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

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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

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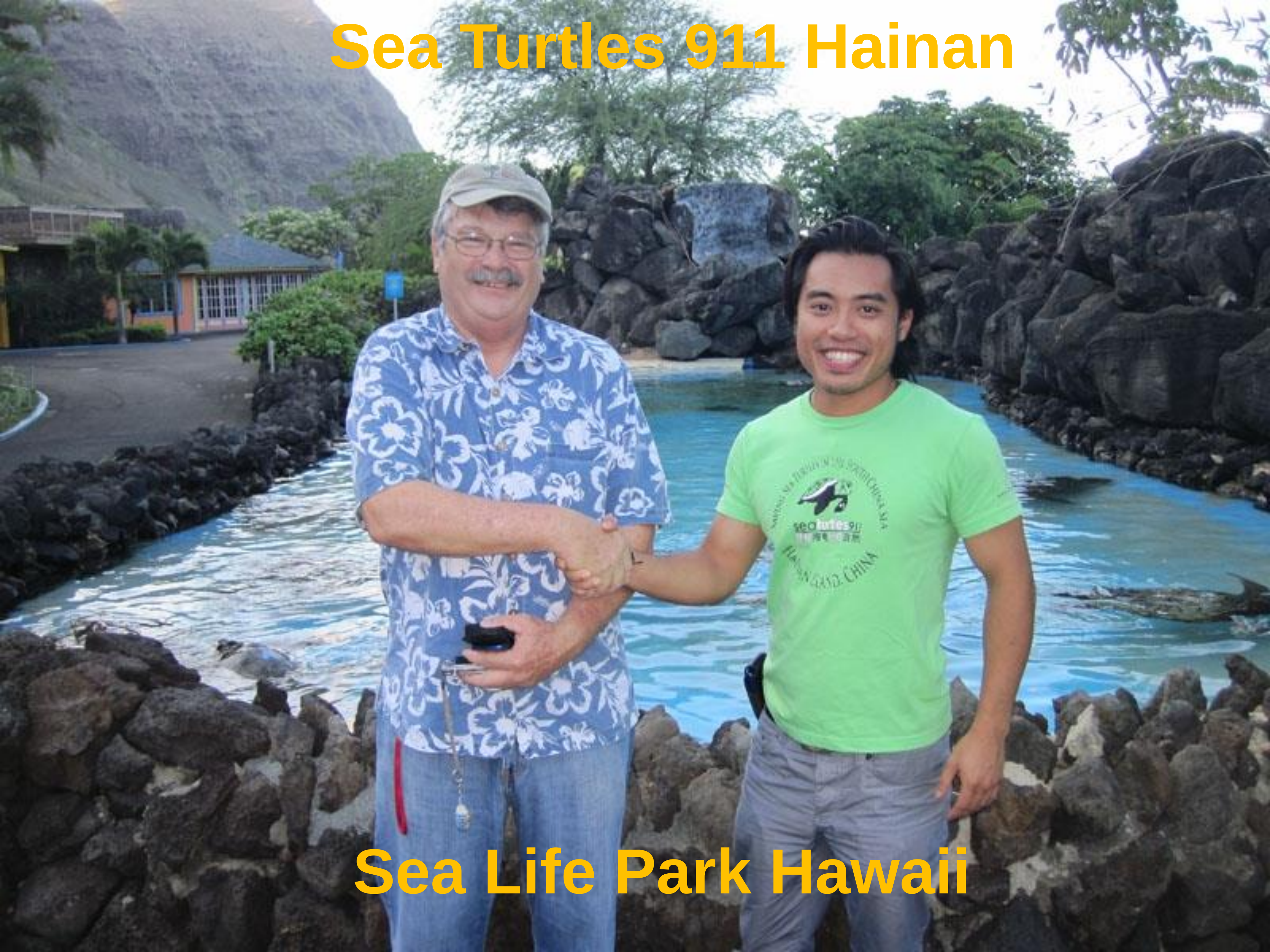
Research Partnerships

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

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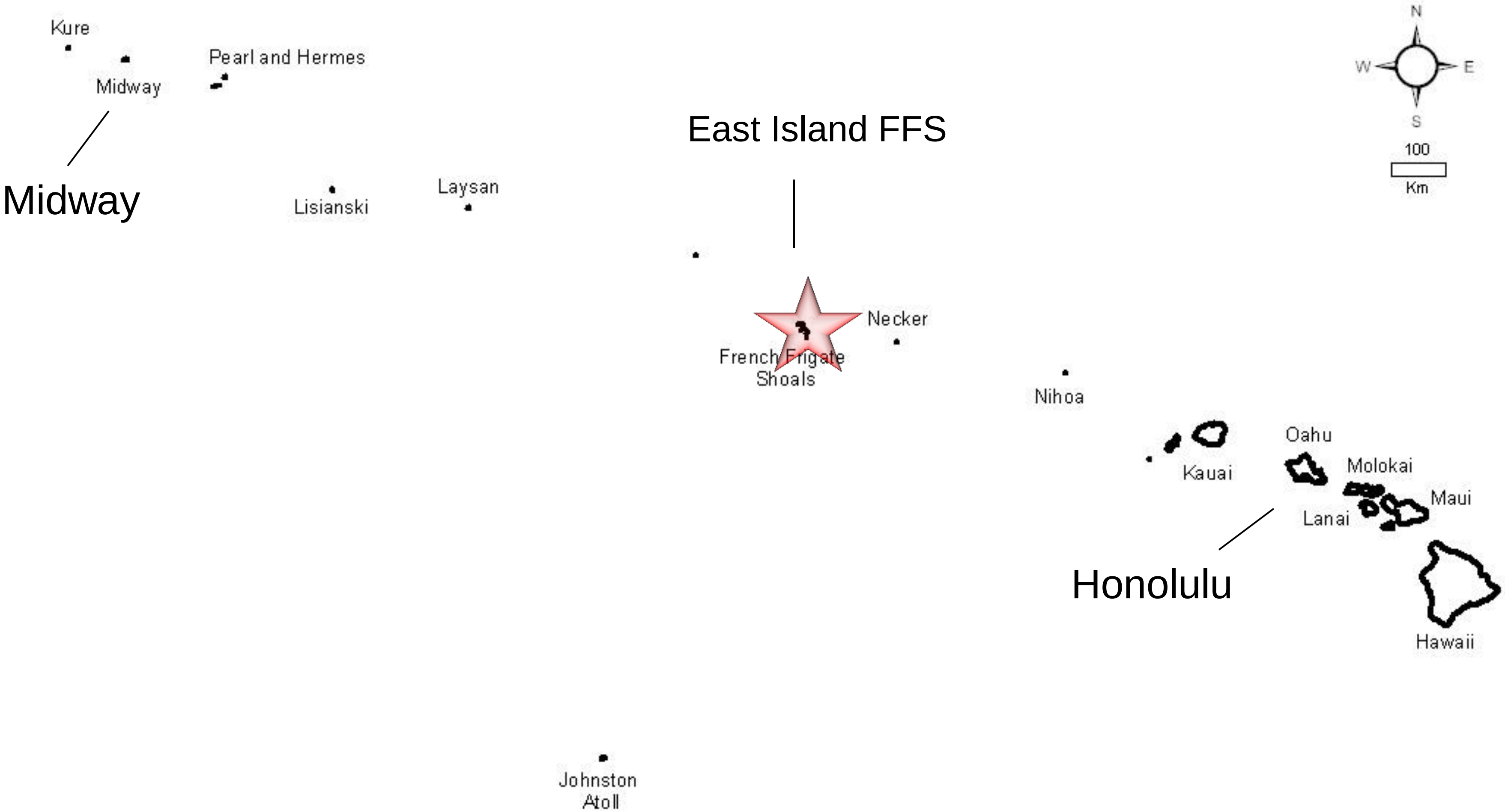
67 Partnership Journal Publications 1999-2011

