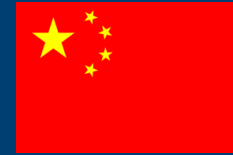
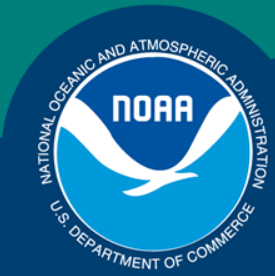


Science, Service, Stewardship



Partnership Research of Marine Turtles at the Pacific Islands Fisheries Science Center: Hawaii, East Asia, and the North Pacific



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Presentation by George Balazs

PIFSC MARINE TURTLE RESEARCH

太平洋島嶼漁業科學中心的海龜研究

Focus of Investigations and Activities

調查與活動的重點

- Pacific Islands sea turtle biology, ecology and life history
太平洋島嶼海龜的生物學、生態學與生命史





History & Evolution of the Tag

- 1972: Monel size 49 → Inconel Size 681 & Titanium
- 1980/1981: Living tag
- Mototool shell etchings
- Facial profiles
- Electronic Tags – VHF, sonic, TDR, satellite
- PIT tags
- Future: genetic tagging





Investigations and Activities

1. Ocean turtle sampling research
2. Nesting and basking beach turtle sampling research
3. Stranding and necropsy turtle sampling research
4. Pelagic ecology turtle sampling research
5. Data management for access and analysis
6. International research assistance and training
7. Educational public outreach of research results
8. **Publish findings for conservation and management**



Research Partnerships

1. Ocean turtle sampling research
 - HPA, USGS, NPS, NIST, UH, HPU, www.turtles.org, SWFSC, MTAP, HIMB
2. Nesting and basking beach turtle sampling research
 - FWS, HPA, TNC, HWF, NPS, SWFSC, *Malama na Honu*, SPREP
3. Stranding and necropsy turtle sampling research
 - USGS, UH-MOP, HPA, NOAA Sanctuary, NPS, State of Hawaii DLNR, PUBLIC (residents & tourists), MTAP, SWFSC, HIMB, MOC
4. Pelagic ecology turtle sampling research
 - EOD, HPA, Nagoya Aquarium, Sea Turtle Association of Japan, Noumea Aquarium, China Gangkou Reserve, Underwater World Singapore, National Taiwan Ocean University, Sea Life Park Hawaii, PIRO Longline Observer Program, Southwest Fisheries Science Center

PIFSC MARINE TURTLE RESEARCH

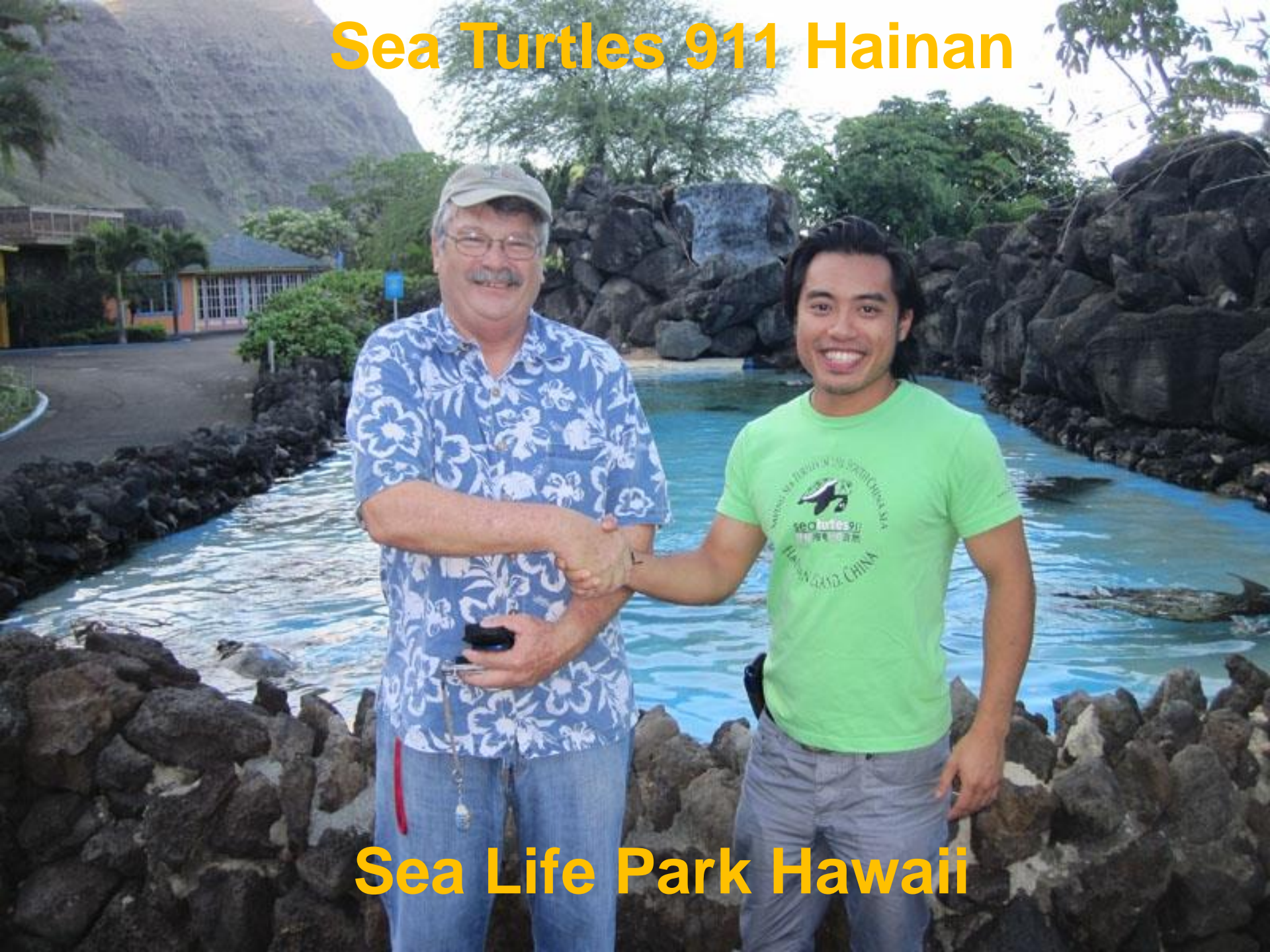
太平洋島嶼漁業科學中心的海龜研究

- Research training and capacity building of Pacific islanders and Pacific Rim personnel

