of routine precautions they take three or four times every year during the hurricane season.

Turtles in display tanks closest to the ocean were moved to tanks across the road. A decision was taken to drain the large breeding pond of its million gallons of water. Moving the breeders was out of the question. There were 352 of them in the tank, their weight ranging from 200 to 600lbs; but, most importantly, the storm came during the nesting season. "To move them then is problematical at best and risky at worst," explains Hydes. As the day progressed, more staff arrived to help. By evening, all personnel were on duty.

"All the signs were that the storm would pass us by," recalls Hydes. "Then, seemingly from nowhere, at 8 pm on Saturday, a large wall of water crashed down on

us. The entire electrical room was flooded." In darkness, staff worked through the night. The ocean swells were large but winds still moderate. The staff slept for a few hours on makeshift bunks at the farm. "I awoke at 7 am," Hydes remembers, "and saw the tanks and buildings intact." He heaved a sigh of relief.

Not five minutes later, he realised just how presumptuous he'd been: an awful spectacle loomed over him. "The ocean stood up. That's the only way to describe it: water towered ten feet above the top of the sea wall and crashed down. Each successive wave became larger and stronger." The breeding pond that had taken three hours to drain, filled fast. The massive breeders were caught by the force of the water, tossed off their beach, pulled back into the pond. Within an hour, Hydes and the staff realised that disaster was staring them in the face. All they could do was try to protect as many turtles as possible.

Community effort

The day's silver lining became visible sooner than anyone could have imagined possible. People appeared from nowhere to help. "The sheer commitment of the entire community was breathtaking," says Hydes. "The Hon McKeever Bush, Chairman of the Farm, took charge of rescue efforts. All the West Bay MLAs were also involved in a hands-on way. It was becoming dangerous. The wind speed was picking up to about 40 mph. There was so much water underfoot that people who didn't know the contours of the farm were at risk. No-one seemed to care. Help came from every



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The farm has a large stock of breeding turtles.



Take part in the turtle release programme.

direction. Equipment arrived, pumps were offered, the police and fire brigade came to help, bottles of drinking water were delivered, restaurants sent food, the Red Cross was on standby.

"The Jackson family in West Bay offered us the use of their saltwater pond. People carried turtles back and forth, up to six thousand turtles were carried there." All the while, the storm raged. Hydes later noted that the clock which had hung high on the wall in the snack bar stopped at 11.32 am. Soon afterwards, the entire restaurant was submerged. It took another seven hours before the storm abated. Then the clean-up began. Still the community wanted to help. "Many people came back at night to help us to secure the property. Staff at our freight company offered to help clear up. The Department of the Environment and the Port Authority, and others, pitched in too. The effort went on for days."

The toll on the farm was heavy. The farm's stock of 24,000 turtles is down to about 20,000. The most devastating loss was from the breeding pond: 77 per cent of the breeding herd was lost. Of the 59 females remaining, some are too young to reliably produce eggs. An appeal to specially-licensed Caymanian fishermen from the Farm's marine biologist Joe Parsons for help in capturing the farm's breeders did not fall on deaf ears. Six weeks after the storm, the first breeder, a 250lb female, was caught in the North Sound and returned to the farm. In the next four months, more than a dozen other breeders were

returned. It will nevertheless take many years to restore the breeding herd to pre-Michelle levels.

Community effort

The good news is that plans to upgrade the Turtle Farm, which were already well advanced before the devastation of Hurricane Michelle, have now been fast-forwarded. Work has started on the new multi-million dollar facility across the road from the old site. Designed after Cayman Turtle Farm consulted with a cross-section of people working in Cayman's tourism industry, the new facility will be both functional as a farm and research center, and attractive as a visitor center. "We will have sophisticated research and farming facilities. But we will also incorporate some of the magnificent natural attractions of the site to offer visitors a snorkel lagoon, a large aviary, a nature trail, an aquarium, a retail village, better viewing tanks... In other words," Hydes says, "instead of a brief visit, people will want to come to spend the day with us." Watch this space!

The children were concerned...

"I felt scared about the storm. The places by the seas got mashed down." Sadi Smalldon.