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

Hawaiian Islands



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Ocean Turtle Sampling Research

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

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Green
Honu
綠蠵龜

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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

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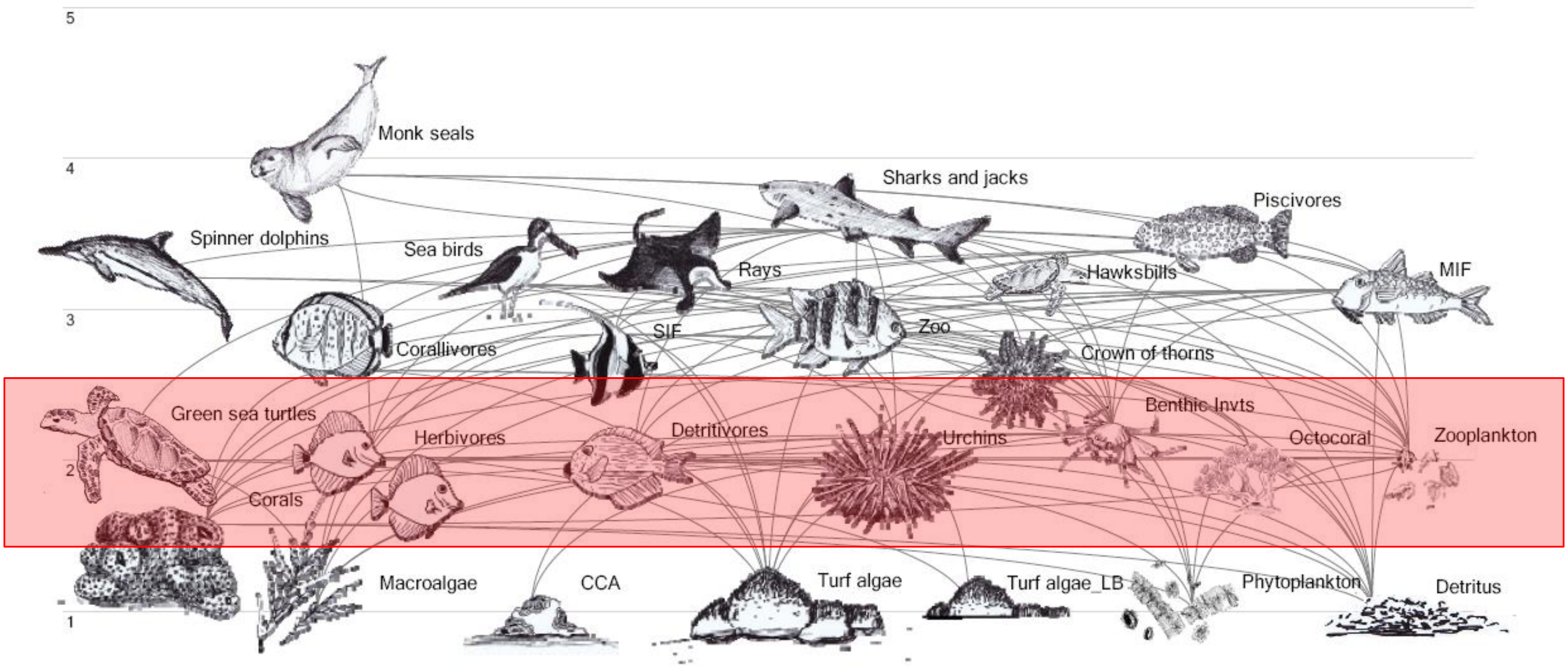
Background

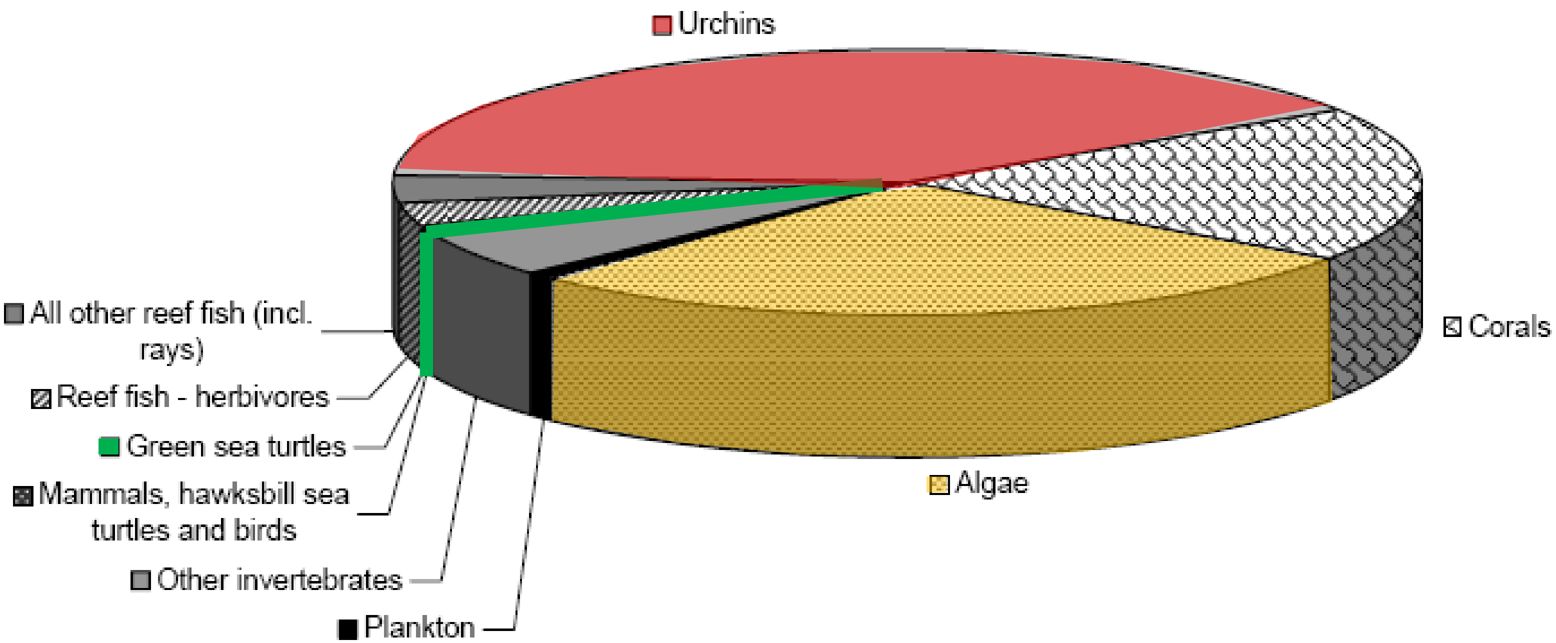
- All foraging aggregations throughout the Hawaiian Islands are one genetic stock
- Growth rates have been declining and reduced body condition at some sites
- Some foraging grounds are at their carrying capacity (e.g. Kaloko-Honokohau)