研究上的訓練，以及太平洋島民與環太平洋人員的培訓



Sea Turtles 911 Hainan



Sea Life Park Hawaii

中國香港特別行政區擱淺及援救海龜的研究

Studies on Stranded and Rescued Sea Turtle in Hong Kong SAR of China



伍家恩

香港城市大學，博士生

NG Ka-yan, Connie

PhD candidate, City University of Hong Kong





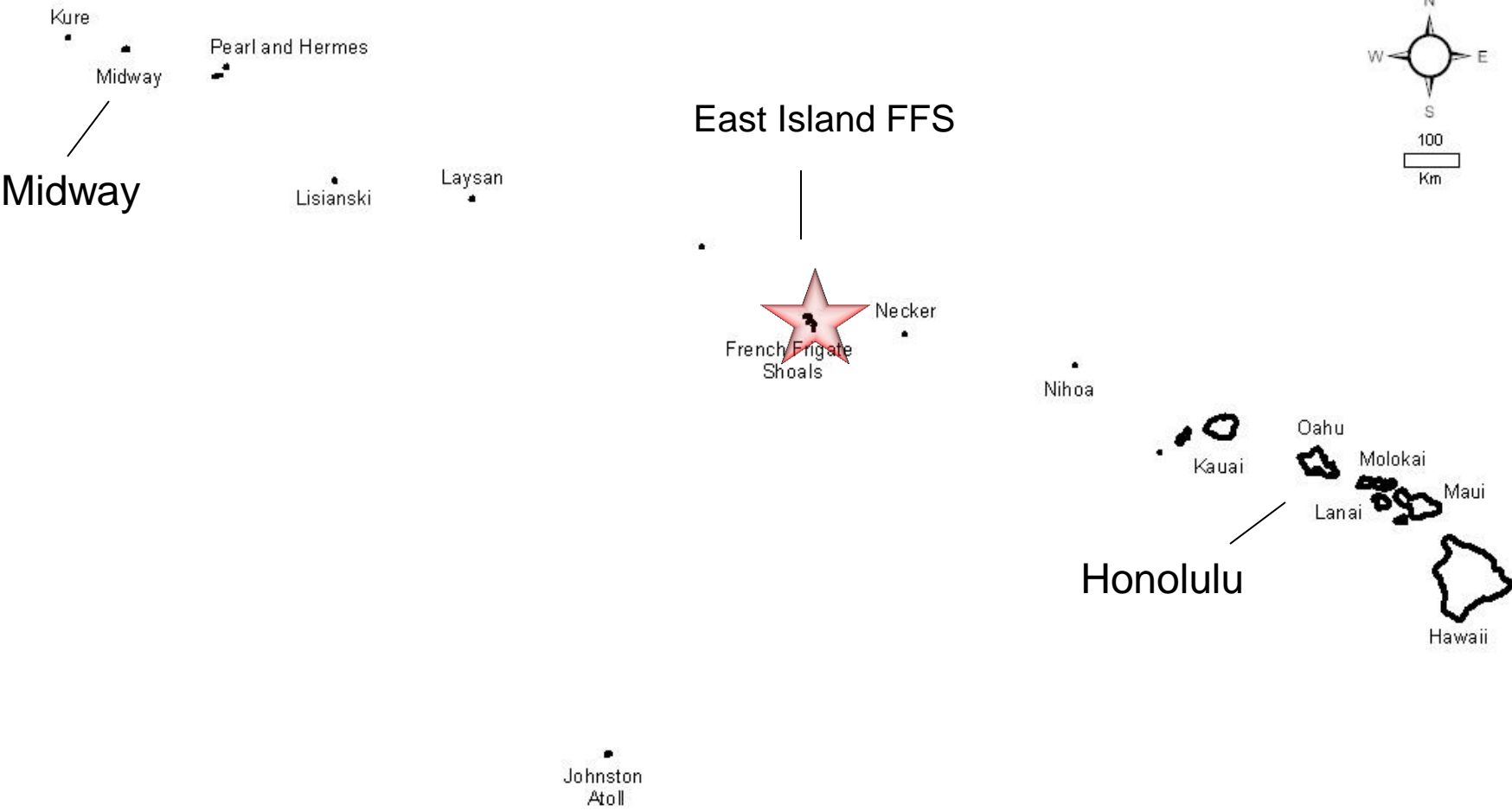
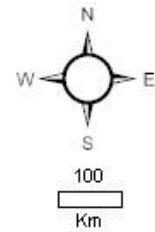
67 Partnership Journal Publications 1999-2011

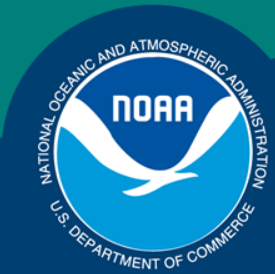
- Trends, Status and Assessment – 13
- Life History and Ecology - 13
- Health & Disease – 24
- Pelagic Ecology – 15
- Research Techniques – 2





Hawaiian Islands





Ocean Turtle Sampling Research

1. Kona Coast Carrying Capacity
2. Kawainui Canal, Oahu - Abundance & Habitat Use

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Green
Honu
綠蠐龜





1) Carrying Capacity of Green Sea Turtles at Kaloko-Honokohau NHP



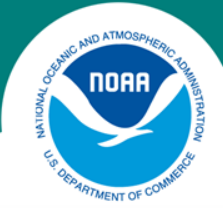
Wabnitz CCC, Balazs G, Beavers S, Bjorndal KA, Bolten AB, Christensen V, Hargrove S, Pauly D (2010) Ecosystem structure and processes at Kaloko Honokohau, focusing on the role of herbivores, including the green sea turtle *Chelonia mydas*, in reef resilience. Marine Ecology Progress Series 420:27–43



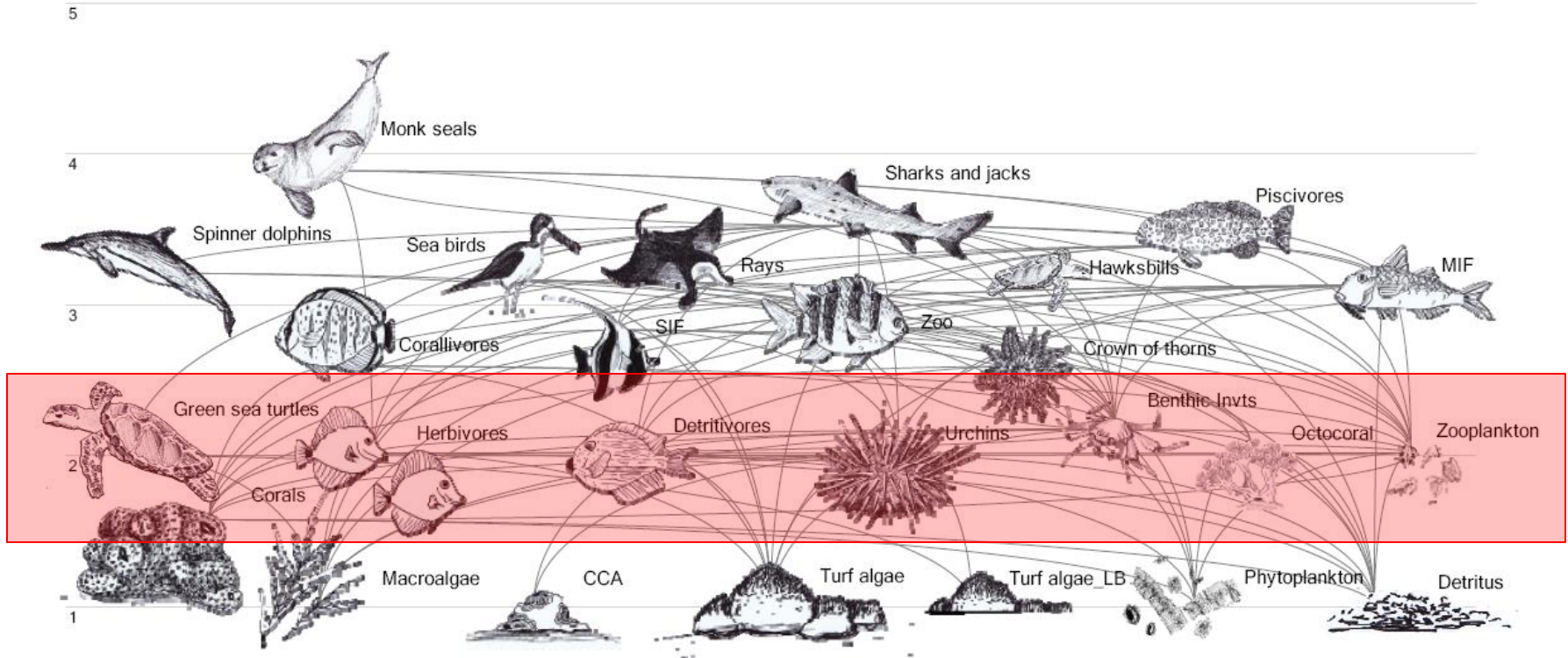
Background

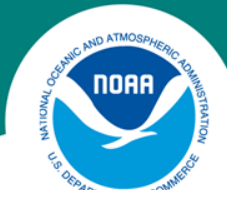
- All foraging aggregations throughout the Hawaiian Islands are one genetic stock
- Growth rates have been declining and reduced body condition at some sites
- Some foraging grounds are at their carrying capacity (e.g. Kaloko-Honokohau)



