4th HPU Sea Turtle Workshop
(Honolulu, Hawaii, USA: October 2024)

Corpulent or malnourished? Depends on where the world's most abundant large marine herbivores live

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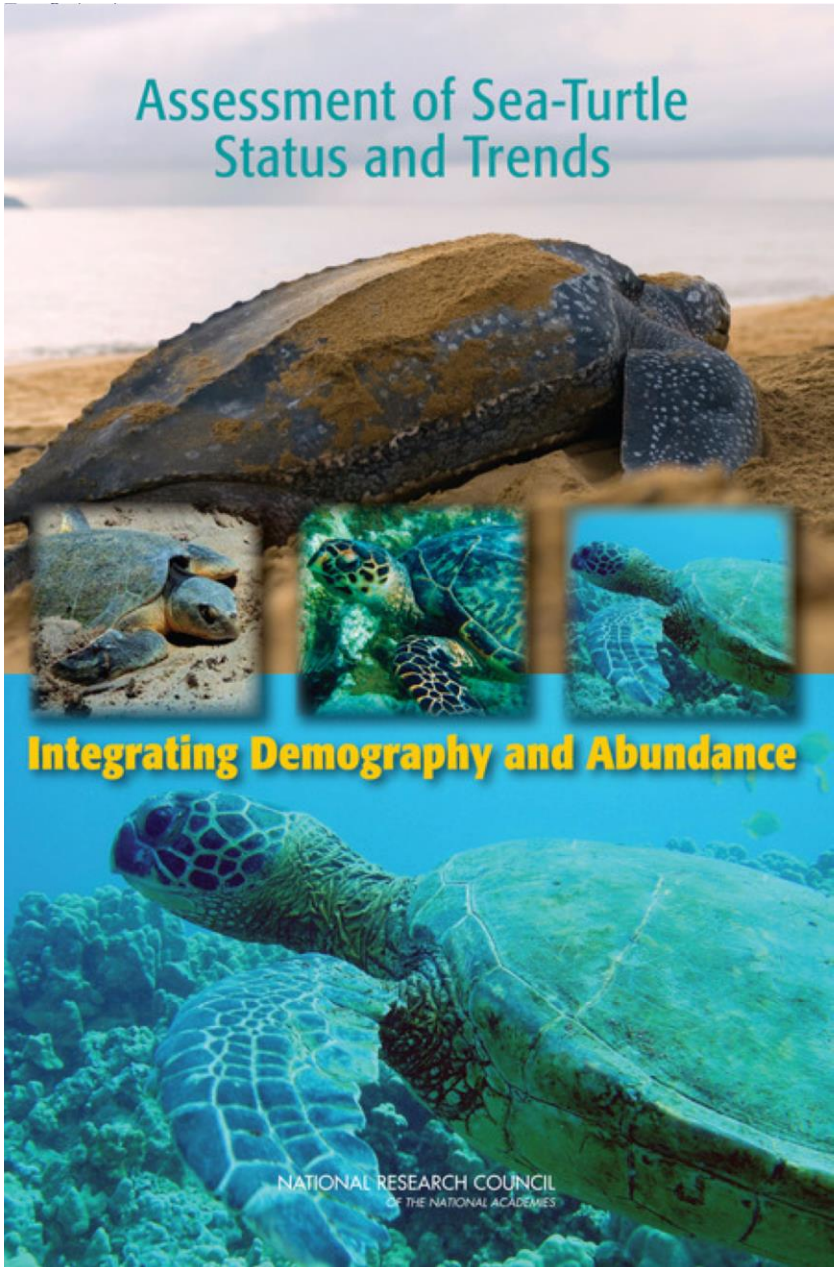
Canonical perspective…



Insights into marine turtle **demographic processes** are essential to diagnose long-term trends in population abundance and support **evidence-informed** conservation

Processes such as habitat-, sex- and age-specific survival, breeding propensity and **somatic growth and maturation**

We focus on **growth and spatial variation** in growth for green turtle stocks resident in 2 major Pacific Ocean ecosystems:

- **Hawaiian Archipelago**
- **Great Barrier Reef**

These 2 genetic stocks have been monitored for **> 40 years** using robust **capture-mark-recapture** sampling program

Long-term monitoring programs are the foundation for robust estimation of green turtle demographic rates and population abundance