Trophic Flows of the Kaloko-Honokohau Ecosystem



C. Wabnitz PhD Dissertation 2011

Biomass Proportions of Aggregated Functional Groups



C. Wabnitz PhD Dissertation 2011

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

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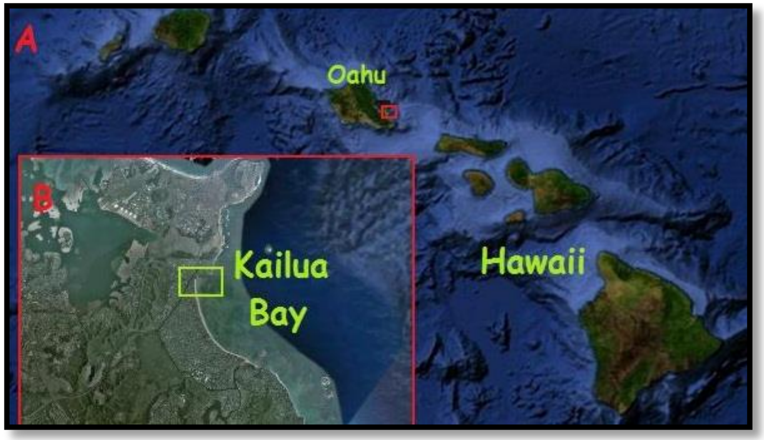
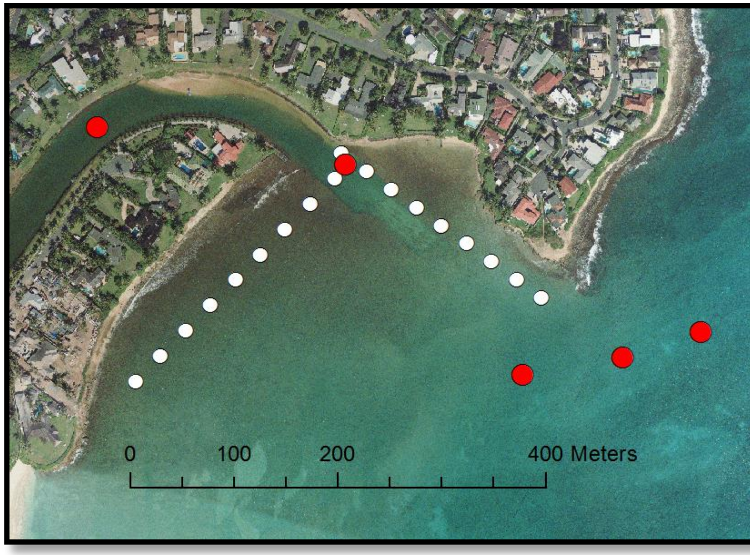
2) Kailua Bay, Oahu - Kawainui Canal Abundance and Habitat Use





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

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Abundance & Habitat Use

- Marked 42 individuals
- Seasonal snorkel surveys
- Lincoln-Petersen mark-recapture estimate

- Acoustic tracking – 12 turtles
- 5 receivers: canal, cove, offshore (3)

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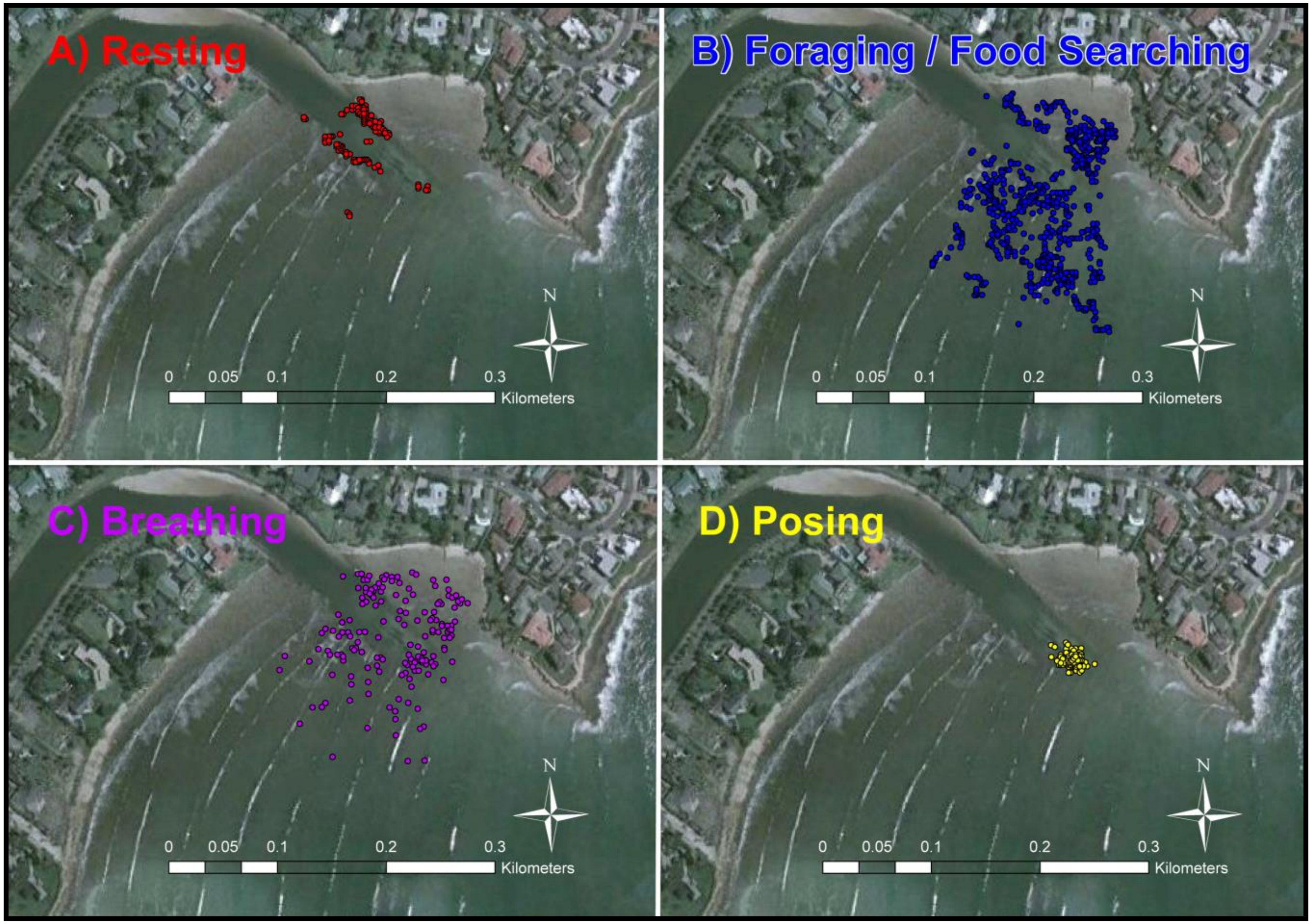
Video Surveys: Habitat Use



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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

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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

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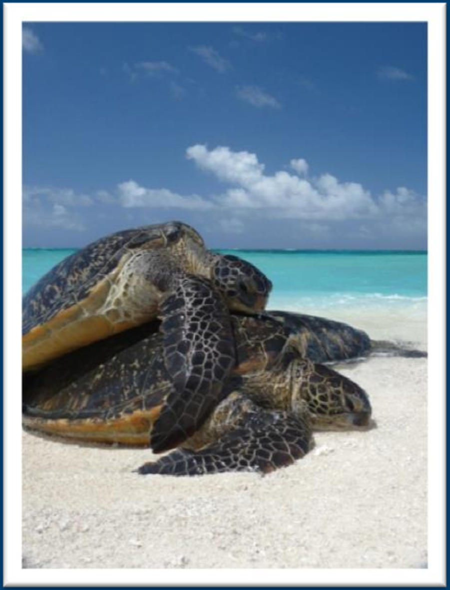
Nesting and Basking Turtle Sampling Research