"The storm was very bad. The Turtle Farm is messy. I hope that the turtles do not become extinct." Rachel Levy.

From the children of Bodden Town Primary



Destruction of the Turtle Farm

Information

For information on the Turtle Farm, including the role it has played in boosting the turtle populations in open seas surrounding the Cayman Islands and its highly-regarded scientific research into the green sea turtle, see the farm's website at:

ES www.turtle.ky

A must-see item on the list of historical highlights in Cayman would have to be Pedro St. James 'Castle'. Built with slave labor from Jamaica in 1780 by an Englishman, William Eden, the massive stone structure, the oldest in the Cayman Islands, has had a very colorful existence. Built as the centre-piece of a surrounding plantation, its functions in the two hundred years since have varied between courthouse, jail, Government Assembly, restaurant and social venue, to name a few. In its time, the 'Castle', with its unique rambling mahogany verandahs, has survived hurricanes, fires and vandalism, leading to speculations of it being jinxed or haunted, to the point where it was completely abandoned for many years and fell into extensive ruin. It was acquired by Government in 1991; restored at great expense, and stands today as a dynamic piece of Caymanian heritage.



Perched on seven acres of land on a spectacular seaside bluff, Pedro 'Castle', as the locals call it, now towers over a separate stone building that tells the story of the castle through a rousing audio-visual show. Complete with lightning and rain effects, the show runs hourly in an air-conditioned theatre and has been rated 'the best in the Caribbean' by observers from the travel trade.

Visitors to the site - it's open daily - can stroll through the historic castle with the restored dungeon that was once used as a jail, and view many of the artifacts commonly used in Cayman at that time. In its early life, the building was also the site of official meetings including one where Caymanians first met to form their own elected assembly, and it is therefore now labelled 'the birthplace of democracy in the Cayman Islands'.

In addition to the artifacts, the building contains some interesting examples of traditional furniture, including the planter's chair, with extendable wooden arms to rest weary legs, and light-weight daybeds that could be moved around the verandahs by residents to catch the shifting shade. The site today also houses a gift shop known for its



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The momentous decision to hold the first district elections for an island legislature took place at Pedro St. James on the 5th of December 1831.

high-quality items, and plans are also in train to display a collection of Caymanian stamps in a 'history room' being developed close to the audio-visual theatre. (By the time you read this, the stamps may be in place.)

Popular as a venue for weddings and other social occasions, Pedro Castle can also boast the most strikingly beautiful seaside view in Grand Cayman. Situated 20 minutes' drive east from the Seven Mile Beach area, it's a memorable one-hour visit.





The farm has a large stock of breeding turtles



Take part in the turtle release programme

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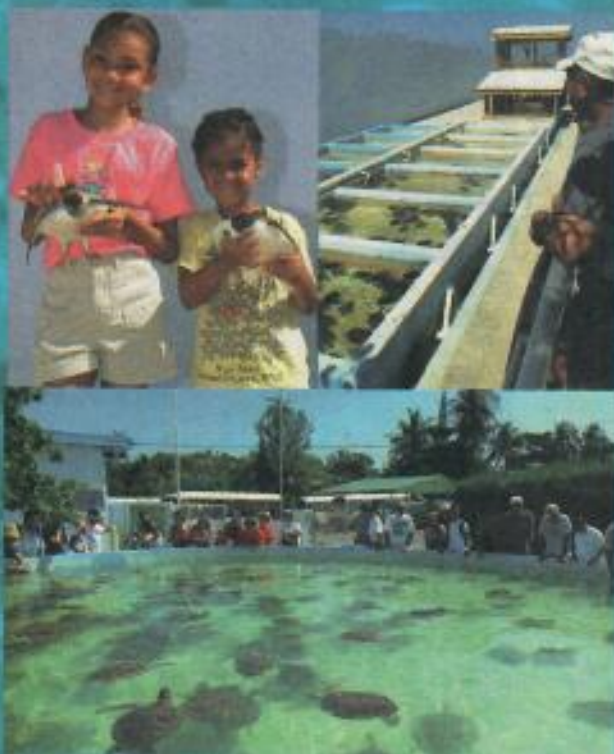
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The Cayman Turtle Farm's conservation programme is the most unique initiative of its kind in the world and the Cayman Islands' most visited attraction.