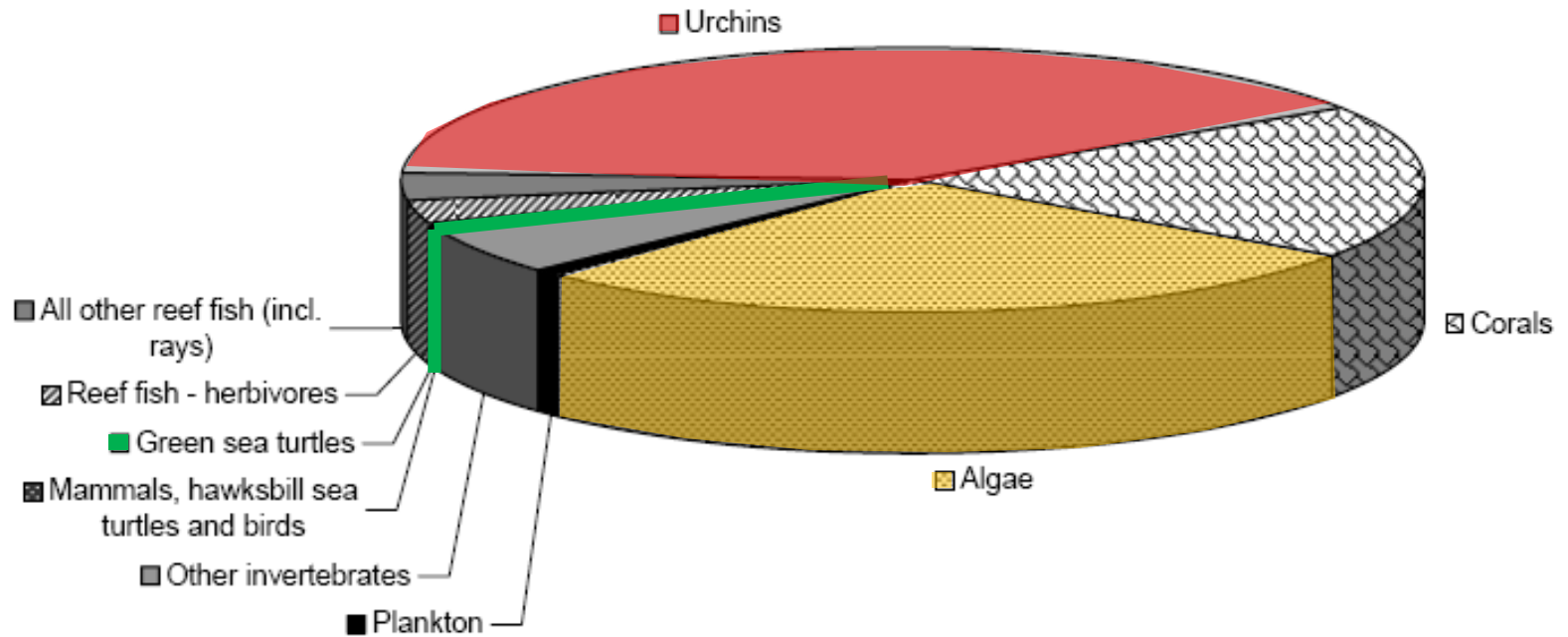


Trophic Flows of the Kaloko-Honokohau Ecosystem





Biomass Proportions of Aggregated Functional Groups



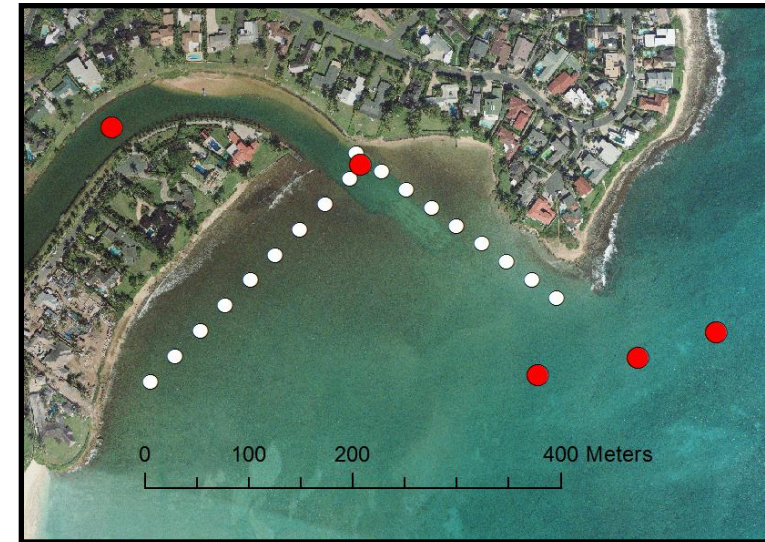
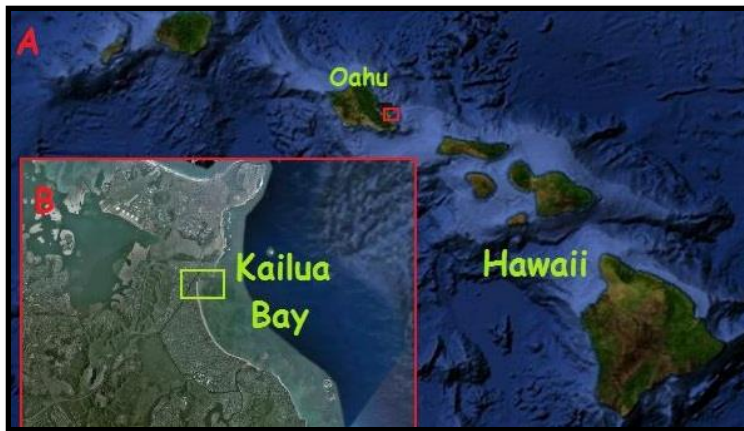


Conclusions

- Strong competition for resources between urchins, fish, and green turtles
- Green turtles are at their carrying capacity at Kaloko-Honokohau
 - Biomass estimates and consumption rates
 - Estimates of turf algae biomass on lava bench and primary production rates of these algae
 - Urchin consumption of turf algae
- Most Kona coast sites are similar to Kaloko-Honokohau with respect to turtle body condition and algal resources
- Turtles at other foraging grounds are in better body condition, yet growth rates are still slow and declining



2) Kailua Bay, Oahu - Kawainui Canal Abundance and Habitat Use



HPU Masters theses:
Brenda Asuncion (Dec 2009)
Devon Francke (Aug 2011)





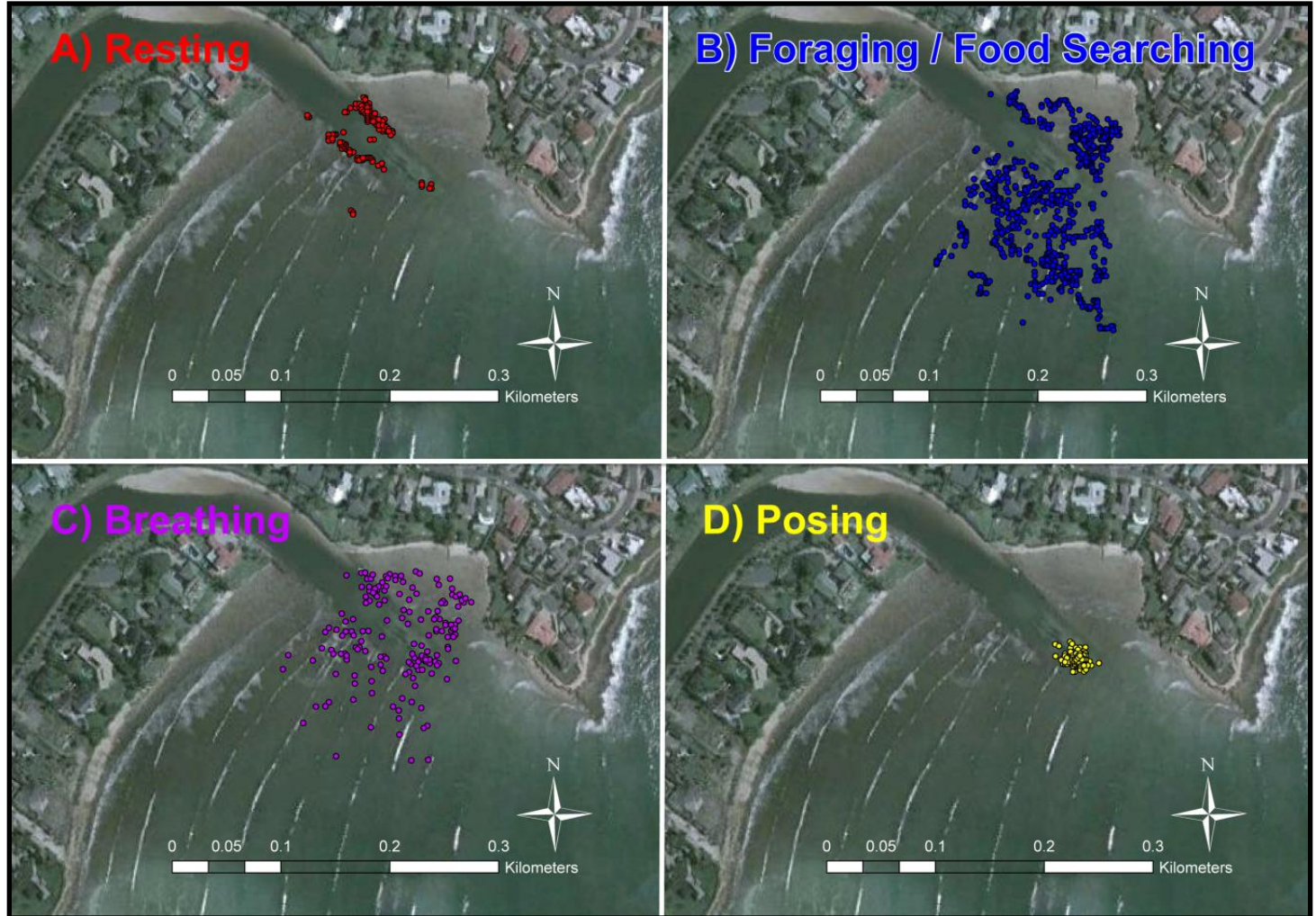
Abundance & Habitat Use

- Marked 42 individuals
- Seasonal snorkel surveys
- Lincoln-Petersen mark-recapture estimate
- Acoustic tracking – 12 turtles
- 5 receivers: canal, cove, offshore (3)





