You are What You Eat:

studying the diet and plastic ingestion of Hawaiian seabirds

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Pelagicos

Speaking on Behalf of a Big Flock

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Road Map

I. Motivation

II. Background

III. Case Studies
- community study
- local index
- regional index

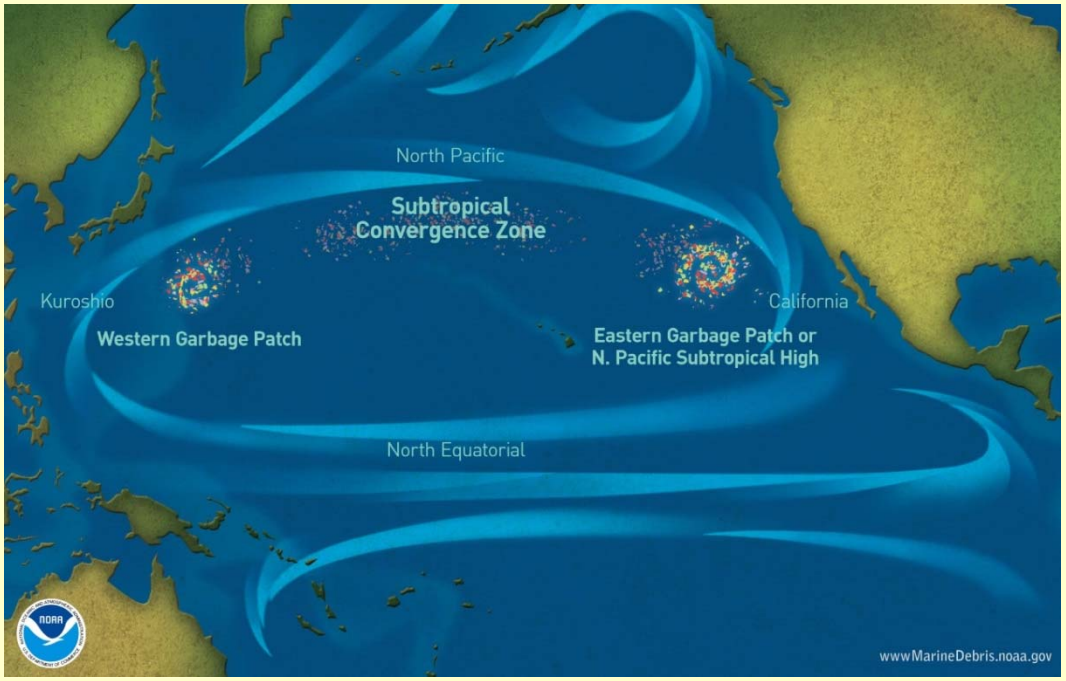
III. Emerging Issues

I. Motivation: Monitoring Trends

Monitoring plastic pollution trends in the North Pacific

Sizes

Types



Challenge: Sampling Plastic in the Ocean

Vessel-based surveys are very expensive and time consuming

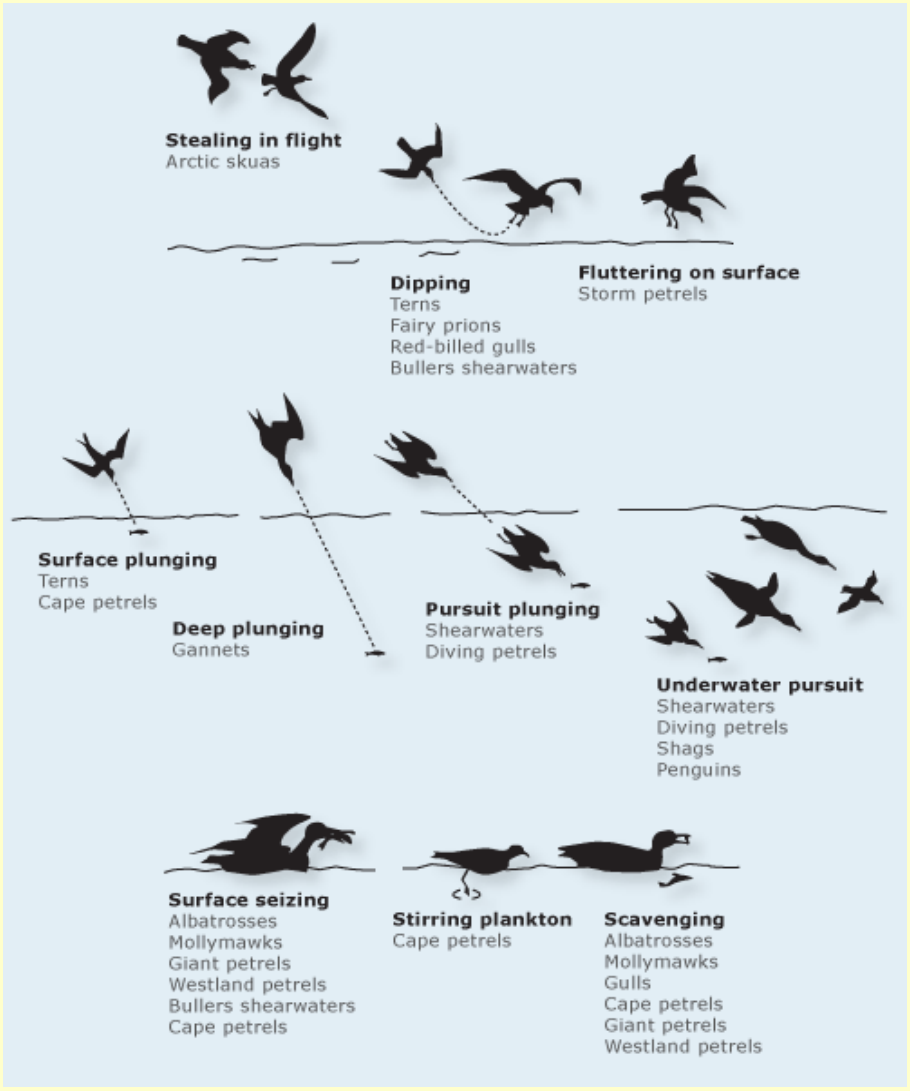
Painting by Sophie Webb

Solution: Let the Birds do the Sampling

Why Use Seabirds to Sample the Ocean ?