Cayman Turtle Farm's most important objective is the breeding of the endangered green sea turtle for education, utilization and research. This pioneering work receives no grant aid or external funding but relies mainly on income derived from our visitors.

During a visit you will gain first hand knowledge of the important work that has made the farm a successful conservation tool. Delight in the tiny hatchlings and marvel at the colossal adults as they glide majestically through the water. Local fauna of the Cayman Islands

compliment your tour. Enjoy the opportunity to photograph the Cayman Green Parrots, Iguanas, Hicatees and the farm has special tanks of young turtles so that visitors get to touch and hold these wonderful sea creatures!

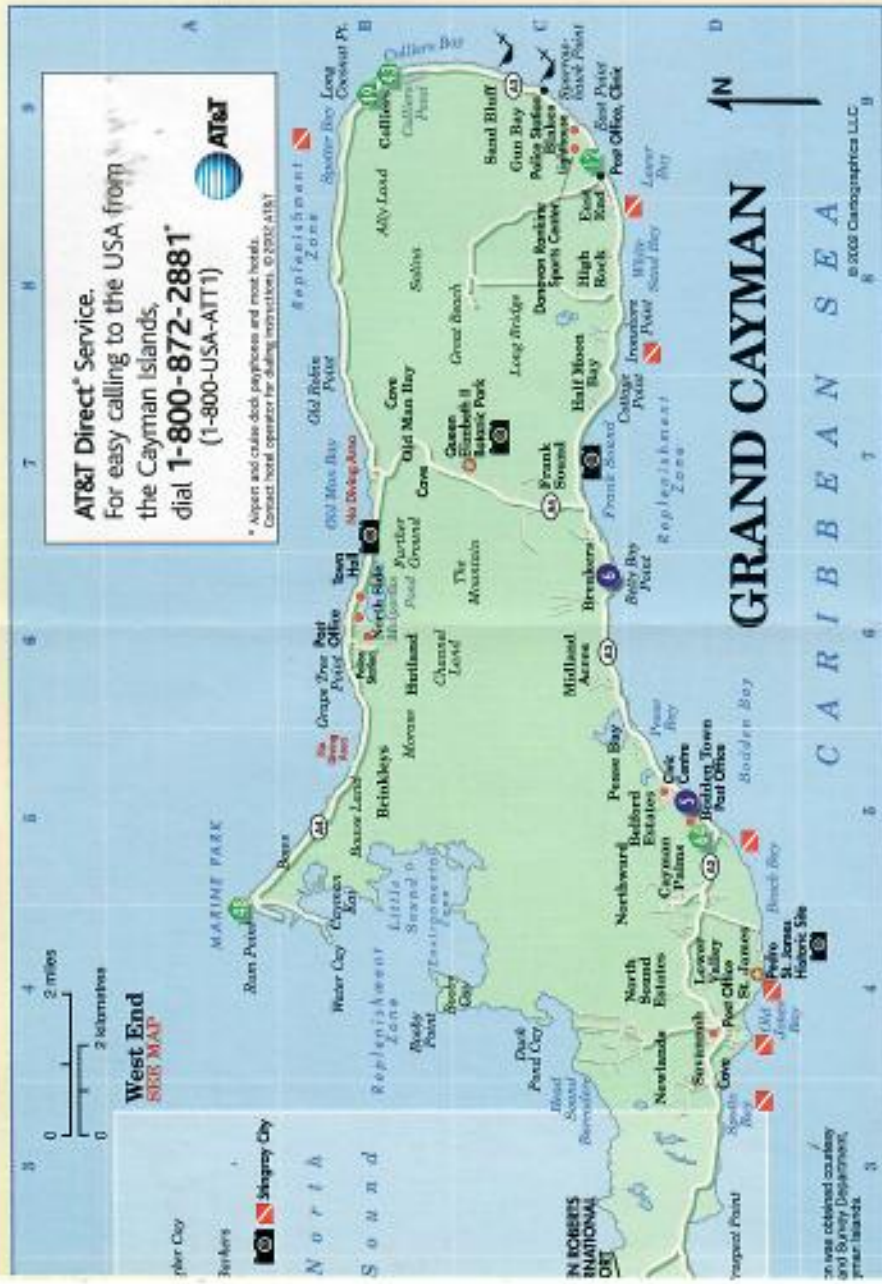
The gift shop offers an unparalleled selection of both turtle and marine-life souvenirs. Every time you visit the farm or make a purchase at our gift shop or online at www.turtle.ly, you are contributing to the continuity of the farm's programmes.