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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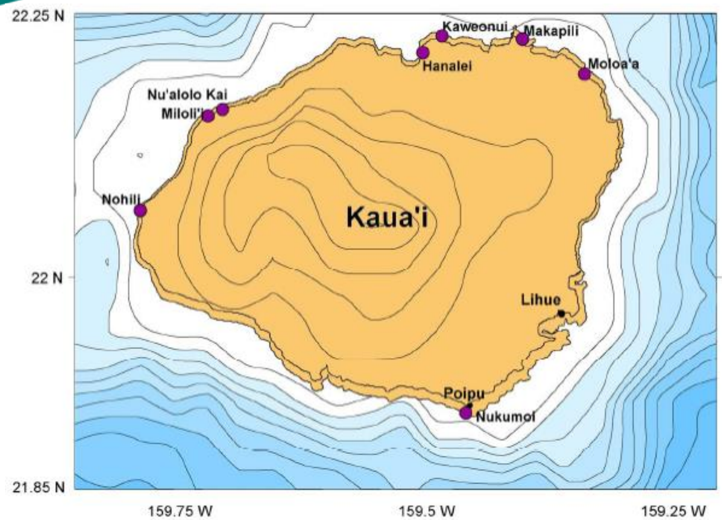
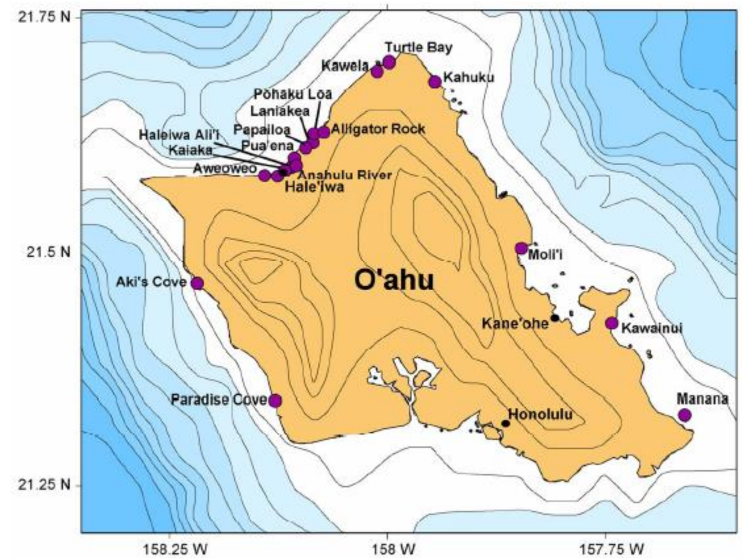
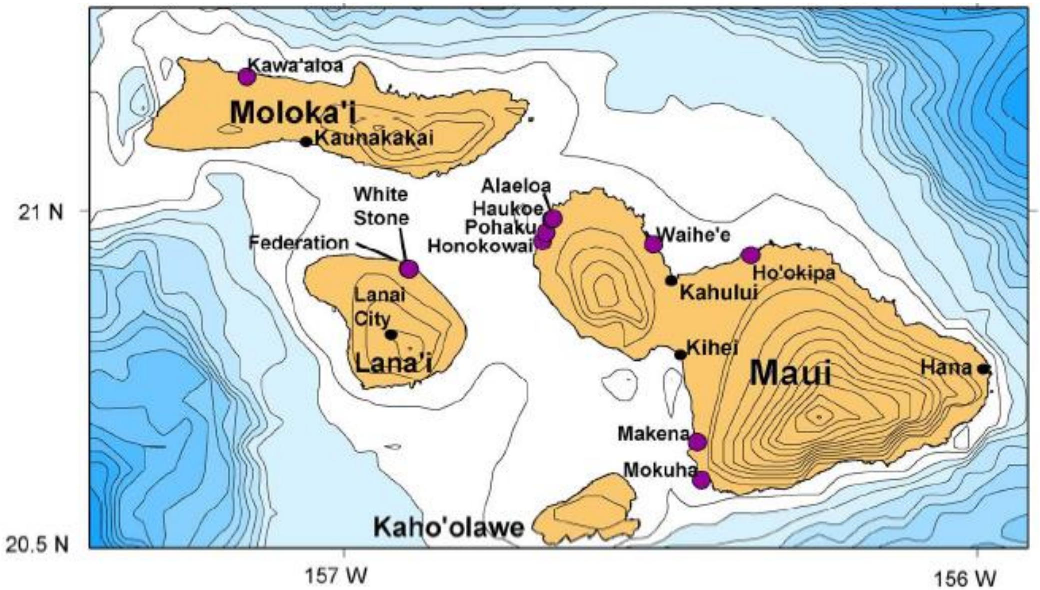
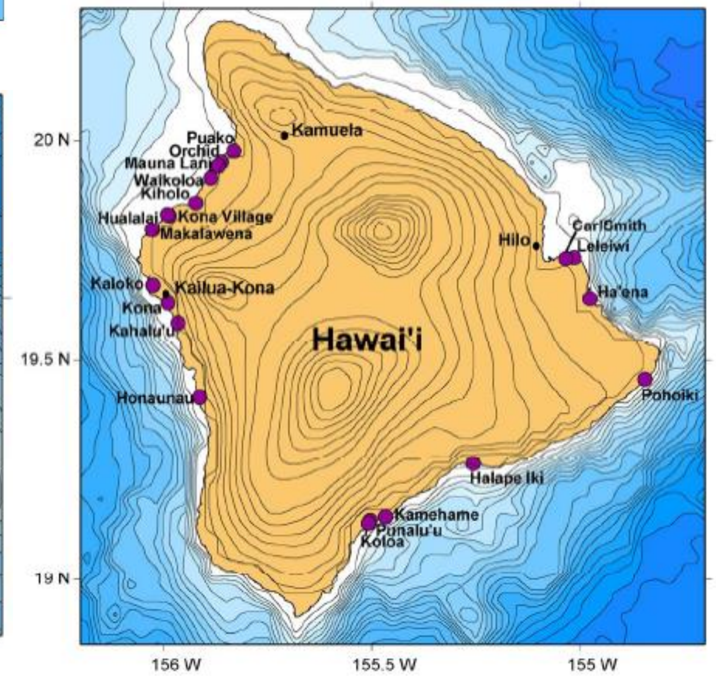
1) Basking Research









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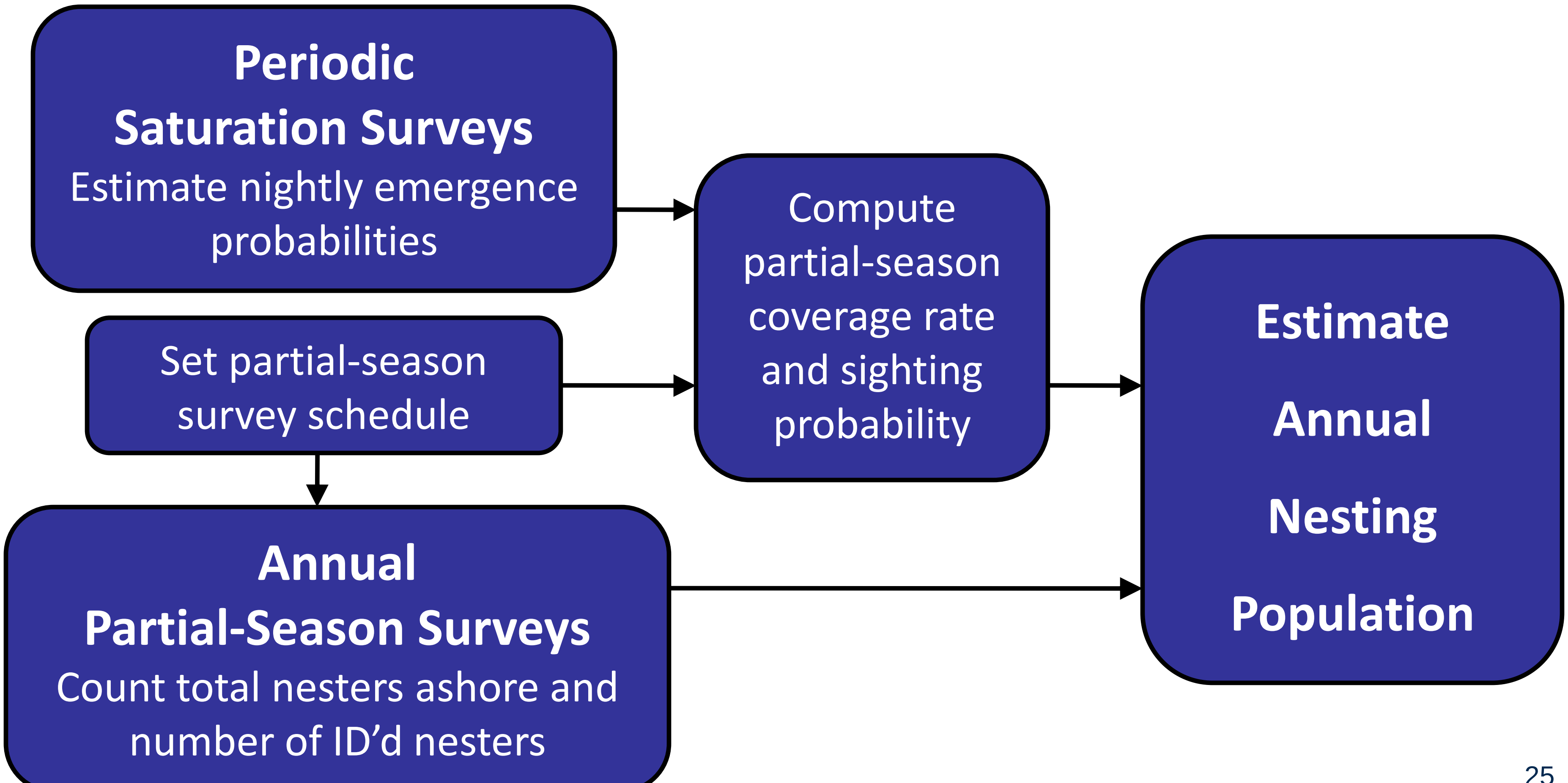
2) Methods:
Strategy for Monitoring Nesters