- Numerous, Far-ranging, Colonial breeders
- Seabird species forage in different areas and catch different prey in different ways

II. Background – Seabird Foraging Guilds



(Ashmole 1971)

Aerial Predators

- Frigates
- Terns
- Storm-petrels

Plungers / Divers

- Terns
- Tropicbirds
- Shearwaters

Surface Foragers

- Albatrosses
- Shearwaters
- Petrels

Diverse Feeding Methods in the Tropics

Opportunistic Feeders

Velella velella

Halobates spp.

Lepas spp.

(Harrison et al., 1983; Gould et al., 1997)

Use Oceanographic Features

- Foraging at features which concentrate prey at surface

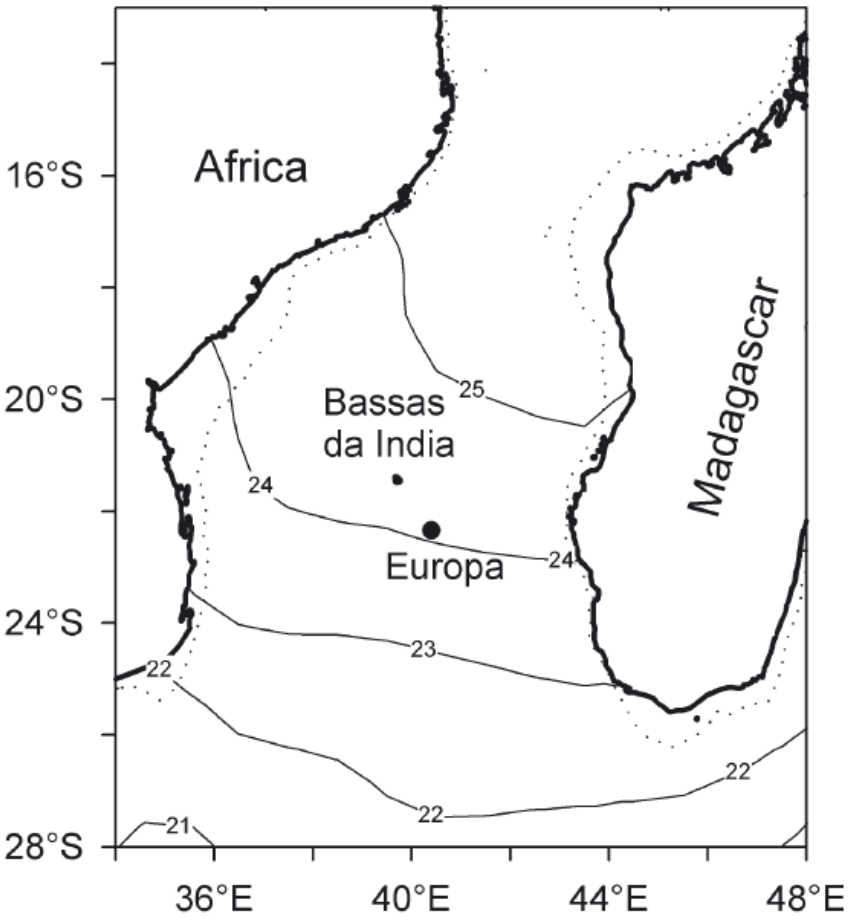
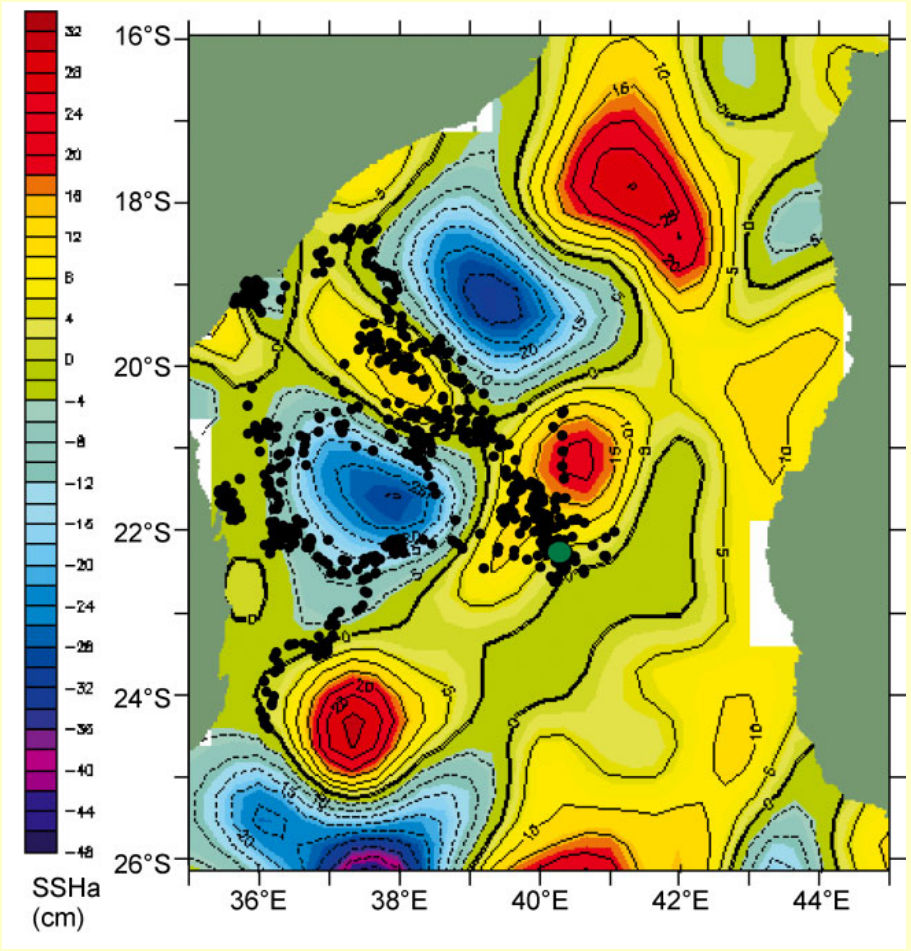