Video Surveys: Habitat Use





Conclusions

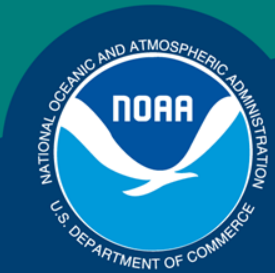
- Canal is heavily used by turtles for resting
 - Other waterways with similar features may also be important habitat for Hawaiian green turtles (e.g. Anahulu River)
- Resident turtles do not frequently move offshore
- Identification of key habitat characteristics may be useful to determine where green turtles are likely to reside and how human use may impact those foraging and resting areas



Hawksbill Captures Main Hawaiian Islands

- 1986 – 2011 = 17 turtles captured
 - Hawaii = 10
 - Molokai = 3
 - Maui = 3
 - Oahu = 1
- 2 recaptured nesting
 - Hawaii = 1 (1989 – 2010)
 - 32.9 cm SCL
 - Molokai = 1 (1986 – 2001)
 - 53.5 cm SCL





Nesting and Basking Turtle Sampling Research

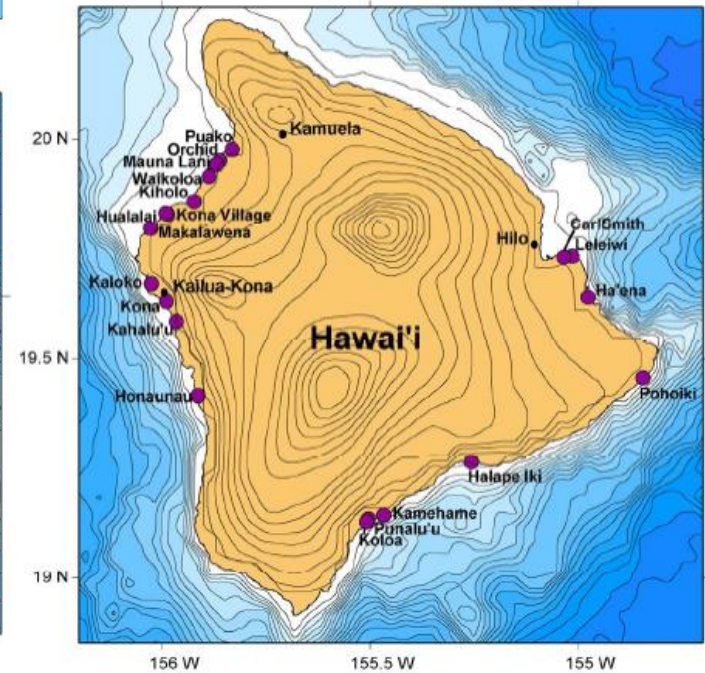
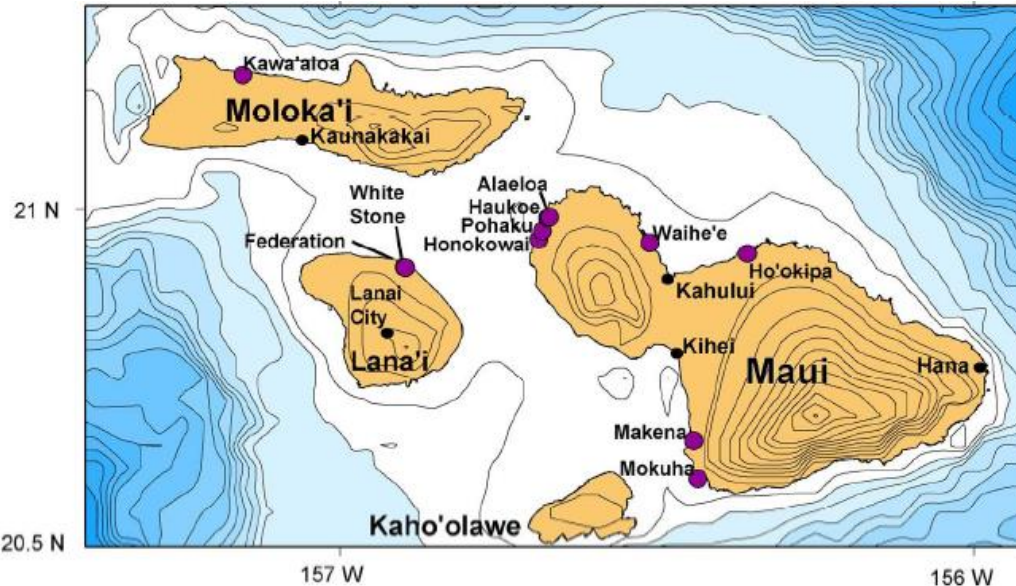
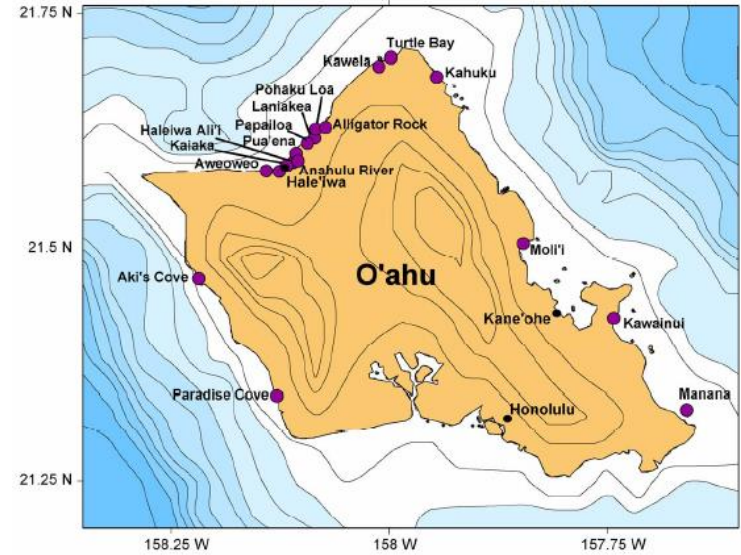
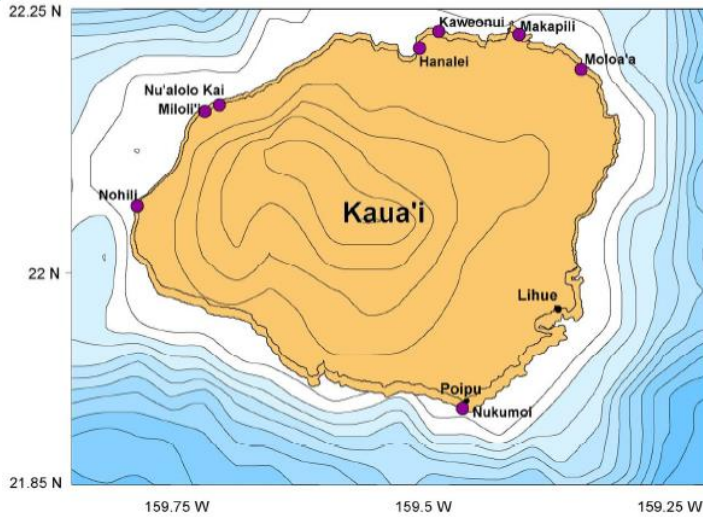
1. Increase in MHI Basking
2. 2011 Nesting Update
3. Methods
4. Tiwari et al. 2010
5. Age at First Reproduction