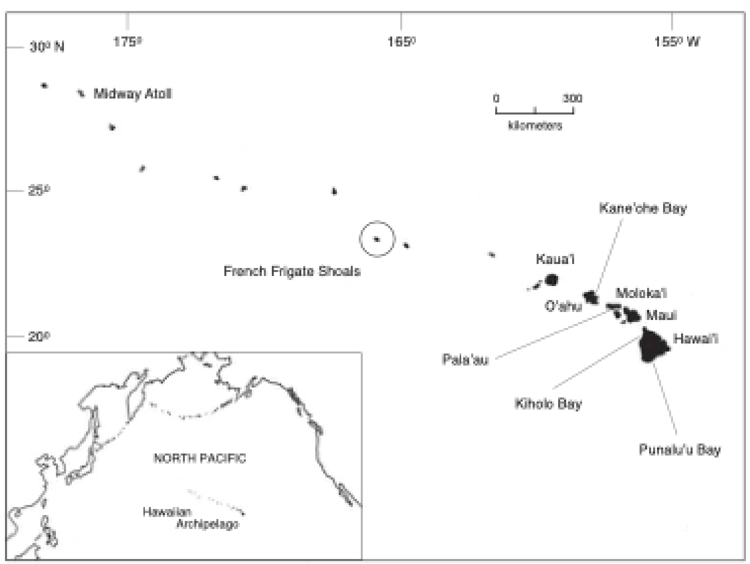
What is so important about growth …

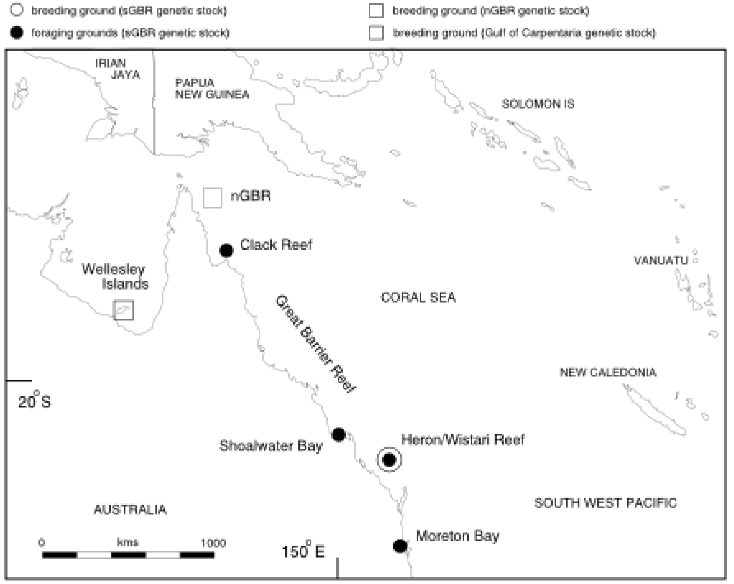
Well, in very simplistic terms:

… the faster you grow the sooner you get to sexual maturity and the sooner you reproduce the sooner you provide off-spring to the next generation