Fig. 1. The Mozambique Channel showing the –200 m depth contour (dotted line) separating neritic shelf areas from oceanic waters, and the sea-surface temperature isotherms (°C) in September 2003



Frigatebirds patrol edge of eddies

(Weimerskirch et al., 2004)

Widespread Reliance on SSPs

(Ballance & Pitman, 1999)

Many tropical seabirds associate with sub-surface predators (tunas/cetaceans)

Widespread: 90 species from 27 genera (Ballance, 1993)

Pervasive: for many species, majority of feeding events in association with subsurface predators

(70% feeding events in flocks, Central Pacific) (King, 1970)

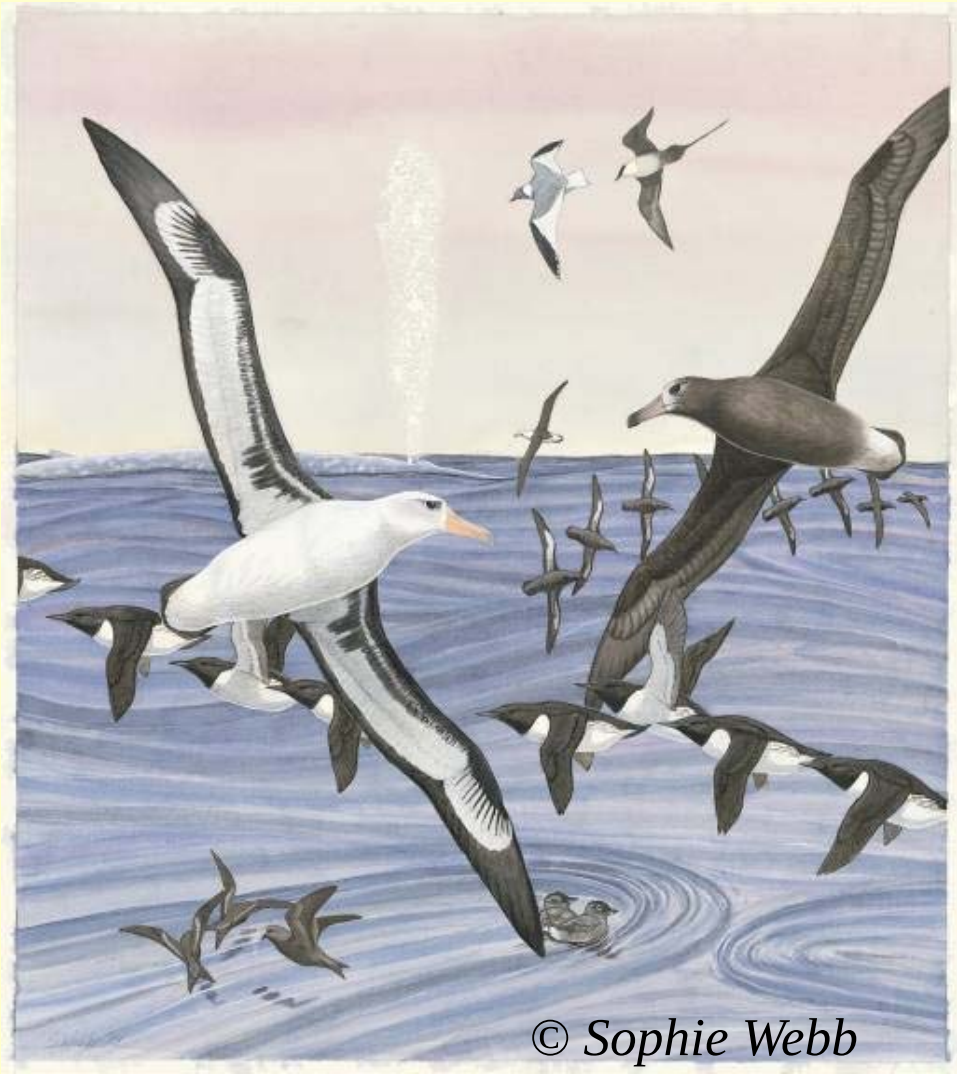
Persistent: distinct "tuna-bird" community (Ballance et al., 1997)

Objective

To sample pelagic plastic (abundance / types) using multiple Hawaiian seabirds

- Develop standardized analysis methods

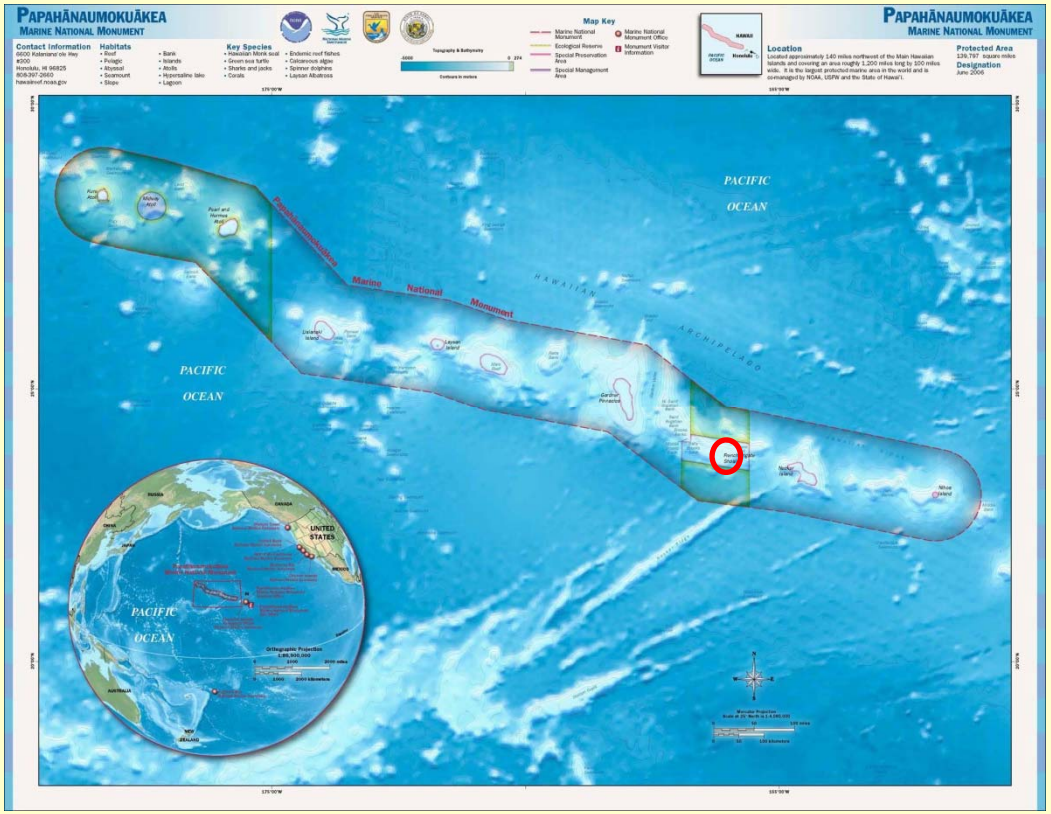
- Establish metrics for pollution monitoring