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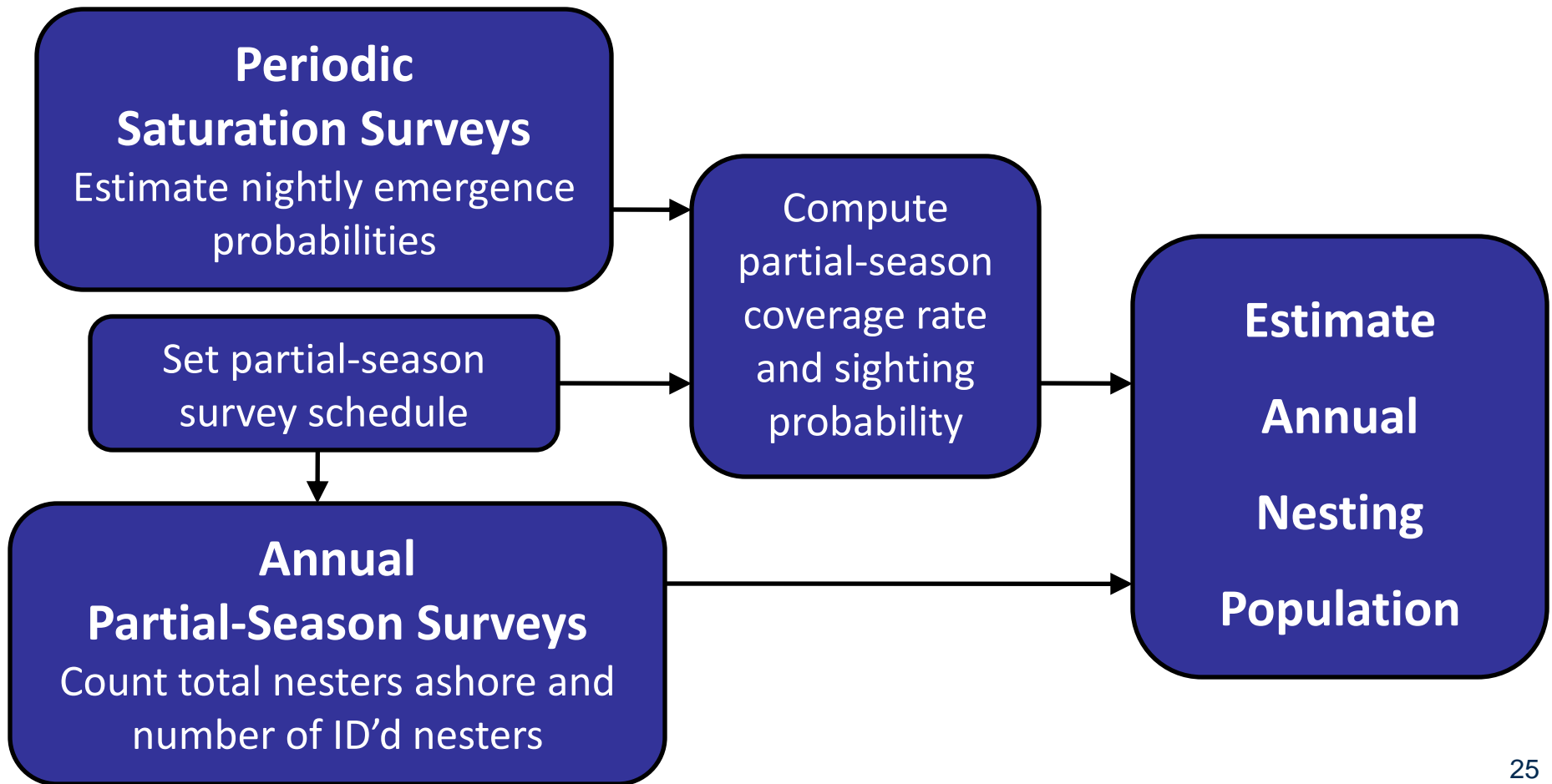
NOAA

1) Basking Research





2) Methods: Strategy for Monitoring Nesters





Horvitz-Thompson type estimator

$$N_i = n_i/p_i$$

where:

N_i = estimated number of female nesters in the i^{th} year

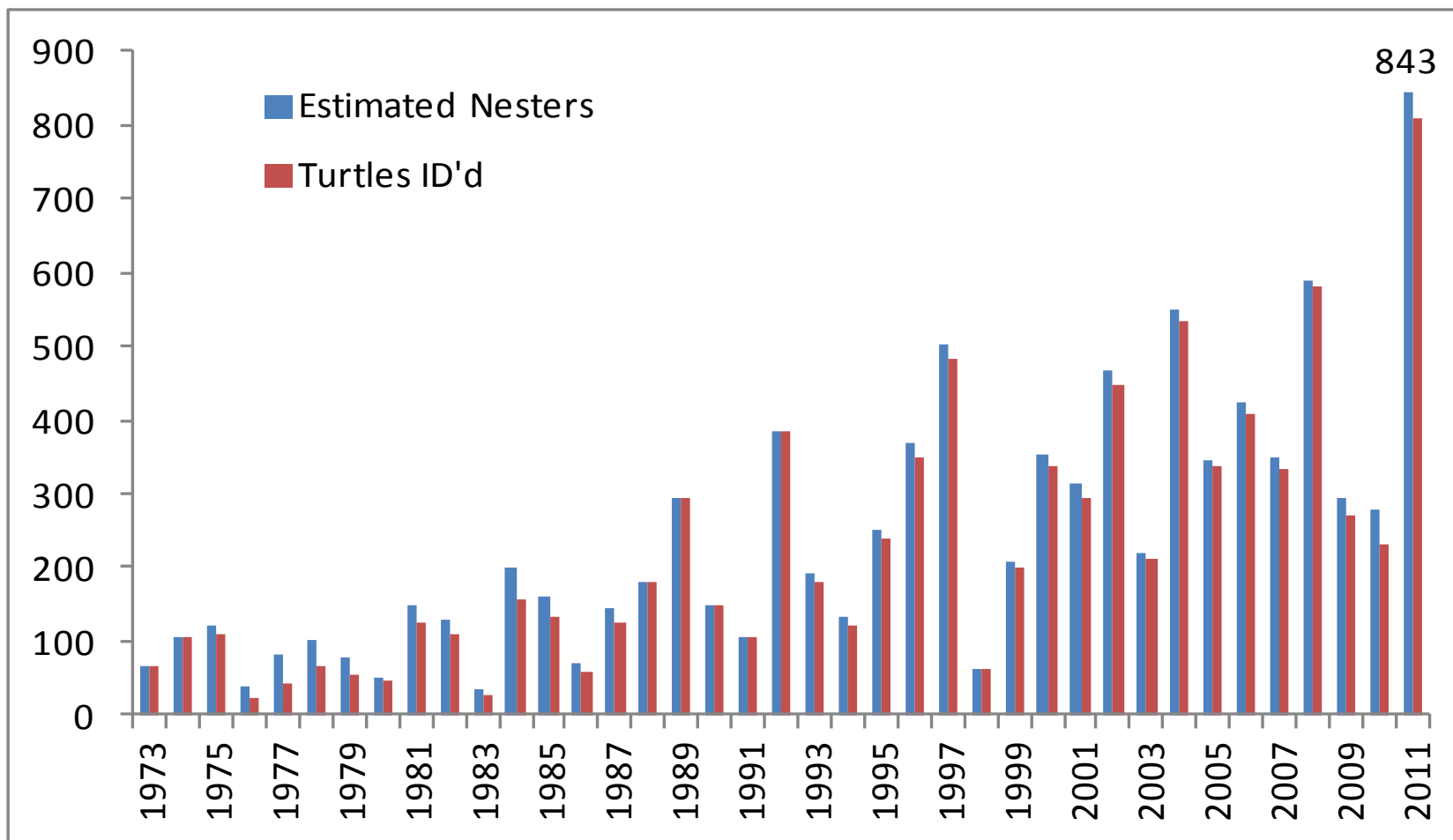
n_i = number of uniquely identified female nesters
recorded for the i^{th} year

p_i = probability of sighting a female that emerges and
nests at least once during the i^{th} year

(Wetherall et al. 1998)