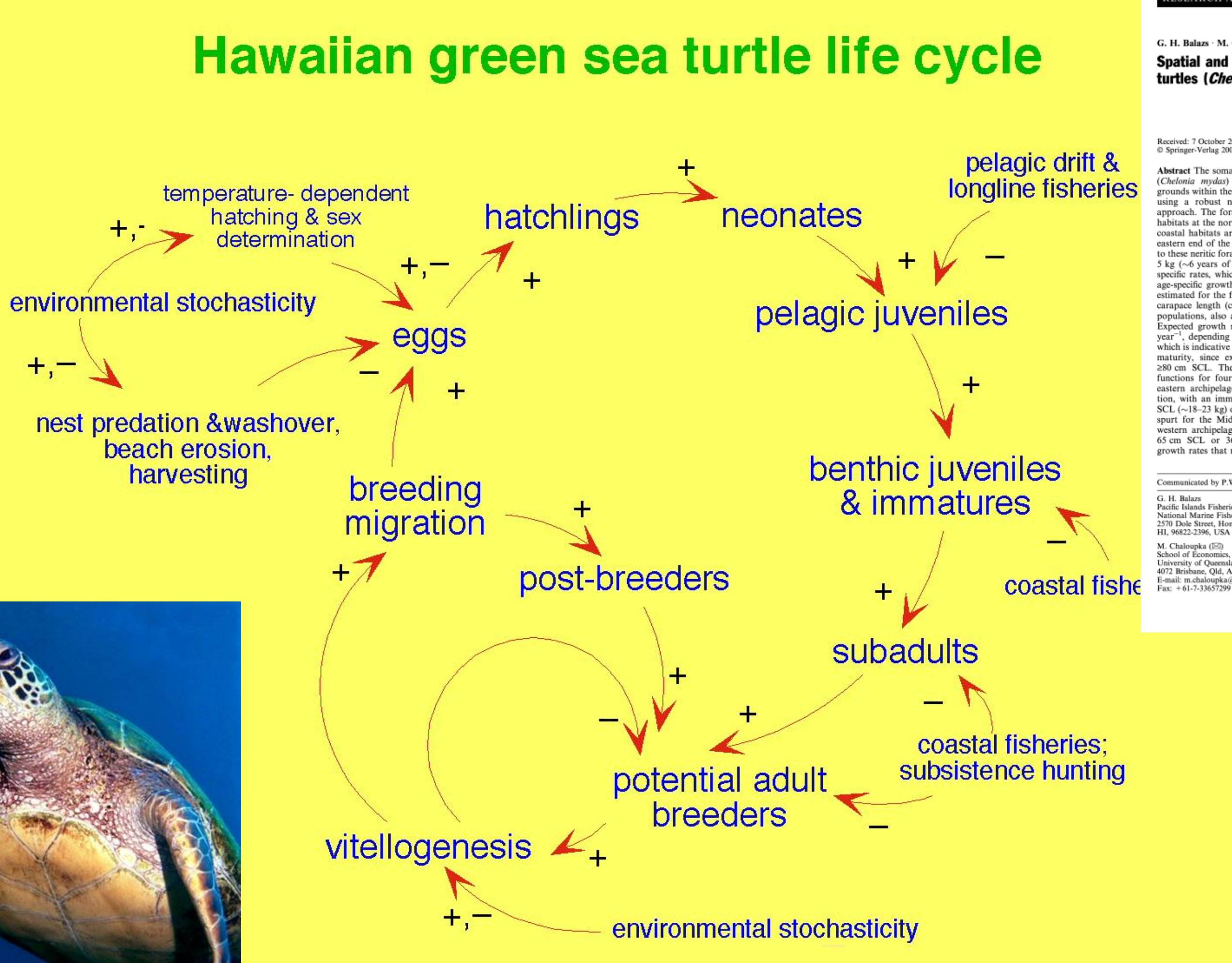
So **somatic growth and maturation** are two sides of the same coin

But **not all green turtles** that are resident in the various foraging habitats for these 2 stocks (Hawaiian Archipelago, Great Barrier Reef) **develop and mature at the same rates**





Hawaiian Archipelago …



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RESEARCH ARTICLE

G. H. Balazs · M. Chaloupka

Spatial and temporal variability in somatic growth of green sea turtles (*Chelonia mydas*) resident in the Hawaiian Archipelago

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Abstract The somatic growth dynamics of green turtles (*Chelonia mydas*) resident in five separate foraging grounds within the Hawaiian Archipelago were assessed using a robust non-parametric regression modelling approach. The foraging grounds range from coral reef habitats at the north-western end of the archipelago, to coastal habitats around the main islands at the south-eastern end of the archipelago. Pelagic juveniles recruit to these neritic foraging grounds from ca. 35 cm SCL or 5 kg (~6 years of age), but grow at foraging-ground-specific rates, which results in quite different size- and age-specific growth rate functions. Growth rates were estimated for the five populations as change in straight carapace length (cm SCL $year^{-1}$) and, for two of the populations, also as change in body mass (kg $year^{-1}$). Expected growth rates varied from ca. 0–2.5 cm SCL $year^{-1}$, depending on the foraging-ground population, which is indicative of slow growth and decades to sexual maturity, since expected size of first-time nesters is ≥80 cm SCL. The expected size-specific growth rate functions for four populations sampled in the south-eastern archipelago displayed a non-monotonic function, with an immature growth spurt at ca. 50–53 cm SCL (~18–23 kg) or ca. 13–19 years of age. The growth spurt for the Midway atoll population in the north-western archipelago occurs at a much larger size (ca. 65 cm SCL or 36 kg), because of slower immature growth rates that might be due to a limited food stock and cooler sea surface temperature. Expected age-at-maturity was estimated to be ca. 35–40 years for the four populations sampled at the south-eastern end of the archipelago, but it might well be > 50 years for the Midway population. The Hawaiian stock comprises mainly the same mtDNA haplotype, with no differences in mtDNA stock composition between foraging-ground populations, so that the geographic variability in somatic growth rates within the archipelago is more likely due to local environmental factors rather than genetic factors. Significant temporal variability was also evident, with expected growth rates declining over the last 10–20 years, while green turtle abundance within the archipelago has increased significantly since the mid-1970s. This inverse relationship between somatic growth rates and population abundance suggests a density-dependent effect on somatic growth dynamics that has also been reported recently for a Caribbean green turtle stock. The Hawaiian green turtle stock is characterised by slow growth rates displaying significant spatial and temporal variation and an immature growth spurt. This is consistent with similar findings for a Great Barrier Reef green turtle stock that also comprises many foraging-ground populations spanning a wide geographic range.