IIIa. Comparative Study: Tern Island (FFS)

- 16 Breeding species
- Diverse foraging guilds

(Dearborn et al. 2001, Harrison et al. 1983)




Albatrosses
Suliformes
Tuna Birds
Nocturnal Petrels
Neuston-Feeding
Terns

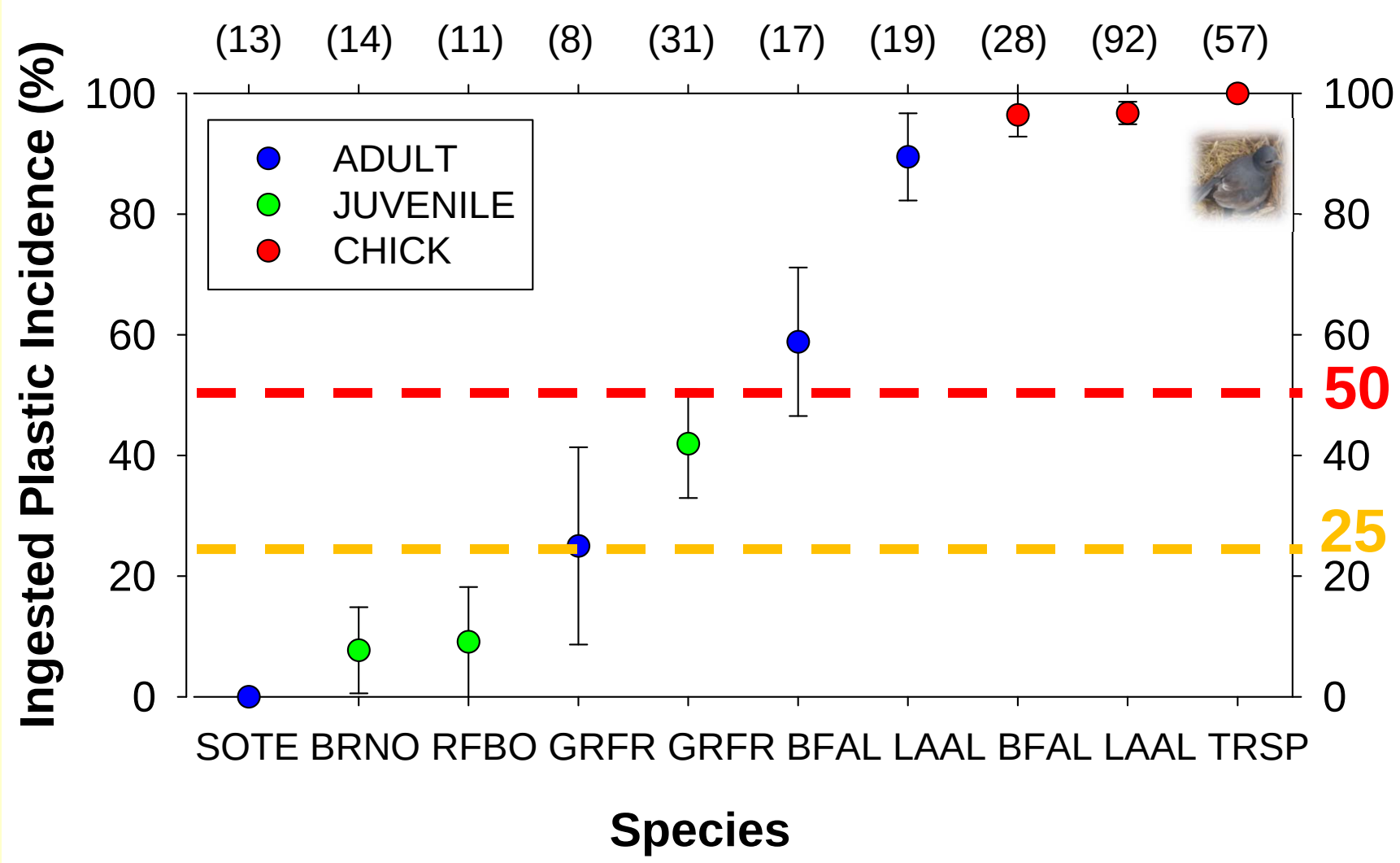
Plastic Ingestion Incidence (2006-13)

Top Five Species with Plastic Ingestion (FFS)

Plastic Incidence (number)