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)

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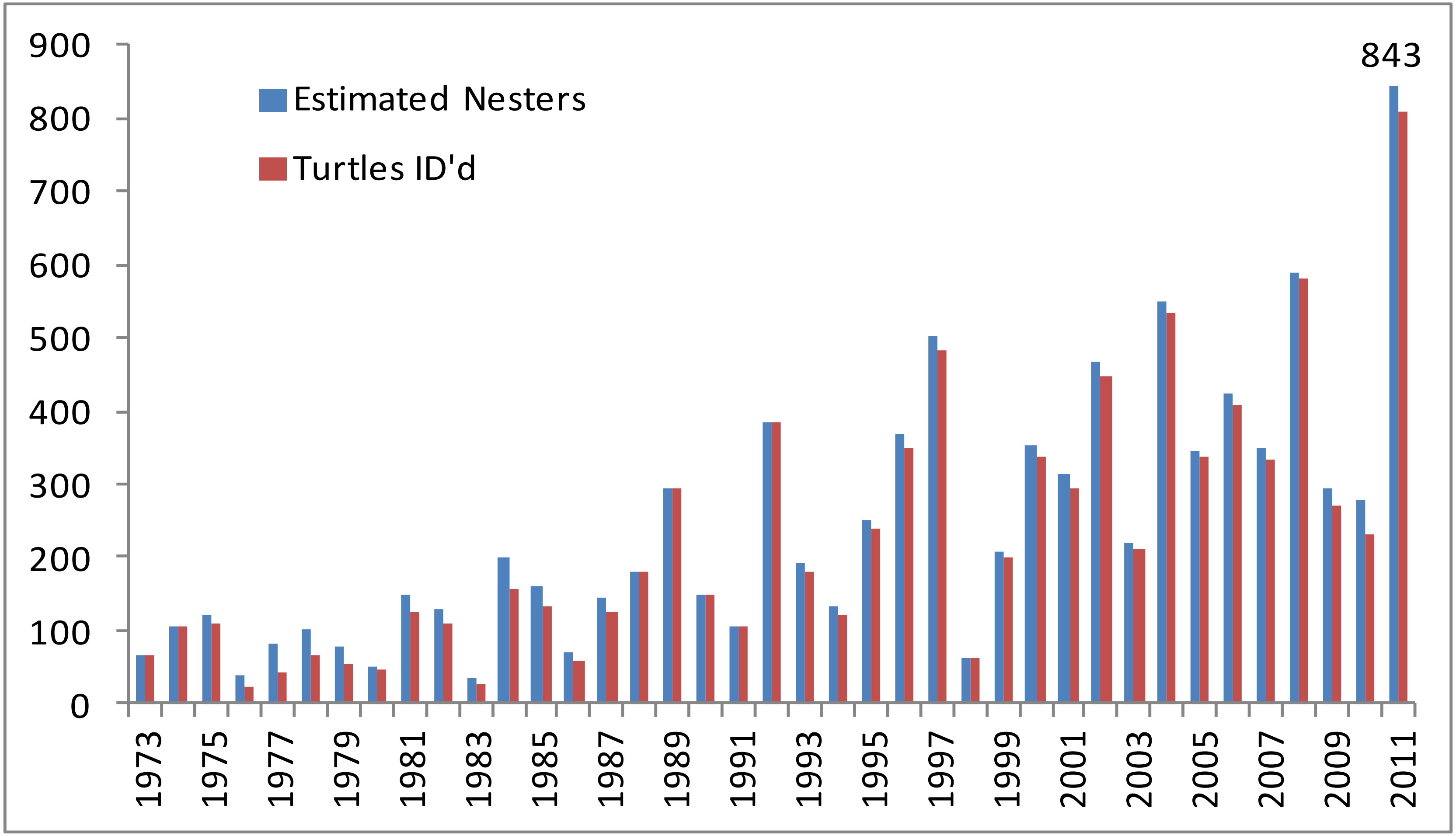
3) Nesting Research: 2011 Update



Pacific Islands Fisheries Science Center

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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

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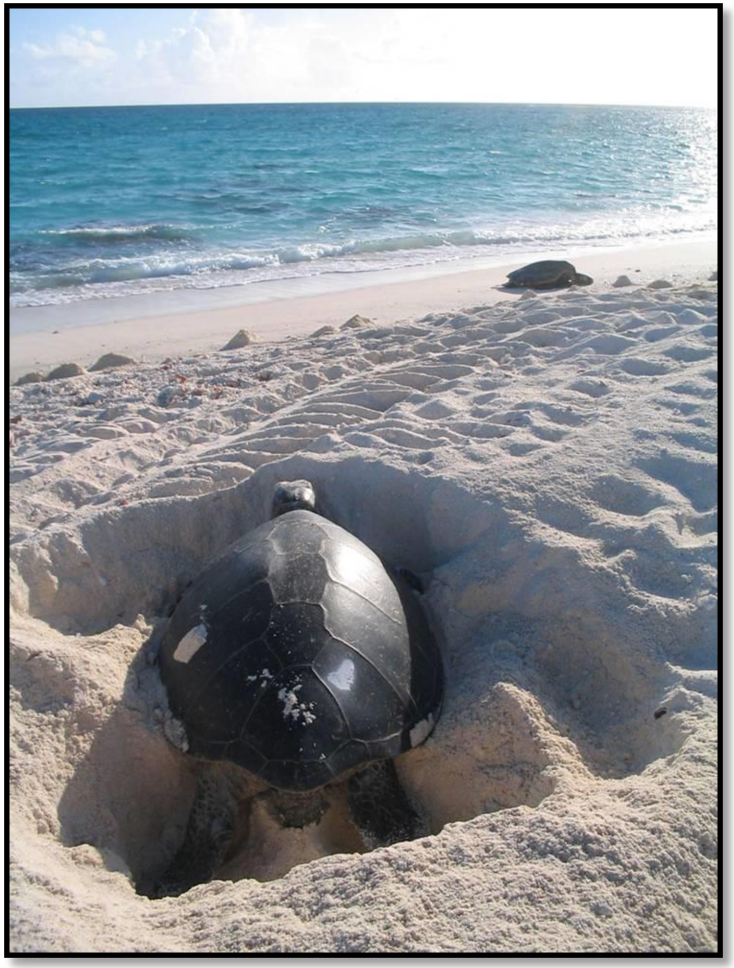
Objective