3) Nesting Research: 2011 Update

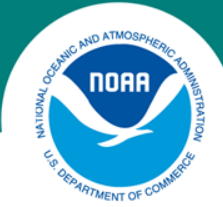




4) Estimating green turtle nesting carrying capacity at East Island

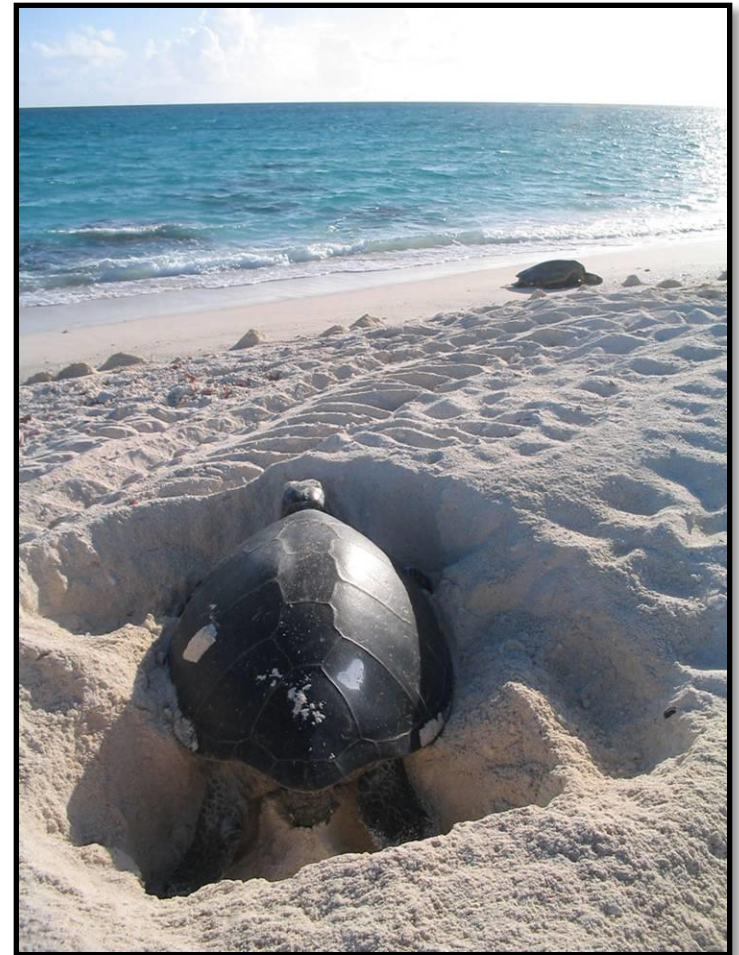


Tiwari M, Balazs GH, Hargrove S (2010) Estimating carrying capacity at the green turtle nesting beach of East Island, French Frigate Shoals. *Marine Ecology Progress Series* 419:289–294



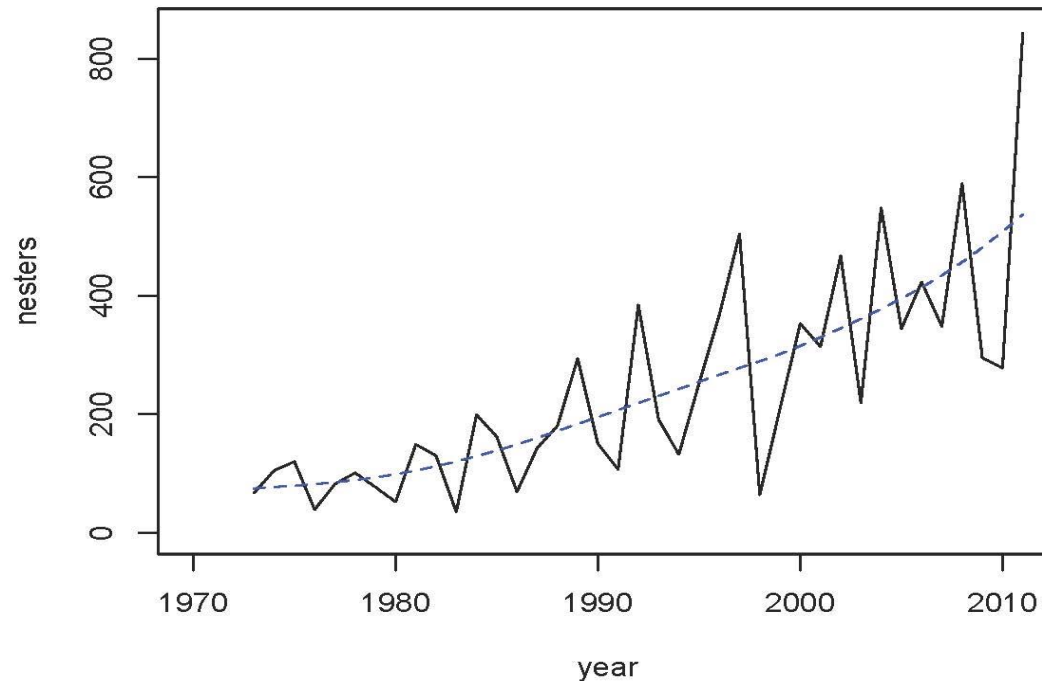
Objective

- Determine carrying capacity of East Island for hatchlings and nesting females under current conditions and predictions of reduced nesting habitat due to sea level rise
- **Carrying capacity** is defined as the maximum number of hatchlings that can be produced in a season





East Island rookery
French Frigate Shoals



- Nesting population increasing at a rate of 5.7% per year (Chaloupka et al. 2008)
- Predicted loss of up to 33% of nesting habitat at East Island by 2100 due to sea level rise (Baker et al. 2006)



Carrying Capacity Where are we now?

- East Island is well below its carrying capacity for nesters/hatchlings
- Current nesting population represents 1.3 – 2% of the 20 – 30K females that would lay 80 – 120K nests at carrying capacity
- Continued growth of the Hawaiian green turtle stock will be limited by foraging habitat



5) Age at First Reproduction

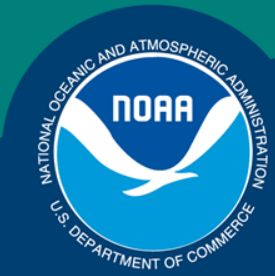
- > 5600 turtles tagged on foraging grounds
- 101 recoveries of nesters originally tagged as juveniles from 1984-2010 (10 at locations other than East Island)
- Compare Capture-Mark-Recapture time-at-large to skeletochronology estimates of age at maturity

Van Houtan, Balazs, and Hargrove manuscript in review



Conclusions

- Time from first capture to nesting for smallest neritic turtles (40-50 cm) ~ < 25 years
- Time from first capture to nesting for large juveniles/sub-adults (70-80 cm) ~ 5-15 years
- Individual variability but less than skeletochronology
- Age at First Reproduction 19-25 years



Stranding and Necropsy Turtle Sampling Research

1. Summary of strandings
2. Cause specific trends in strandings
3. Fibropapilloma tumor disease research

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PIFSC MARINE TURTLE RESEARCH

太平洋島嶼漁業科學中心的海龜研究

- Stranding, salvage and necropsy research for long term population dynamics data collection

擱淺、搶救與解剖研究，以長期蒐集群體的動態資料





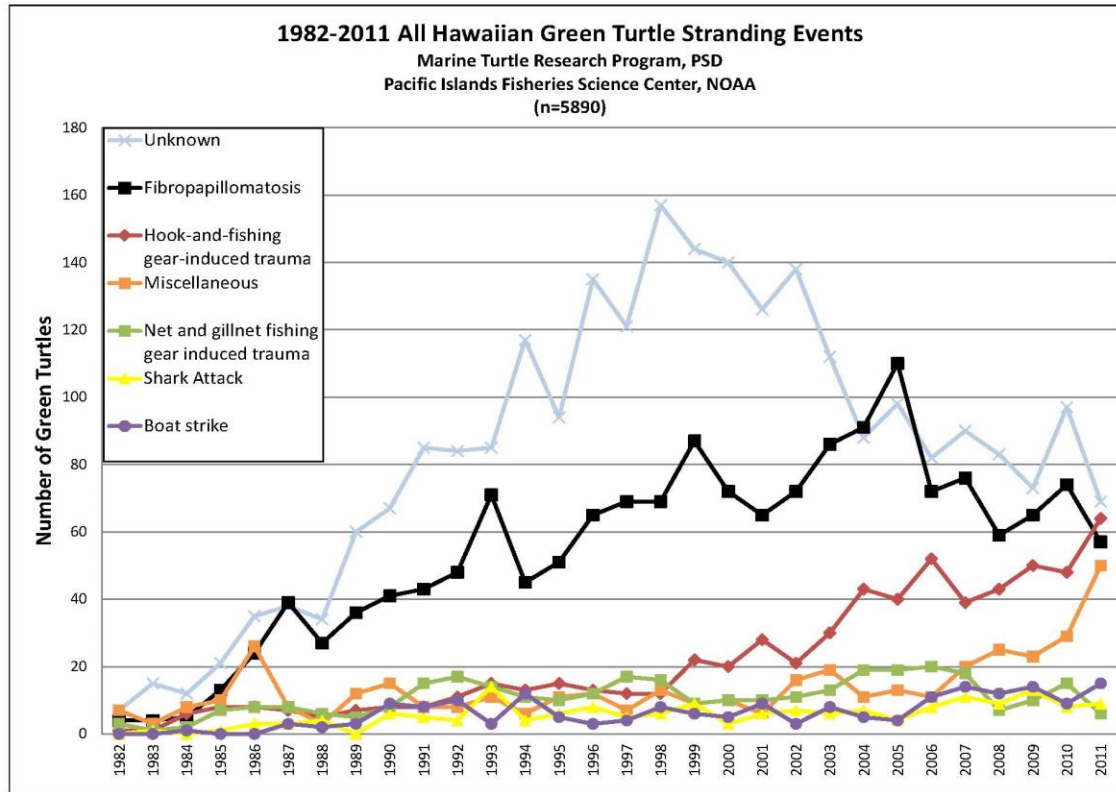
1) Summary of Marine Turtle Strandings in Hawaii (1982-2011)