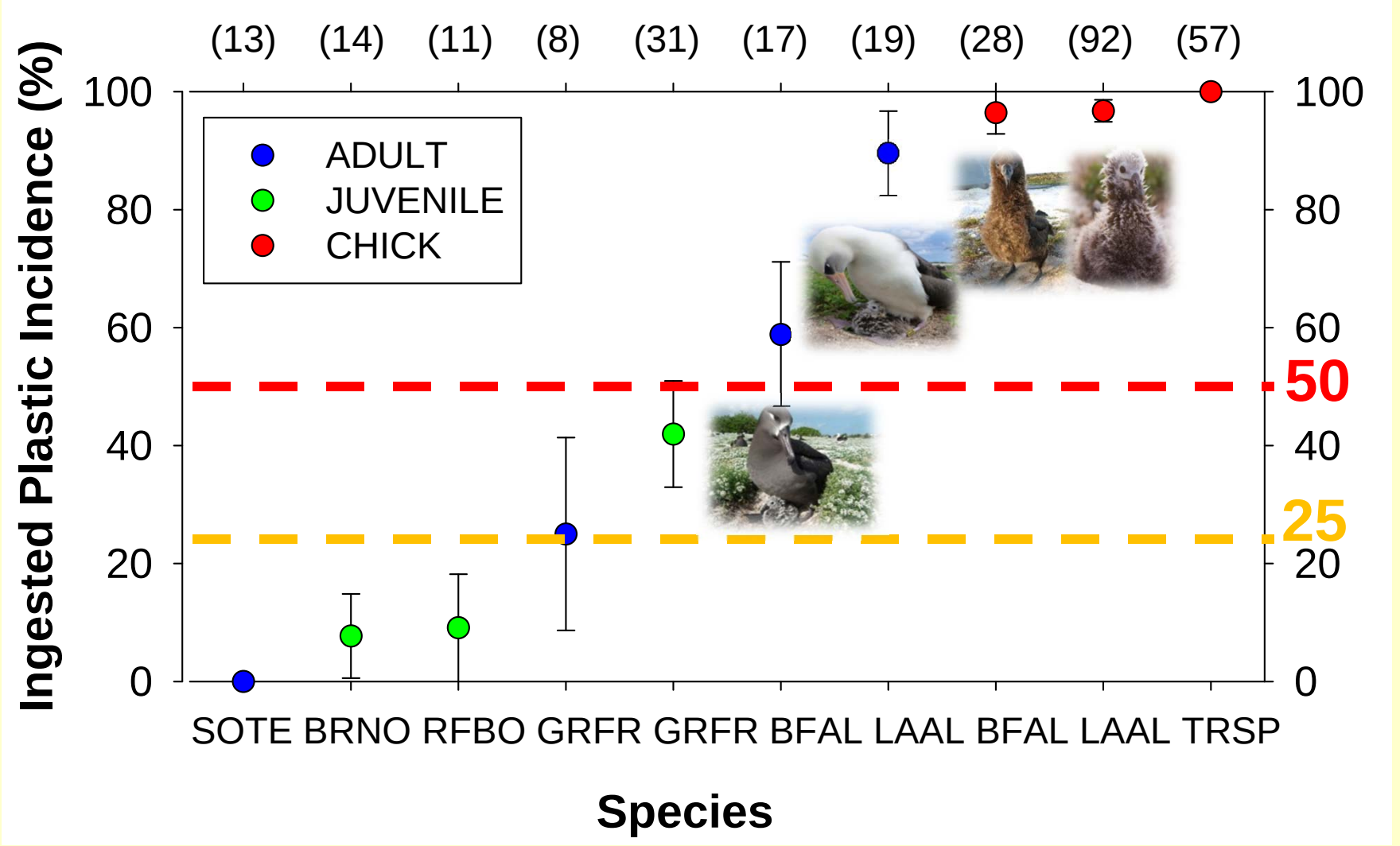
Age / Species	TRSP	BOPE	LAAL	BFAL	WTSH
Chicks	100% (57)	100% (5)	96.7 (92)	96.4% (28)	50% (2)
Adults	100% (1)	100% (1)	89.5 (19)	58.8% (17)	100% (2)

Plastic Ingestion Incidence (2006-13)



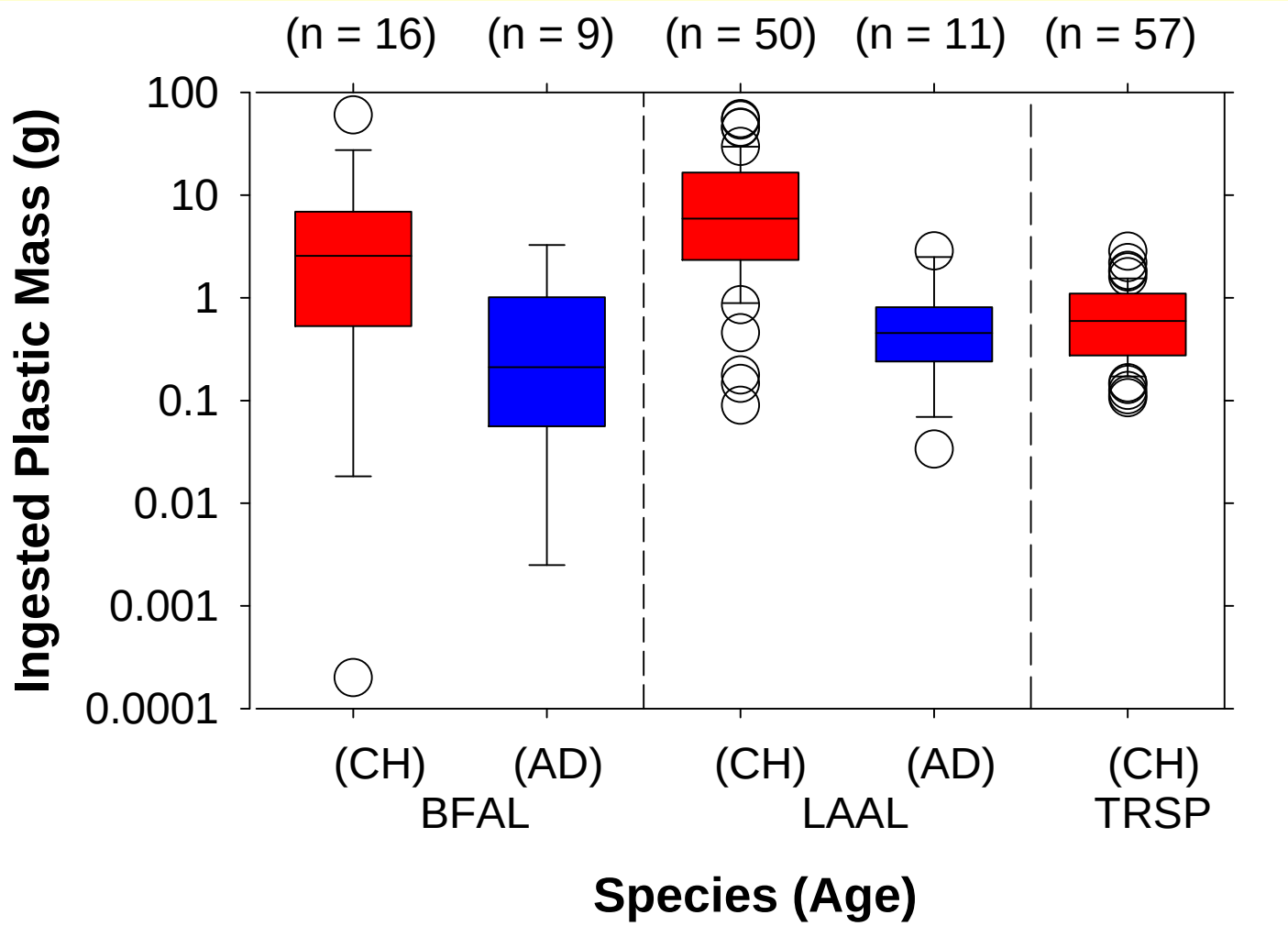
NOTE: Only "common" Species * Age groups (> 8 birds sampled) are considered