- 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



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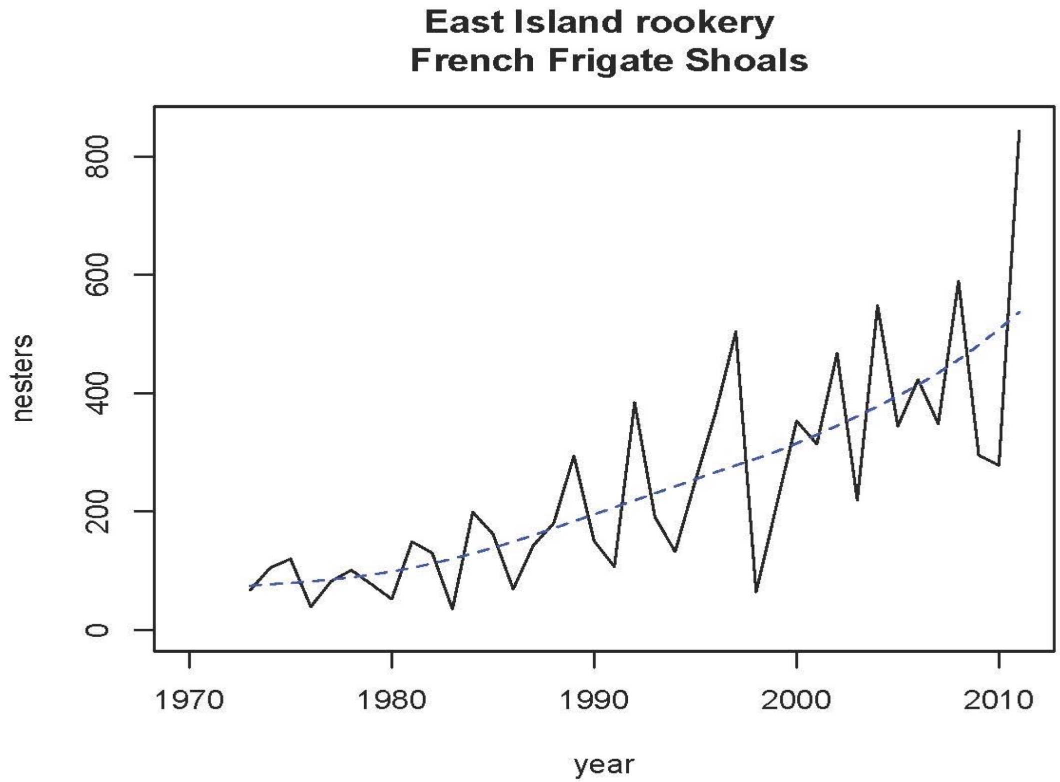

- Nesting population increasing at a rate of 5.7% per year (Chaloupka et al. 2008)
- Predicted loss of up to 33% of nesting habitat at East Island by 2100 due to sea level rise (Baker et al. 2006)

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

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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

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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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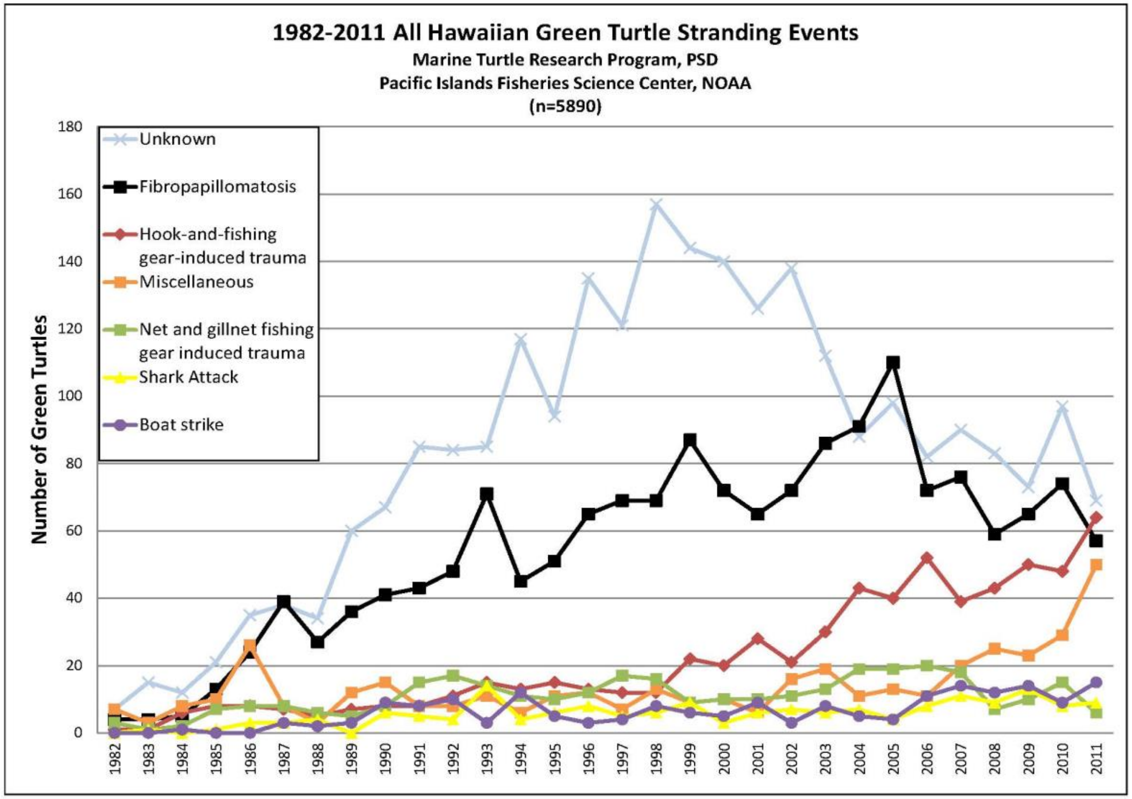
太平洋島嶼漁業科學中心的海龜研究