Communicated by P.W. Sammarco, Chauvin

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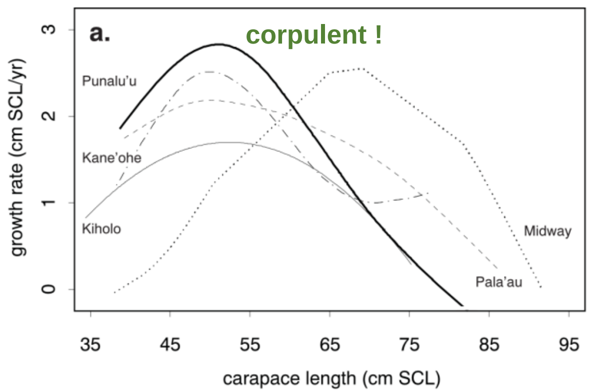
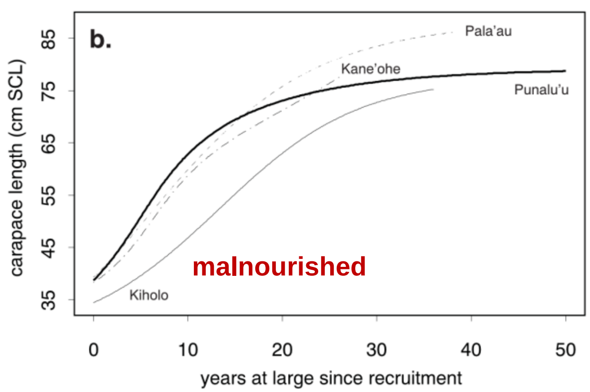
Introduction

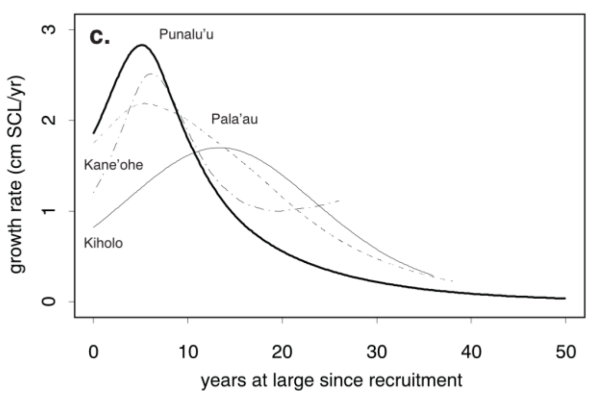
The green sea turtle (*Chelonia mydas*) is a threatened marine turtle species with a broad pan-tropical distribution and distinct regional population substructures (Bowen et al. 1992). Green turtles are the most abundant large, long-lived marine herbivores (Bjorndal 1997) and have a long history of human exploitation for meat and eggs (Parsons 1962; Frazier 1980; Witzell 1994). Many green turtle stocks in the Pacific region are in serious decline (Seminoff 2002), with the populations resident in Great Barrier Reef and Hawaiian waters representing some of the few remaining stocks with apparently viable