Plastic Ingestion Incidence (2006-13)



- Laysans have higher incidence than Black-foots
- Chicks have higher incidence than adults

Plastic Mass Ingested by Petrels



% Body Mass

BFAL (< 4 %)

LAAL (< 12%)

TRSP (< 2 %)

- Ingested plastic mass higher in chicks than adults

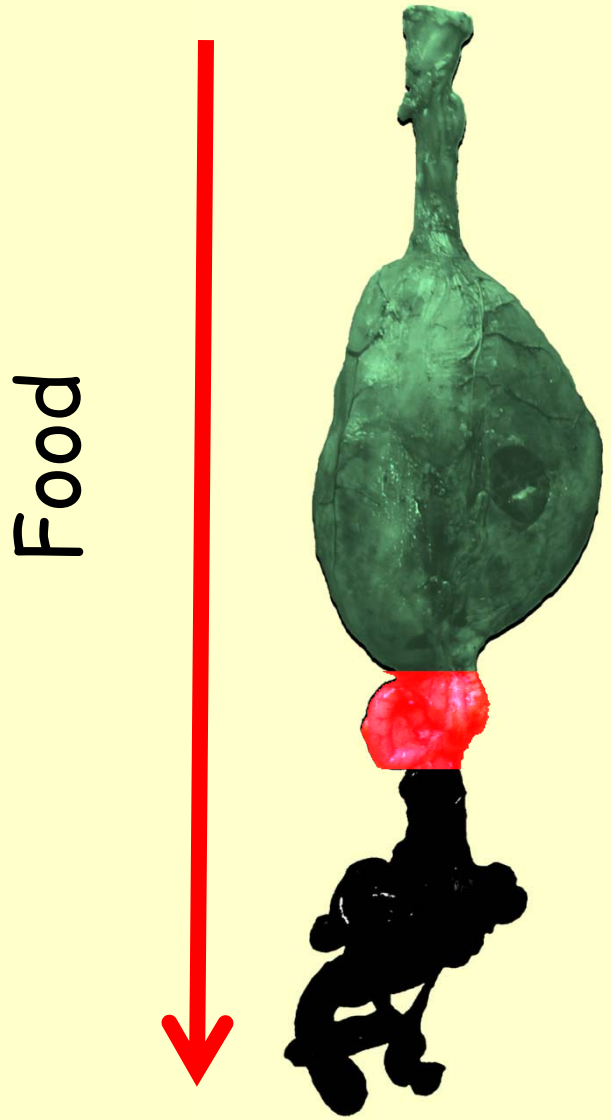
Tristram's Storm Petrel (Oceanodroma tristrami)

Poorly studies: small / nocturnal / burrowing

100 % plastic ingestion incidence (n = 57 birds)

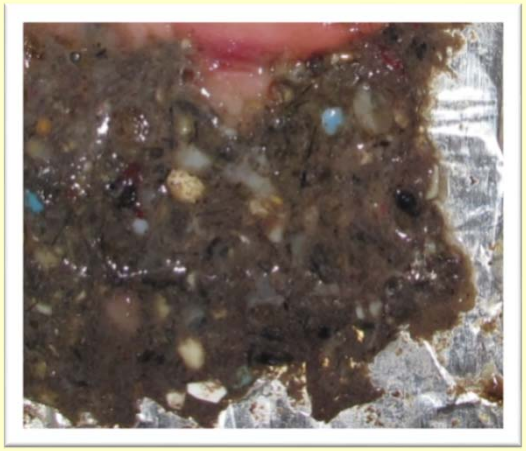
Tubenose Seabirds (Order Procellariiformes)

Two Stomach Chambers



- **Proventriculus (upper GI)**
  - Expandable
  - Thin walled
  - Storage
  - Chemical digestion
- **Gizzard (upper GI)**
  - Robust
  - Muscular
  - Physical digestion
- **Intestines (Lower GI)**
  - Nutrient absorption
  - Water absorption

TRSP – Stomach Contents



Sieve
(0.5 mm)