2002



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23. **The Coralstone Club**, Seven Mile Beach (C-5) 945-5820
24. **Crescent Point Resort**, Seven Mile Beach (I-4) 945-2243
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26. **Eldemire's Guesthouse**, George Town (L-4) 949-6907
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28. **Grand Cayman Marriott Beach Resort**
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29. **Grand Caymanian Golf Resort**, North Sound (F-6) 949-3100
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31. **Graptree Cocoplum**, George Town (I-4) 949-5640
32. **Harbour Heights**, Seven Mile Beach (F-5) 945-4295
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35. **Hyatt Regency**, Seven Mile Beach (H-5) 949-1234
36. **Indies Suites**, Seven Mile Beach (E-5) 945-5025
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38. **Islands Club**, Seven Mile Beach (H-5) 945-5211
39. **Lacovia Condominiums**, Seven Mile Beach (H-5) 949-7599
40. **Little Cayman Beach Resort**, South Town,
(Little Cayman Map D-2) 948-1033
41. **London House**, Seven Mile Beach (E-4) 945-4060
42. **The Meridian**, Seven Mile Beach (G-5) 945-4002
43. **Morrill's Tortuga Club & Resort**, East End
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44. **Paradise Villas**, South Town (Little Cayman Map D-2) 948-0001
45. **Plantanaa Condos**, Seven Mile Beach (F-5) 945-4430
46. **Plantation Village**, Seven Mile Beach (I-4) 949-4199
47. **Regal Beach Club**, Seven Mile Beach (I-5) 945-6189
48. **Retreat at Rum Point**, Rum Point