- 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



GraphsofHawaiianGreenStrandingData_revised
1/13/2012
WM

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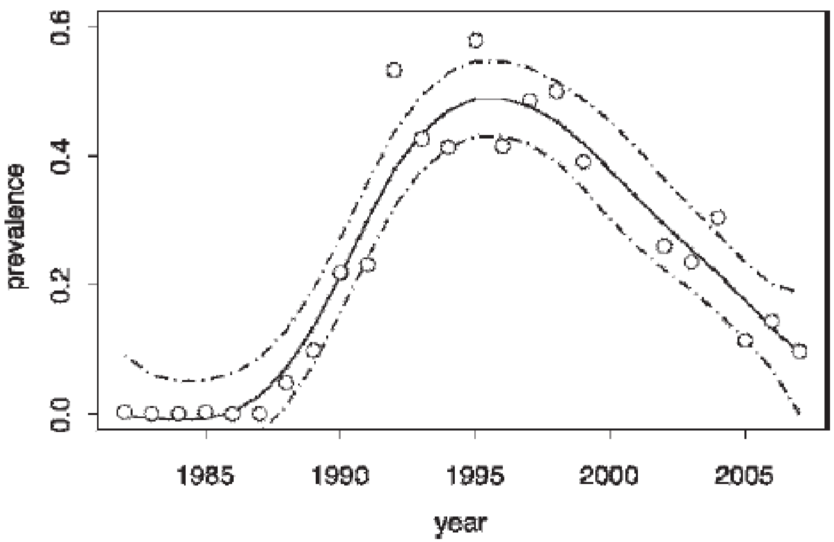
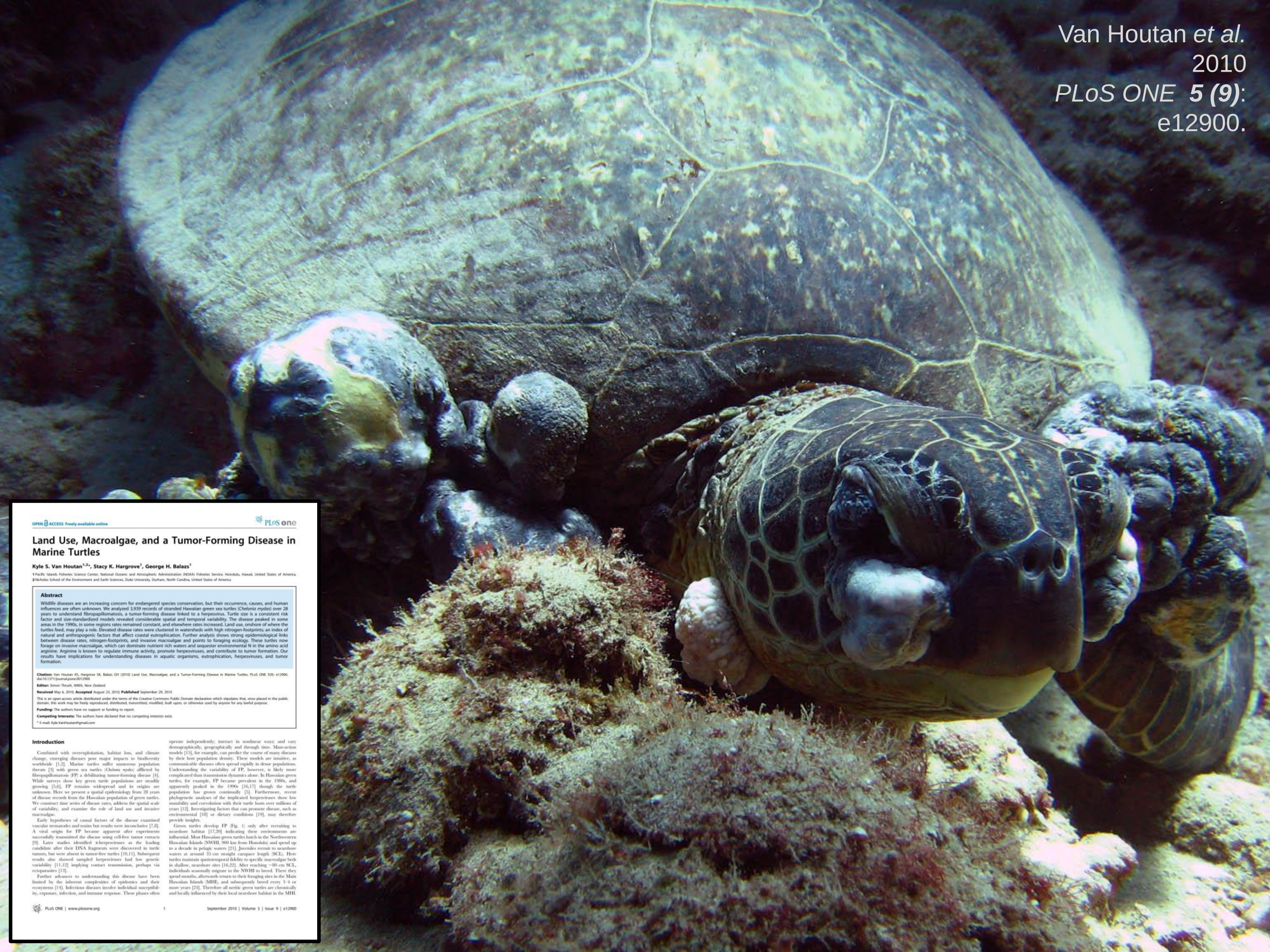
Disease Research
Fibropapilloma Tumors



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.

USGS science for a changing world



OPEN ACCESS Freely available online
PLoS one

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

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Abstract

Wildlife diseases are an increasing concern for endangered species conservation, but their occurrence, causes, and human influences are often unknown. We analyzed 3,939 records of stranded Hawaiian green sea turtles (*Chelonia mydas*) 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, onshore 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 eutrophication. 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 sequester environmental N 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.0012900

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

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Introduction

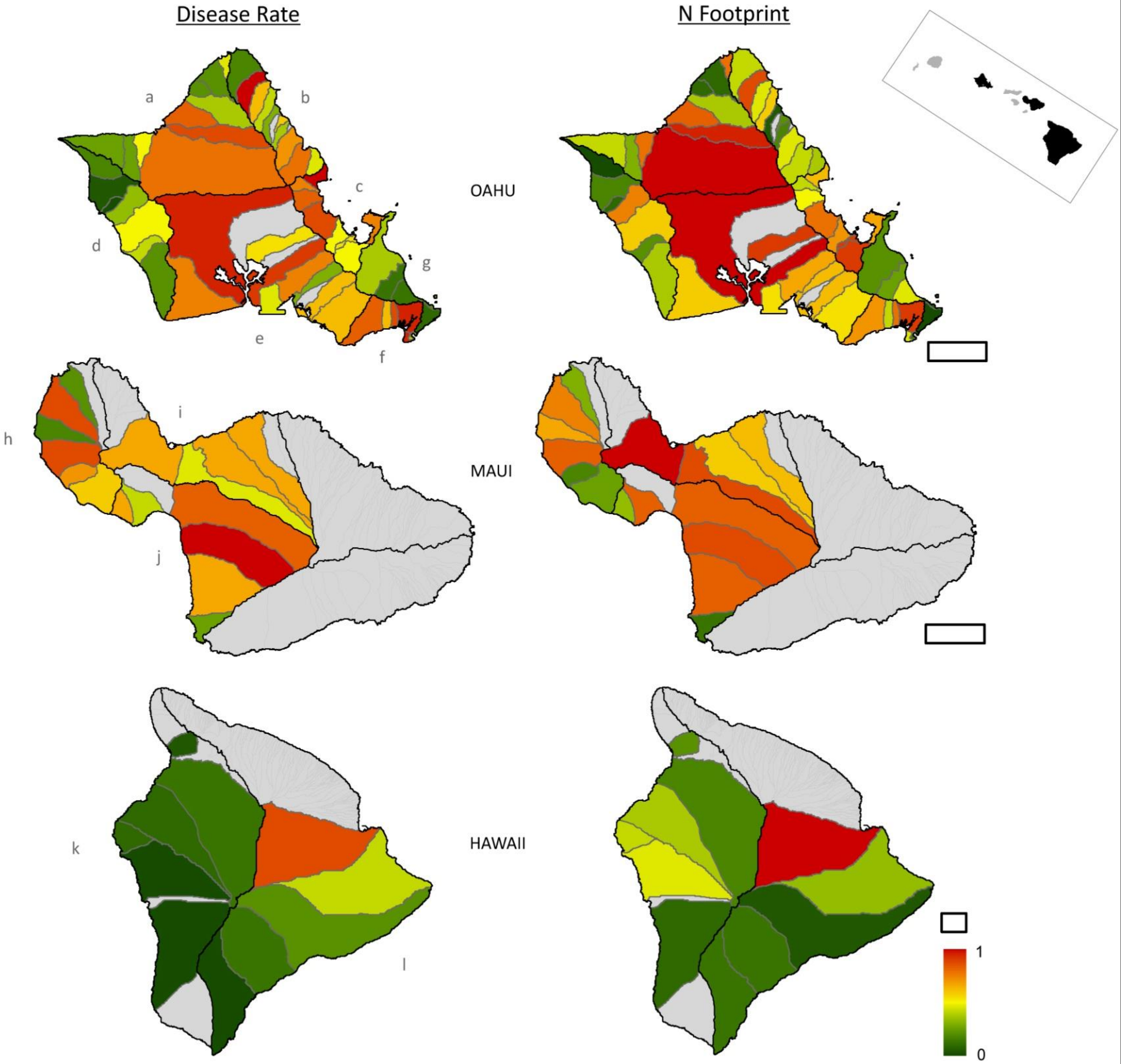
Combined with overexploitation, habitat loss, and climate change, emerging diseases pose major impacts to biodiversity worldwide [1,2]. Marine turtles suffer numerous population threats [3] with green sea turtles (*Chelonia mydas*) afflicted by fibropapillomatosis (FP) a debilitating tumor-forming disease [4]. While surveys show key green turtle populations are steadily growing [5,6], FP remains widespread and its origins are unknown. Here we present a spatial epidemiology from 28 years of disease records from the Hawaiian population of green turtles. We construct time series 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 vascular trematodes and toxins but results were inconclusive [7,8]. A viral origin for FP became apparent after experiments successfully transmitted the disease using cell-free tumor extracts [9]. Later studies identified α-herpesviruses as the leading candidate after their DNA fragments were discovered in turtle tumors, but were absent in tumor-free turtles [10,11]. Subsequent results also showed sampled herpesviruses had low genetic variability [11,12] implying contact transmission, perhaps via ectoparasites [13].