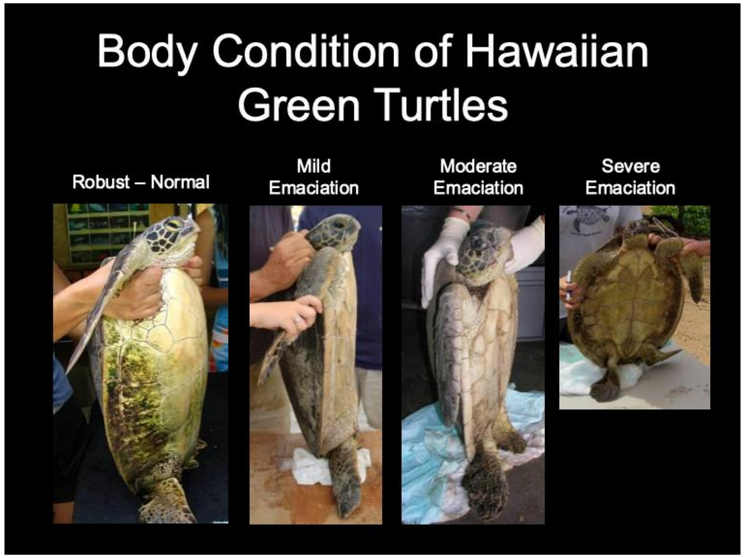
Source: Ursula Bennett

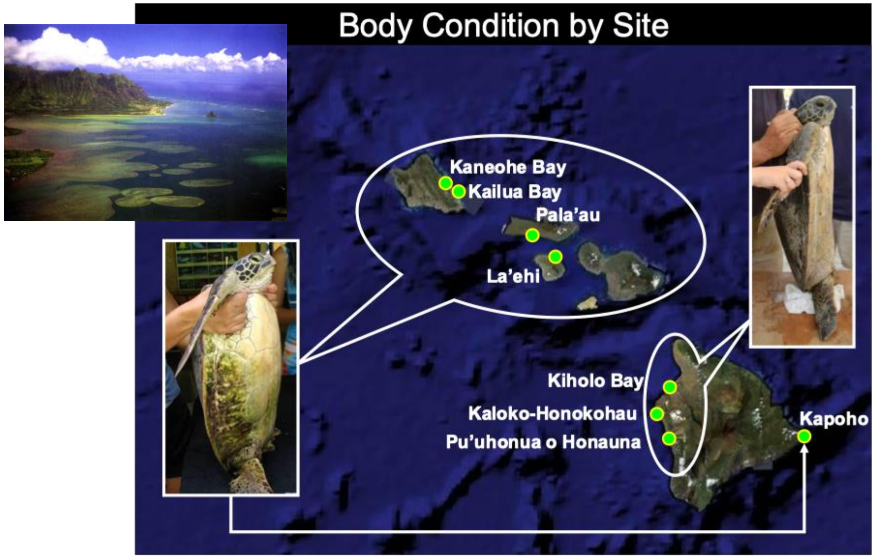
Spatial variation in the Hawaiian Archipelago …











Spatial variation within the Great Barrier Reef…

Coral Reefs (2004) 23: 325–335
DOI 10.1007/s00338-004-0387-9

REPORT

Milani Chaloupka · Colin Limpus · Jeffrey Miller

Green turtle somatic growth dynamics in a spatially disjunct Great Barrier Reef metapopulation

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Abstract The growth dynamics of green sea turtles resident in four separate foraging grounds of the southern Great Barrier Reef genetic stock were assessed using a nonparametric regression modeling approach. Juveniles recruit to these grounds at the same size, but grow at foraging-ground-dependent rates that result in significant differences in expected size- or age-at-maturity. Mean age-at-maturity was estimated to vary from 25–50 years depending on the ground. This stock comprises mainly the same mtDNA haplotype, so geographic variability might be due to local environmental conditions rather than genetic factors, although the variability was not a function of latitudinal variation in environmental conditions or whether the food stock was seagrass or algae. Temporal variability in growth rates was evident in response to local environmental stochasticity, so geographic variability might be due to local food stock dynamics. Despite such variability, the expected size-specific growth rate function at all grounds displayed a similar nonmonotonic growth pattern with a juvenile growth spurt at 60–70 cm curved carapace length, (CCL) or 15–20 years of age. Sex-specific growth differences were also evident with females tending to grow faster than similar-sized males after the juvenile growth spurt. It is clear that slow sex-specific growth displaying both spatial and temporal variability and a juvenile growth spurt are distinct growth behaviors of green turtles from this stock.