- 6020 total strandings
 - 5890 (98.0% - *Chelonia mydas*)
 - +20 hatchlings
 - 74 (1.2% - *Eretmochelys imbricata*)
 - +35 hatchlings
 - 43 (*Lepidochelys olivacea*)
 - +2 hatchlings
 - 5 (*Dermochelys coriacea*)
 - 2 (*Caretta caretta*)
 - 6 (not determined)



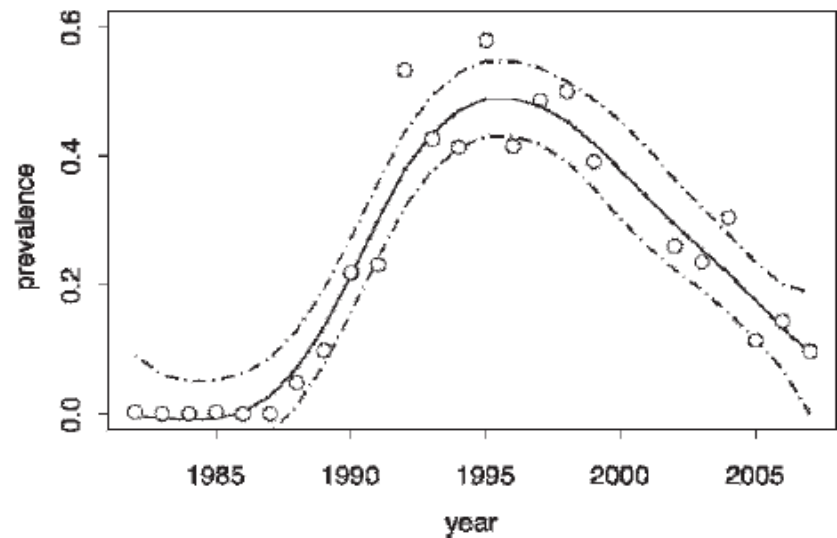


1982-2011 Trends in Hawaiian Green Turtle Causes of Strandings





Disease Research Fibropapilloma Tumors



Chaloupka, M., G. H. Balazs, and T. M. Work. 2009. Rise and fall over 26 years of a marine epizootic in Hawaiian green sea turtles. *J. Wildl. Dis.* 45(4):1138-1142.

OPEN ACCESS Freely available online



Land Use, Macroalgae, and a Tumor-Forming Disease in Marine Turtles

Kyle S. Van Houtan^{1,2*}, Stacy K. Hargrove¹, George H. Balazs¹

1 Florida, Island Fisheries Science Center, National Oceanic and Atmospheric Administration (NOAA), Fisheries Service, Honolulu, Hawaii, United States of America, **2**Michigan School of the Environment and Earth Sciences, Clark University, North Andover, North Carolina, United States of America

Abstract

Invasive diseases are an increasing concern for endangered species conservation, but their occurrence, causes, and human influences are often unknown. We analyzed 3,839 records of stranded Hawaiian monk seal turtles (*Neomonachus monachus*) over 28 years to understand fibropapillomatosis, a tumor-forming disease linked to a herpesvirus. Turtle size is a consistent risk factor and size-standardized models revealed considerable spatial and temporal variability. The disease peaked in some areas in the 1990s. In some regions rates remained constant, and elsewhere rates increased. Land use (proportion of where the turtles feed) may play a role. Elevated disease rates were clustered in watersheds with high nitrogen footprints; an index of natural and anthropogenic factors that affect coastal acidification. Further analysis shows strong epidemiological links between disease rates, nitrogen footprints, and invasive macroalgae and points to foraging ecology. These turtles now forage on invasive macroalgae, which can dominate nutrient rich waters and degrade environmental DNA in the amino acid arginine. Arginine is known to regulate immune activity, promote herpesviruses, and contribute to tumor formation. Our results have implications for understanding diseases in aquatic organisms, eutrophication, herpesviruses, and tumor formation.

Citation: Van Houtan KS, Hargrove SK, Balazs GH (2010) Land Use, Macroalgae, and a Tumor-Forming Disease in Marine Turtles. PLoS ONE 5(9): e12900. doi:10.1371/journal.pone.0129000

Editor: James Neukirch, New Zealand

Received: May 6, 2010; **Accepted:** August 23, 2010; **Published:** September 28, 2010

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Funding: The authors have no support or funding to report.

Competing Interests: The authors have declared that no competing interests exist.

* kvan@hawaii.noaa.gov

Introduction

Combined with overexploitation, habitat loss, and climate change, emerging diseases pose major threats to biodiversity worldwide [1,2]. Marine turtles suffer numerous population declines [3] with green sea turtles (*Chelonia mydas*) affected by fibropapillomatosis (FP), a debilitating tumor-forming disease [4]. While surveys show key green turtle populations are steadily growing [5,6], FP remains widespread and its origin is unknown. Here we present a spatial epidemiology from 28 years of disease records from the Hawaiian population of green turtles. We construct four sets of disease rates, address the spatial scale of variability, and examine the role of land use and invasive macroalgae.

Early hypotheses of causal factors of the disease examined variation in immune function but strong associations [7,8]. A viral origin for FP became apparent after other experiments successfully transmitted the disease using cell-free tumor extracts [9]. Later studies identified a herpesvirus as the leading candidate after their DNA sequences were discovered in turtle tumors but were absent in non-tumor turtles [10,11]. Subsequent results also showed sampled herpesviruses had low genetic variability [11,12] implying constant transmission, perhaps via coaggregation [13].

Further advances to understanding this disease have been limited by the inherent complexity of epidemiology and disease transmission [14]. Infectious diseases involve individual susceptibility, exposure, infection, and immune response. These phases often

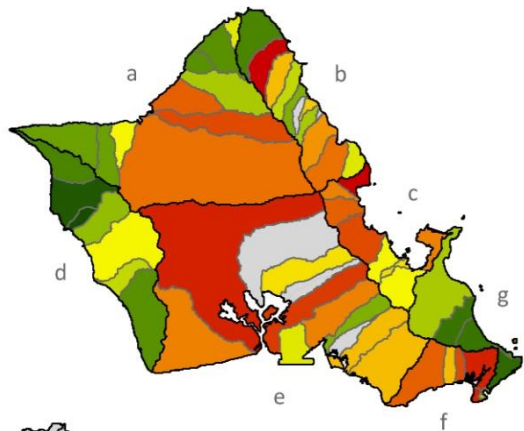
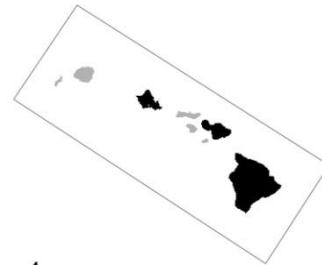
operate independently, interact in nonlinear ways, and vary demographically, geographically and through time. Mechanistic models [15], for example, can predict the course of many diseases in host populations directly. These models are sensitive to compartmental disease rates often spread rapidly to dense populations. Understanding the variability of FP, however, is highly more complicated than transmission dynamics alone. In Hawaiian green turtles, for example, FP became prevalent in the 1980s, and apparently peaked in the 1990s [16,17] through the turtle population has grown continually [5]. Furthermore, recent phylogenetic analyses of the implicated herpesvirus show low similarity and covariation with their turtle hosts over millennia of years [12]. Investigating factors that can promote disease, such as environmental [18] or dietary conditions [19], may therefore provide insights.

Green turtles develop FP [6], 10–15 years after reaching an important habitat [17,20] indicating their environment are influential. Most Hawaiian green turtles track in the Northwestern Hawaiian Islands (NHI), 500 km from Honolulu and spend up to a decade in pelagic waters [21]. Juveniles recruit to nearshore waters at around 35 cm straight carapace length (SCL). Here turtles maintain a quiescent period of 6–10 yr before migrating back to shallow, nearshore sites [18,22]. After reaching ~90 cm SCL, individuals seasonally migrate to the NHI to breed. There they spend months, afterwards return to their foraging sites in the Main Hawaiian Islands (MHI), and subsequently breed every 3–4 yr more years [23]. Therefore all viable green turtles are chronically and locally influenced by their local nearshore habitat in the MHI.