(Grand Cayman Map A-4) 947-9135
49. **Royal Reef Resort**, East End (Grand Cayman B-9) 945-8400
50. **Sammy's Airport Inn**, George Town (K-6) 945-2100
51. **Seagull Condos**, Seven Mile Beach (H-5) 949-5756
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53. **Seven Mile Beach Resort**, Seven Mile Beach (I-4) 949-0332
54. **Silver Sands Condos**, Seven Mile Beach (D-4) 949-3343
55. **Southern Cross Club**, South Town
(Little Cayman Map D-3) 948-1099
56. **Spanish Bay Reef Resort**, Conch Point (A-4) 949-3765
57. **Sunset House**, South Church Street (I-4) 949-7111
58. **Sunshine Suites**, Seven Mile Beach (G-5) 949-3000
59. **Tamarind Bay**, Seven Mile Beach (I-4) 949-4593
60. **Tarquay Manor**, Seven Mile Beach (E-4) 945-4038
61. **Treasure Island Condos**, Seven Mile Beach (I-4) 949-8533
62. **Treasure Island Resort**, Seven Mile Beach (I-4) 949-7777
63. **Turtle Beach Villas**, Seven Mile Beach (I-4) 949-6347
64. **Turtle Nest Inn**, Bodden Town
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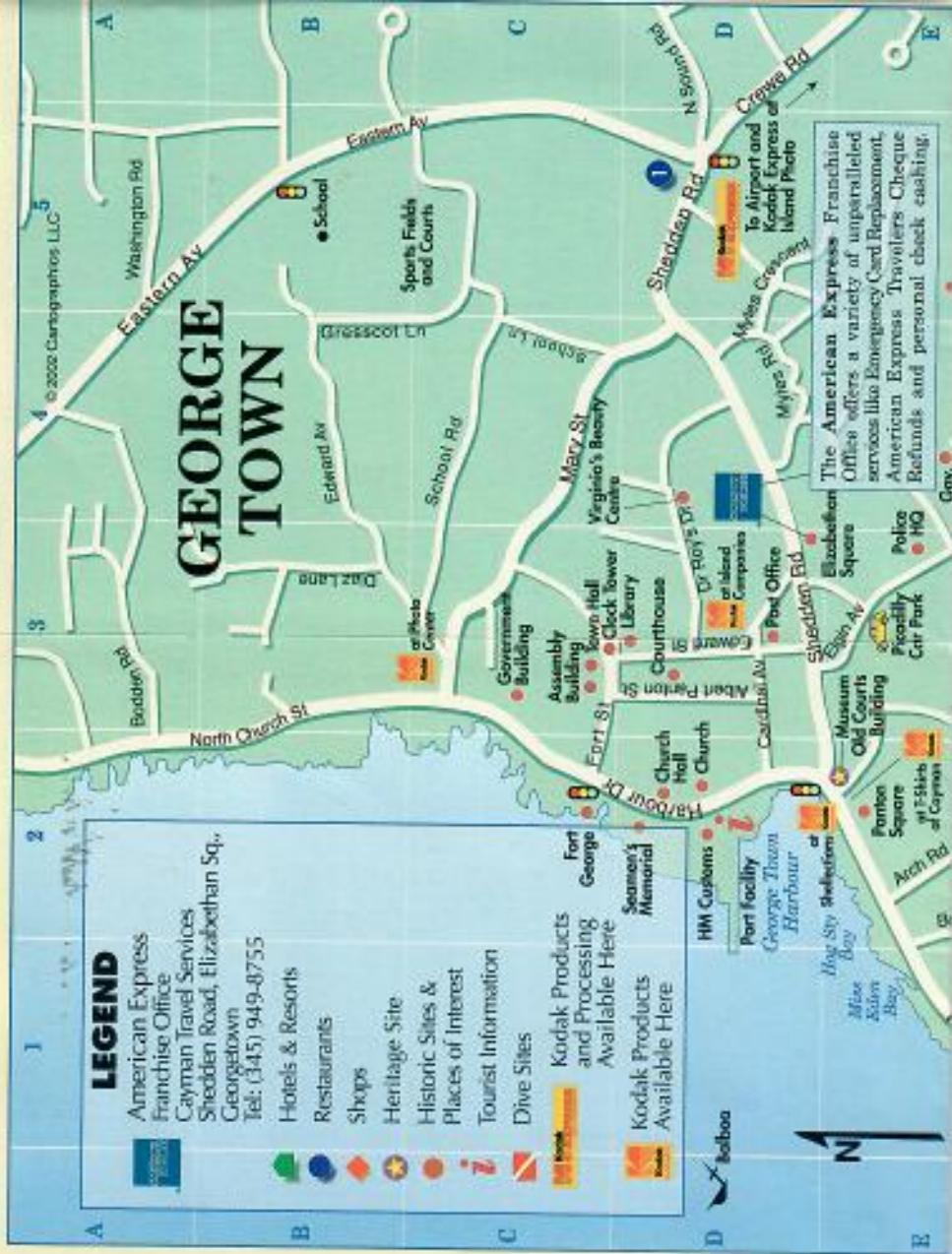


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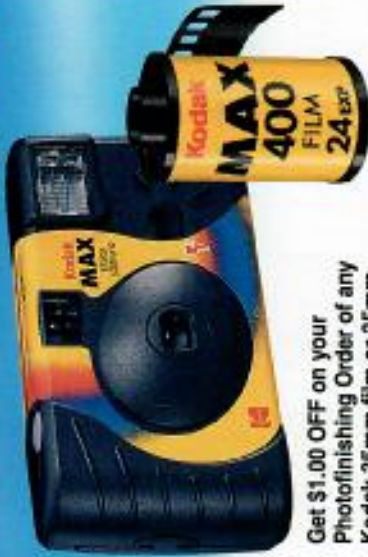
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 23. **The Coralstone Club, Seven Mile Beach (G-5)** 945-5820
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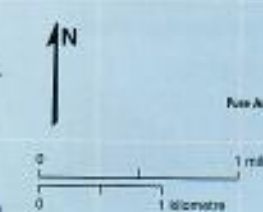
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Published by
Cartographics LLC
1501 Red Hook Plaza
Suite 201 PMB
St. Thomas, USVI 00602
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