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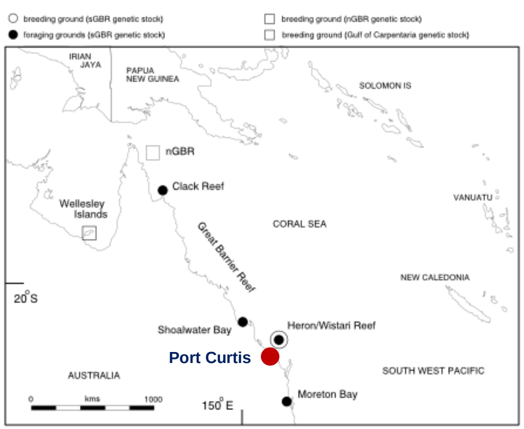
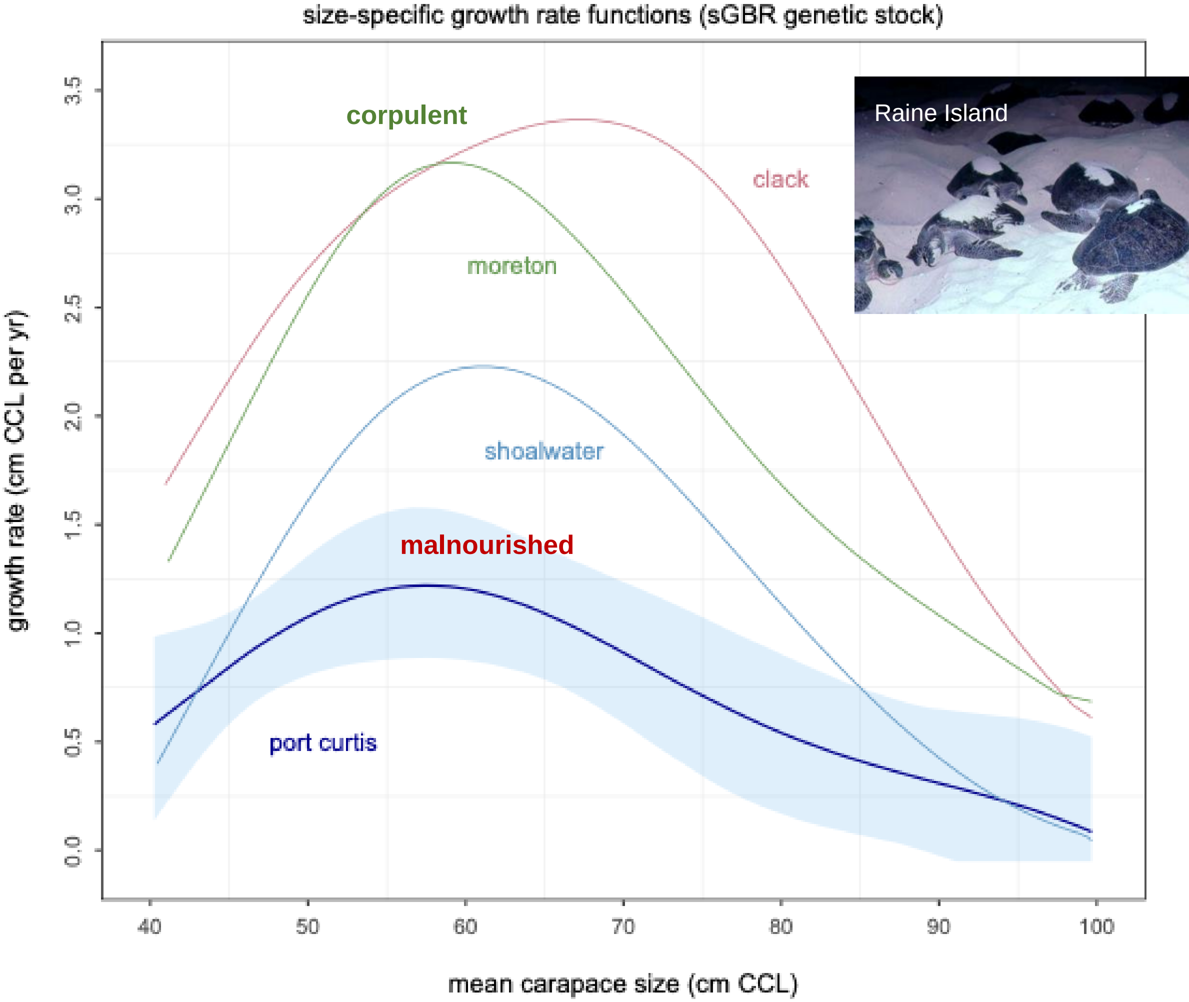
Keywords *Chelonia mydas* · Green sea turtle · Great Barrier Reef · Somatic growth · Spatial variability · Nonparametric regression modeling

Introduction

The green sea turtle (*Chelonia mydas*) has a broad pantropical distribution and distinct regional population substructures (Bowen et al. 1992). The green turtle is also the most abundant large herbivore in marine ecosystems and feeds mainly on seagrasses and a wide range of soft algae (Bjorndal 1997). While the somatic growth dynamics of this ubiquitous sea turtle are not well known (Chaloupka and Musick 1997), some recent studies provide important new findings concerning environmentally induced temporal variability (Limpus and Chaloupka 1997) and variation due to regional stock-specific differences (Bjorndal et al. 2000). An important source of growth variability that has yet to be considered in any detail is spatial or geographic variability within the same genetic stock.