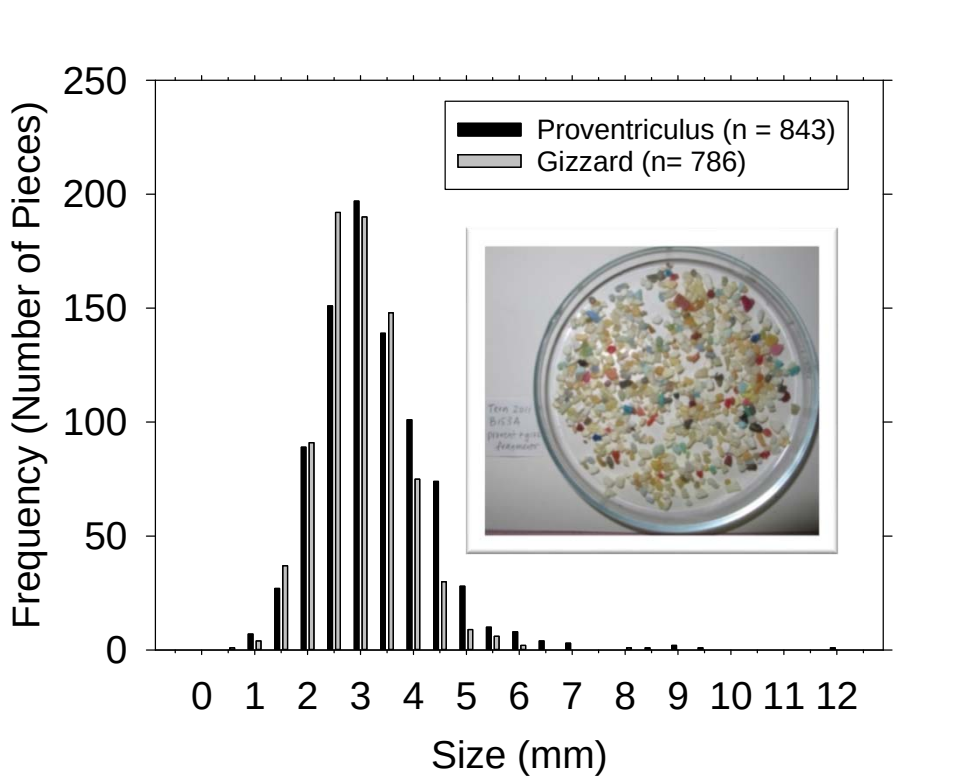
Sort

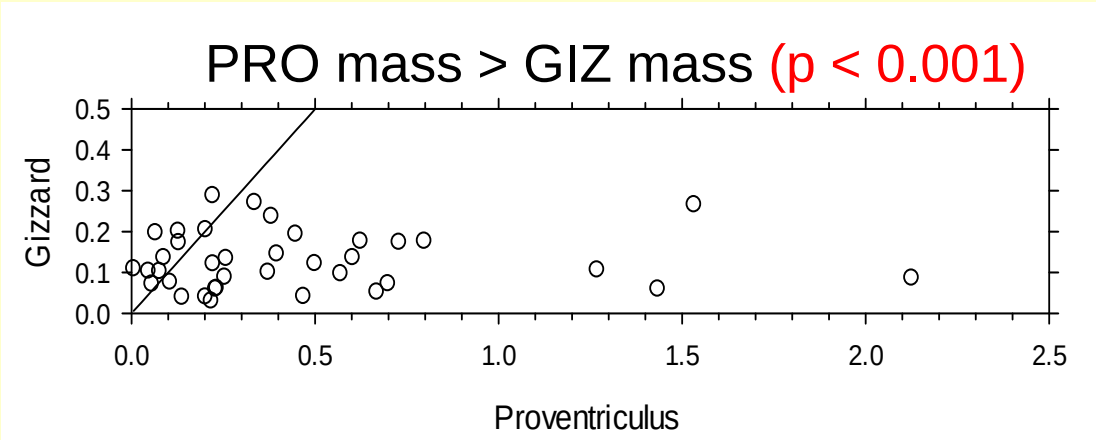
Plastic

Natural Food

Natural Non-Food

Tristram's Storm-Petrel – Plastics





- Large number of ingested fragments

  32 – 615 pieces per bird

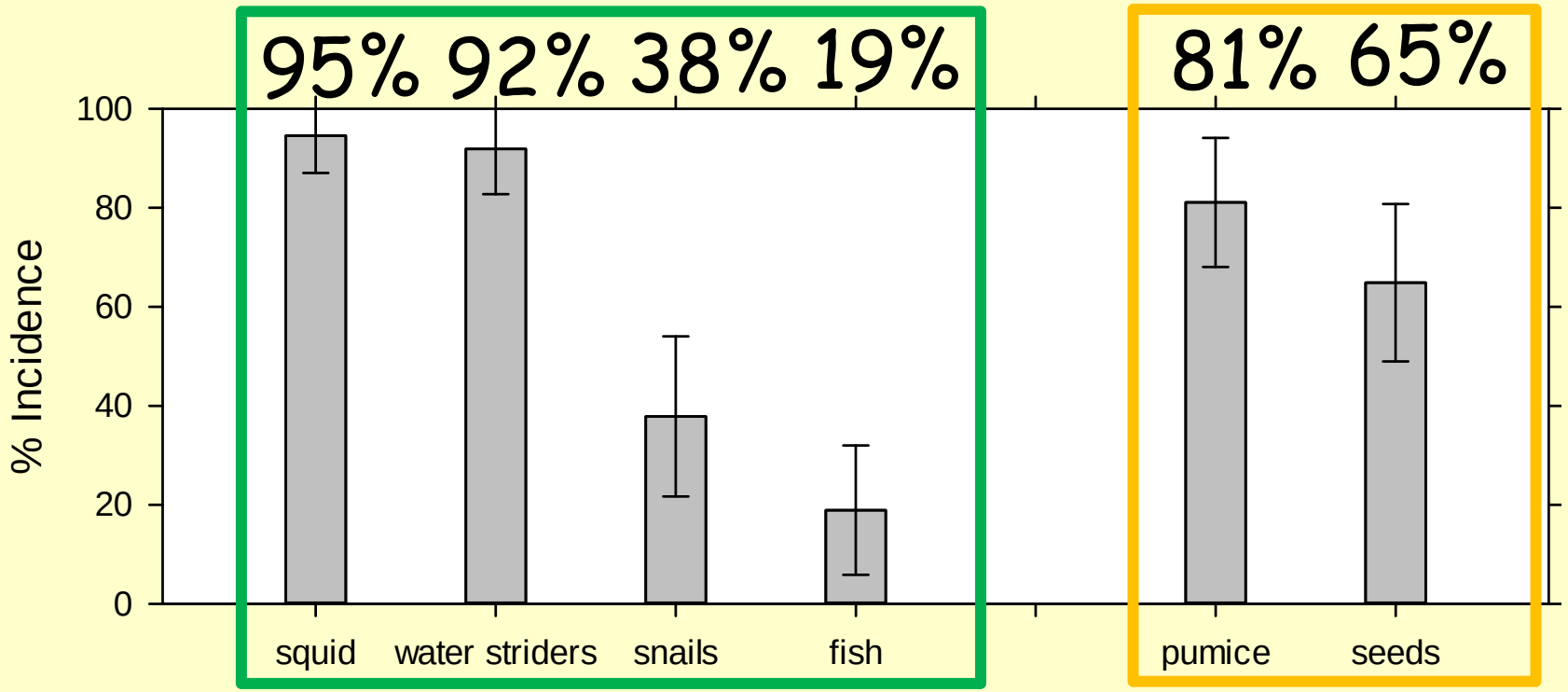
- Overlap in fragment size by chamber

  Pro: 0.64 – 11.58 mm
  Giz: 0.35 – 7.50 mm

- Significantly larger fragment sizes in the proventriculus
- Larger plastic mass in the Proventriculus