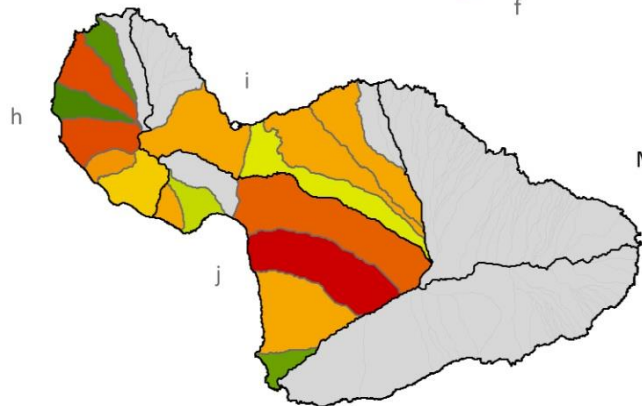
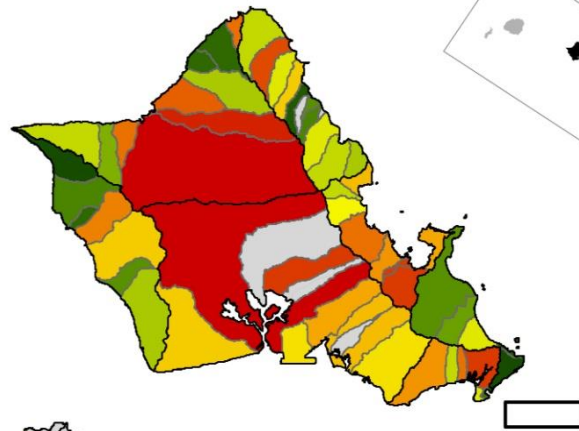
Disease ecology

Disease Rate

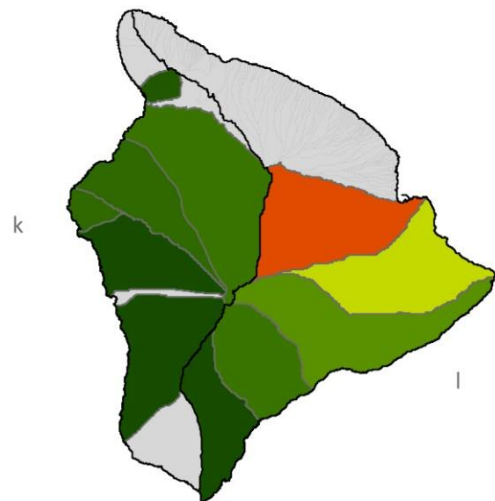
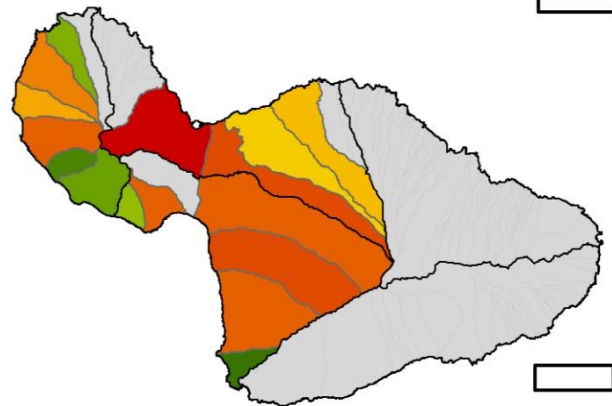
N Footprint



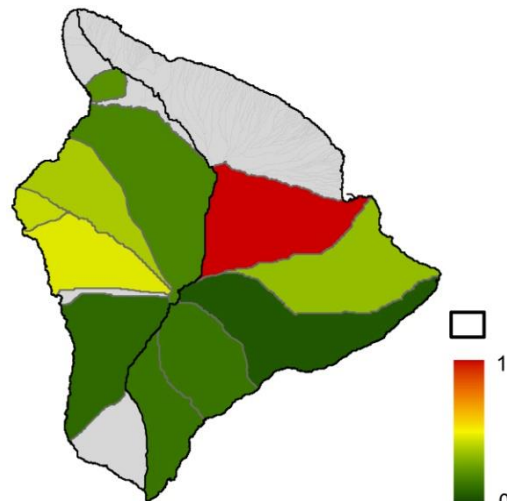
OAHU



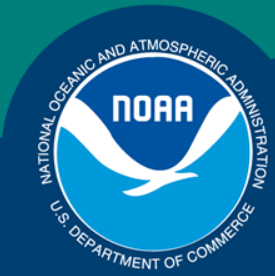
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Stock Structure - Genetics

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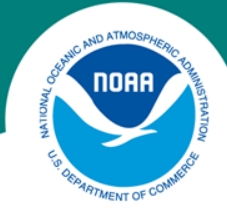
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Hawaiian Islands Case Study

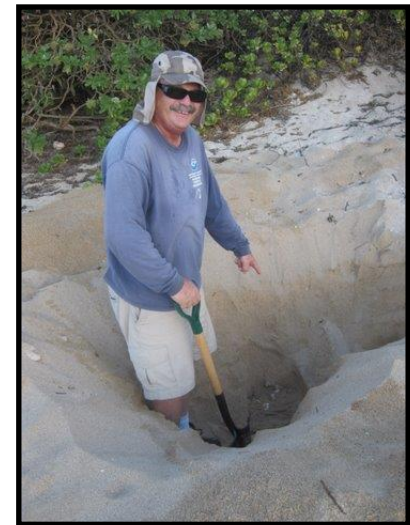
Question: what nesting stocks do juvenile and adult foraging populations around the Hawaiian Islands belong to? **Answer: Foraging populations derived from a single nesting stock – French Frigate Shoals.**

Nesting stock	Mean	SD	Median	Lower quantile	Upper quantile
FFS	0.999	0.002	0.998	0.993	1.000
Mexico-REV	0.001	0.002	0.001	0.000	0.006
Mexico-MICH	0.000	0.001	0.000	0.000	0.003
Galapagos	0.000	0.001	0.000	0.000	0.003



Main Hawaiian Islands Nesting

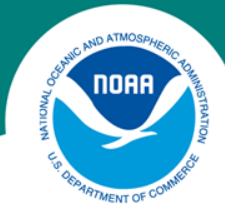
- Recent scattered nesting around Main Hawaiian Islands
- Nesters mostly unobserved
- Widespread nests sampled



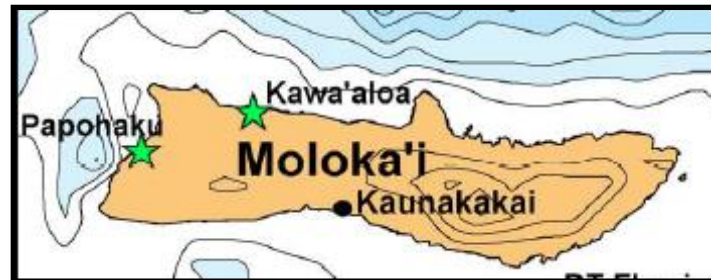


Genetic approach to nesting census

- 188 salvaged embryos/hatchlings from 77 nests
- One sample per nest was sequenced (mtDNA)
- All samples were genotyped using 15 microsatellite loci
- Software reconstructed maternal genotypes and matched unknown nests
- Determined number of females that laid nests



Genetic Census of Green Turtle Nests on Molokai



	'04	'06	'07	'08	'09	'10
Molokai-Papohaku				2*		
Molokai- Kawaaloa	2	4	10	3	11	8
No. Females	2	1	4	2*	5	3
Female 7	1	-	5	-	-	3
Female 8	1	4	-	-	3	-
Female 11	-	-	1	-	3	-
Female 12	-	-	3	-	1	-

} Nests/yr



Nesting in Main Hawaiian Islands Summary-Preliminary findings

- Reconstructed MHI nester genotypes show high degree of relatedness
- Nests laid by relatively few, but related individuals (mtDNA+ nDNA)
- MHI nesting “population” established from new founders derived from FFS genetic stock
- Contribution of hatchlings (12,000) and juveniles from Sea Life Park Hawaii captive breeding



THE FUTURE

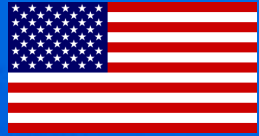
Data Management & Data Mining

- Nearshore ~ 25,800 records 1963-2011
- Stranding ~ 5,950 records 1982-2011
- Nesting ~ 38,500+ records 1975-2009
- Tags ~ 36,900
- TurtleIDs ~ 15,550

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Reef fish cleaning a green turtle

珊瑚魚正在為綠蠟龜清洗



The End
報告完畢