The southern Great Barrier Reef (sGBR) genetic stock of green turtles comprises a spatially disjunct metapopulation (Stith et al. 1996) with numerous foraging grounds spanning ca. 12° latitude and 1,800 km ranging from aseasonal tropical waters in the northern Great Barrier Reef (nGBR) to warm temperate seasonal waters in southern coastal Queensland. Juvenile green turtles recruit to these foraging grounds at ca. 40 cm CCL (curved carapace length) after pelagic development in the southwestern Pacific Ocean (Limpus and Chaloupka 1997). Pelagic green turtle stage duration is poorly known but estimated at ca. 5–6 years (Limpus et al. 1994; Limpus and Chaloupka 1997). Adult turtles resident in these foraging grounds then migrate every few years to breed in sGBR waters with females nesting on nearby coral cays. All the sGBR rookeries comprise the same panmictic interbreeding sGBR stock, which is distinct genetically from other Australian stocks (Norman et al. 1994; FitzSimmons et al. 1997).





Spatial variation also occurs across the Caribbean & western Atlantic …

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PRIMARY RESEARCH ARTICLE

WILEY Global Change Biology

Ecological regime shift drives declining growth rates of sea turtles throughout the West Atlantic

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Application of growth and maturation insights…

Green sea turtles nesting on Raine Island (Great Barrier Reef). Source: Dr CJ Limpus

Stochastic simulation model of green turtle population dynamics (southern Great Barrier Reef)

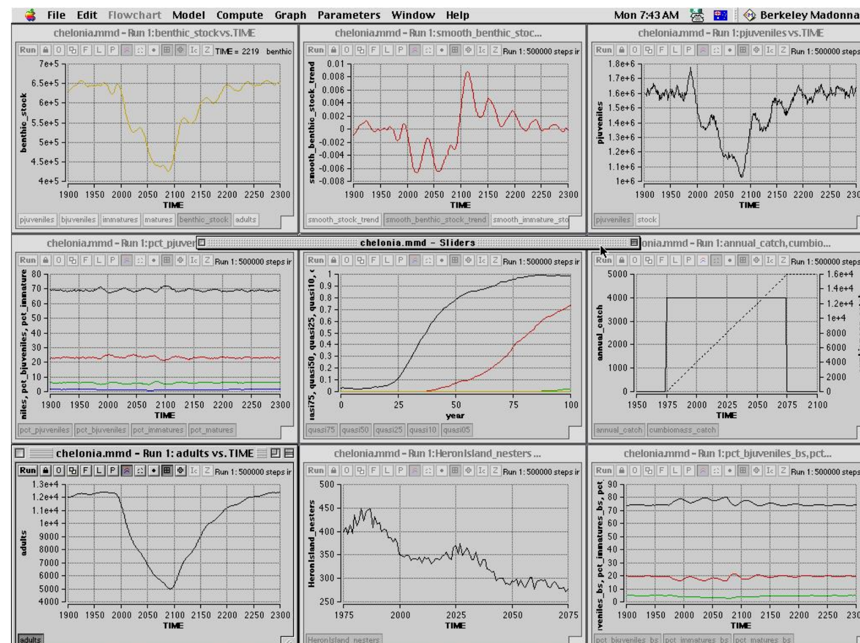
GBRMPA Training Session

14 August 2001

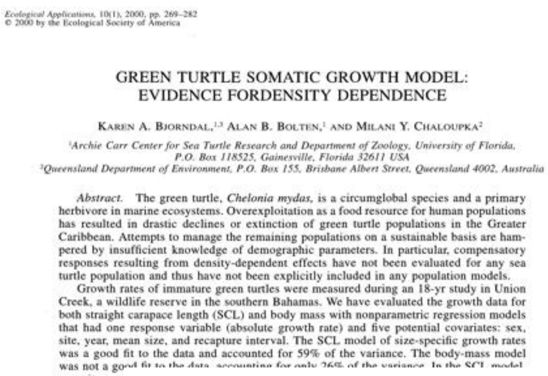
Developed by: Dr Milani Chaloupka
UniQuest and CRC (Coastal, Estuary and Waterway Management)