Further advances to understanding this disease have been limited by the inherent complexities of epidemics and their ecosystems [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. Mass-action models [15], for example, can predict the course of many diseases by their host population density. These models are intuitive, as communicable diseases often spread rapidly in dense populations. Understanding the variability of FP, however, is likely 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] though the turtle population has grown continually [5]. Furthermore, recent phylogenetic analyses of the implicated herpesviruses show low mutability and coevolution with their turtle hosts over millions 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 (Fig. 1) only after recruiting to nearshore habitat [17,20] indicating these environments are influential. Most Hawaiian green turtles hatch in the Northwestern Hawaiian Islands (NWHI, 900 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 spatiotemporal fidelity to specific macroalgae beds in shallow, nearshore sites [16,22]. After reaching ~80 cm SCL, individuals seasonally migrate to the NWHI to breed. There they spend months, afterwards return to their foraging sites in the Main Hawaiian Islands (MHI), and subsequently breed every 3–4 or more years [23]. Therefore all neritic green turtles are chronically and locally influenced by their local nearshore habitat in the MHI.

Disease ecology



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Stock Structure - Genetics

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Hawaiian Islands Case Study

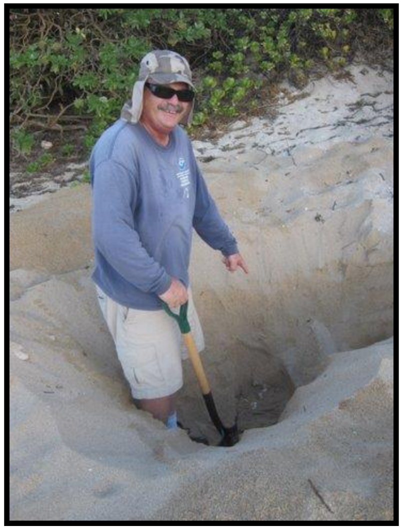
Question: what nesting stocks do juvenile and adult foraging populations around the Hawaiian Islands belong to? **Answer: Foraging populations derived from a single nesting stock – French Frigate Shoals.**

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

Dutton, Balazs et al. 2008. Endangered Species Research 5: 37-44

Main Hawaiian Islands Nesting

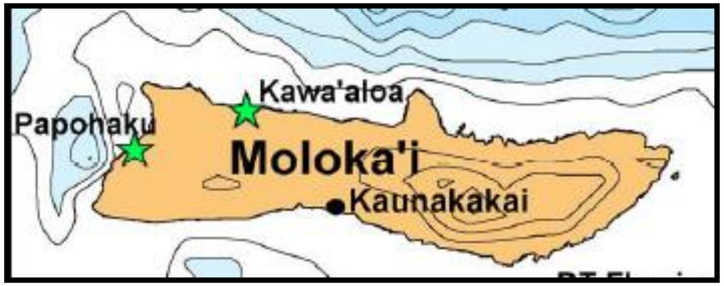
- Recent scattered nesting around Main Hawaiian Islands
- Nesters mostly unobserved
- Widespread nests sampled



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 (Molokai-Papohaku and Molokai- Kawaaloa rows)

Frey, Balazs, Dutton, *in prep*

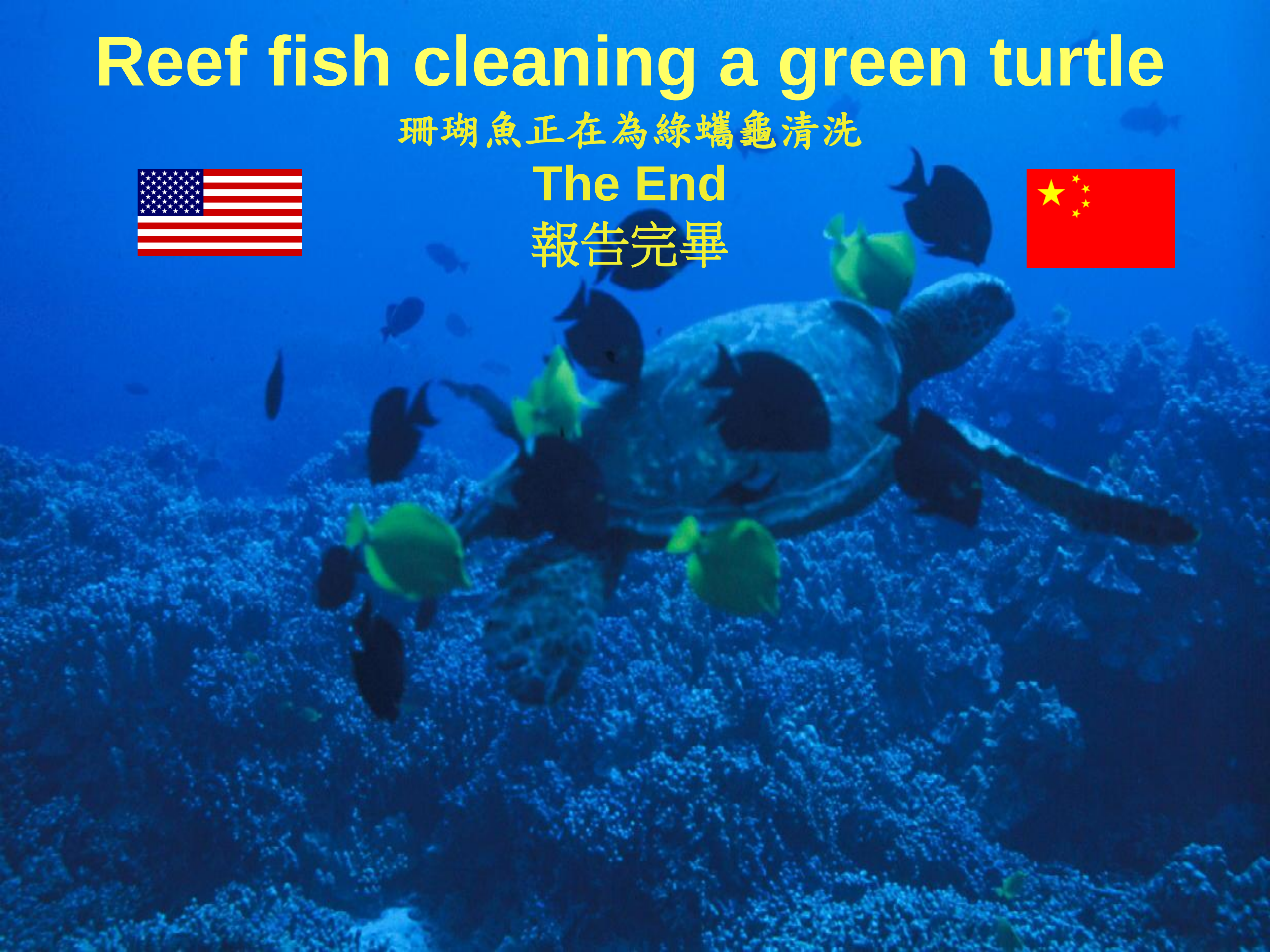
Nesting in Main Hawaiian Islands Summary-Preliminary findings

- 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


Reef fish cleaning a green turtle
珊瑚魚正在為綠蠵龜清洗
The End
報告完畢