Commissioned by: Queensland Environmental Protection Agency
Great Barrier Reef Marine Park Authority
Environment Australia

We can evaluate various hypotheses about the **population-level consequences of spatial variation in the food supply** using simulation-based modelling of **green turtle metapopulation dynamics** — with various foraging habitat populations of the same genetic stock exposed to different food supply dynamics



You are what you eat
(or what was available to eat)…



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GREEN TURTLE SOMATIC GROWTH MODEL:
EVIDENCE FORDENSITY DEPENDENCE

Karen A. Bjorndal,[1,3] Alan B. Bolten,[1] and Milani Y. Chaloupka[2]

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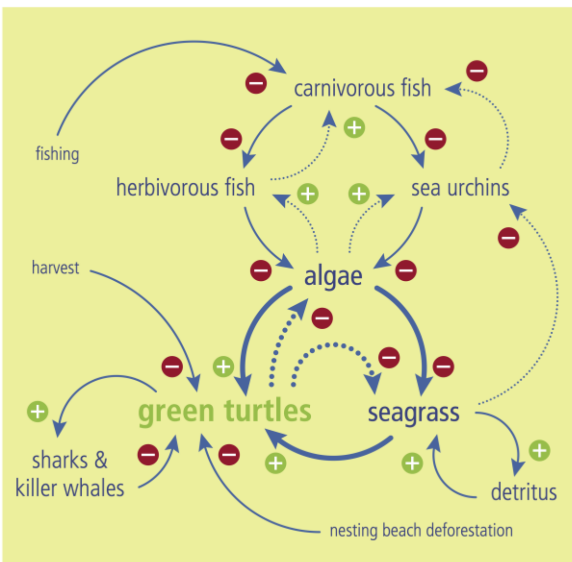
Abstract. The green turtle, *Chelonia mydas*, is a circumglobal species and a primary herbivore in marine ecosystems. Overexploitation as a food resource for human populations has resulted in drastic declines or extinction of green turtle populations in the Greater Caribbean. Attempts to manage the remaining populations on a sustainable basis are hampered by insufficient knowledge of demographic parameters. In particular, compensatory responses resulting from density-dependent effects have not been evaluated for any sea turtle population and thus have not been explicitly included in any population models.

Growth rates of immature green turtles were measured during an 18-yr study in Union Creek, a wildlife reserve in the southern Bahamas. We have evaluated the growth data for both straight carapace length (SCL) and body mass with nonparametric regression models that had one response variable (absolute growth rate) and five potential covariates: sex, site, year, mean size, and recapture interval. The SCL model of size-specific growth rates was a good fit to the data and accounted for 59% of the variance.



This conceptual diagram shows a virtual green turtle population in the context of its ecosystem, using causal loop techniques for *qualitative* modeling of complex biological systems. It is remarkably difficult to develop *quantitative* models of this sort without a substantial amount of time-series data. Such data do not currently exist for any marine species.
DIAGRAM COURTESY OF MILANI CHALOUPKA

Once recruited to coastal benthic habitats, the local food supply dictates ongoing growth rates — subsequently, **corpulent or malnourished**.

If the supply (algae, seagrass) is limited, then stunted growth occurs in those foraging habitats — recruiting to a productive foraging habitat is **a fortunate stroke of serendipity**! It all depends on where you settle, recruit and live.

Green turtles can survive with limited food intake for long periods of time but are **malnourished** resulting in mature turtles **skipping breeding seasons** and reduced **lifetime egg productivity**

Malnourished turtles are likely more **susceptible to disease** with increased morbidity & mortality

Population-level consequences are reduced reproductive output and population size in the longer term — with **unintended ecosystem consequences** driven by increased algal and/or seagrass biomass (see figure opposite)

Acknowledgements …

Long-term (multi-decadal) monitoring studies are the foundation for **deriving deep ecological insights** and **evidence-informed conservation**

So very special thanks to

Karen Bjorndal, Colin Limpus, George Balazs

for many years of support and their dedication to maintaining robust marine turtle monitoring programs based on capture-mark-recapture over many decades