Tristram's Storm-Petrel – Diet

Incidence +/- 2 S.D. (Binomial Probability)



- Diverse diet: squid and fish; neustonic prey
- Ingestion of natural non-prey items

Tristram's Storm-petrel – Prey

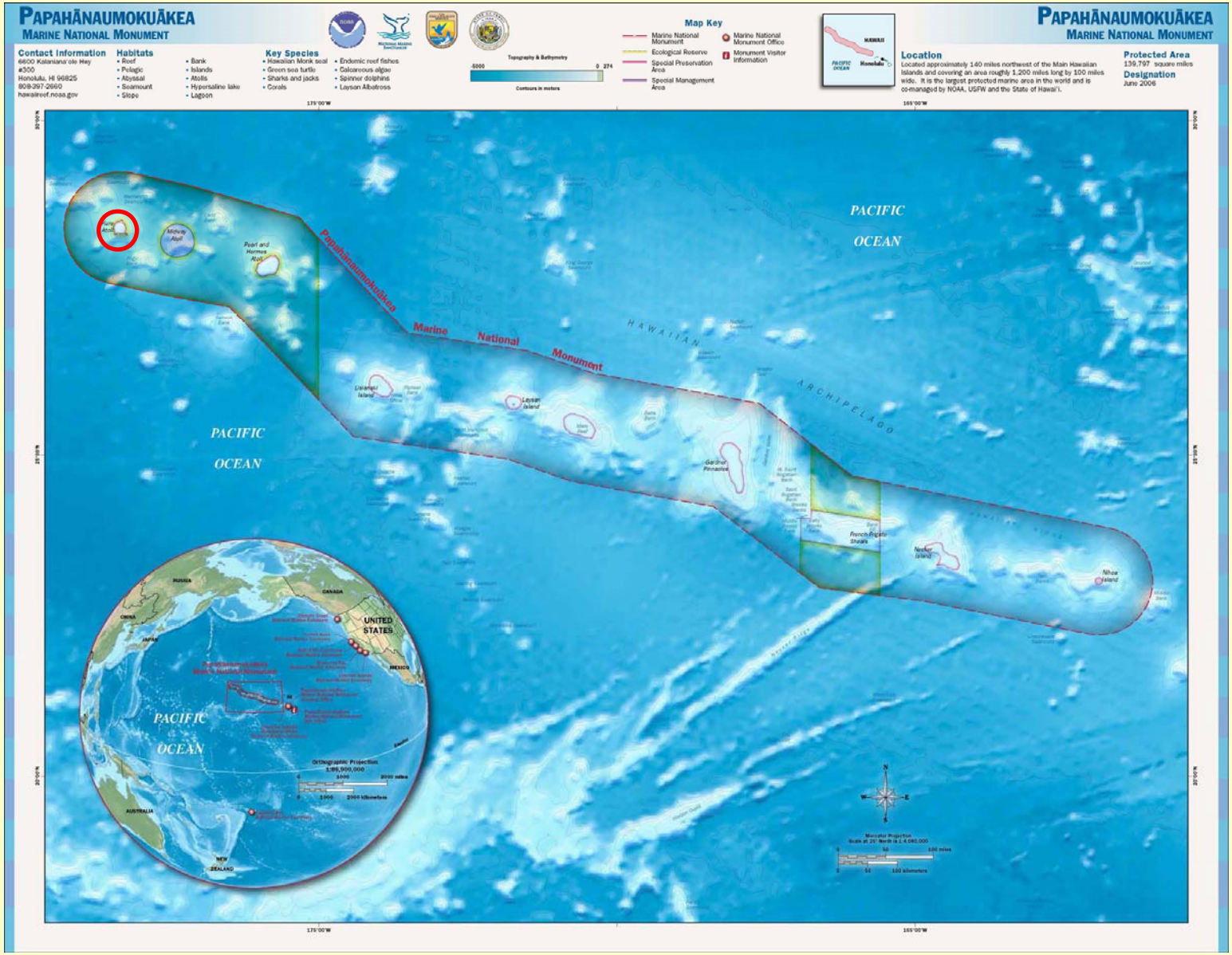
Halobates spp.

Janthina spp.

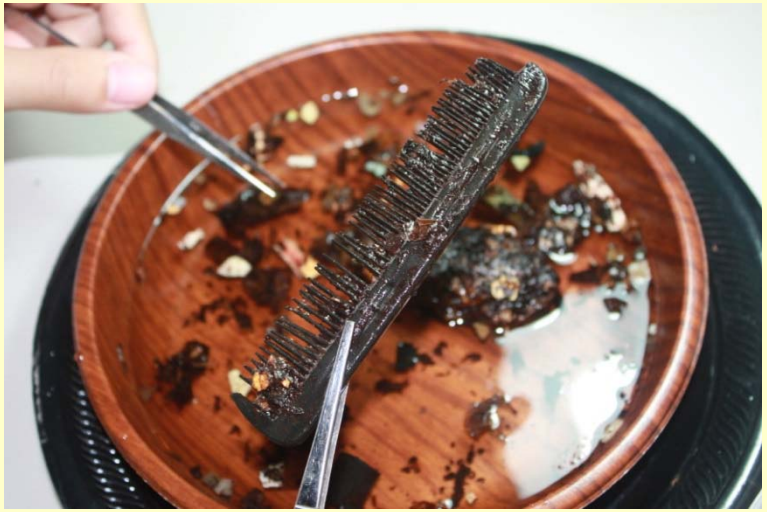
Myctophids

Flying Squid

IIIb. Case Study 2: Regional Metrics



Approach - Chick Boluses



Methods - Characterizing Plastic

- 4 Categories

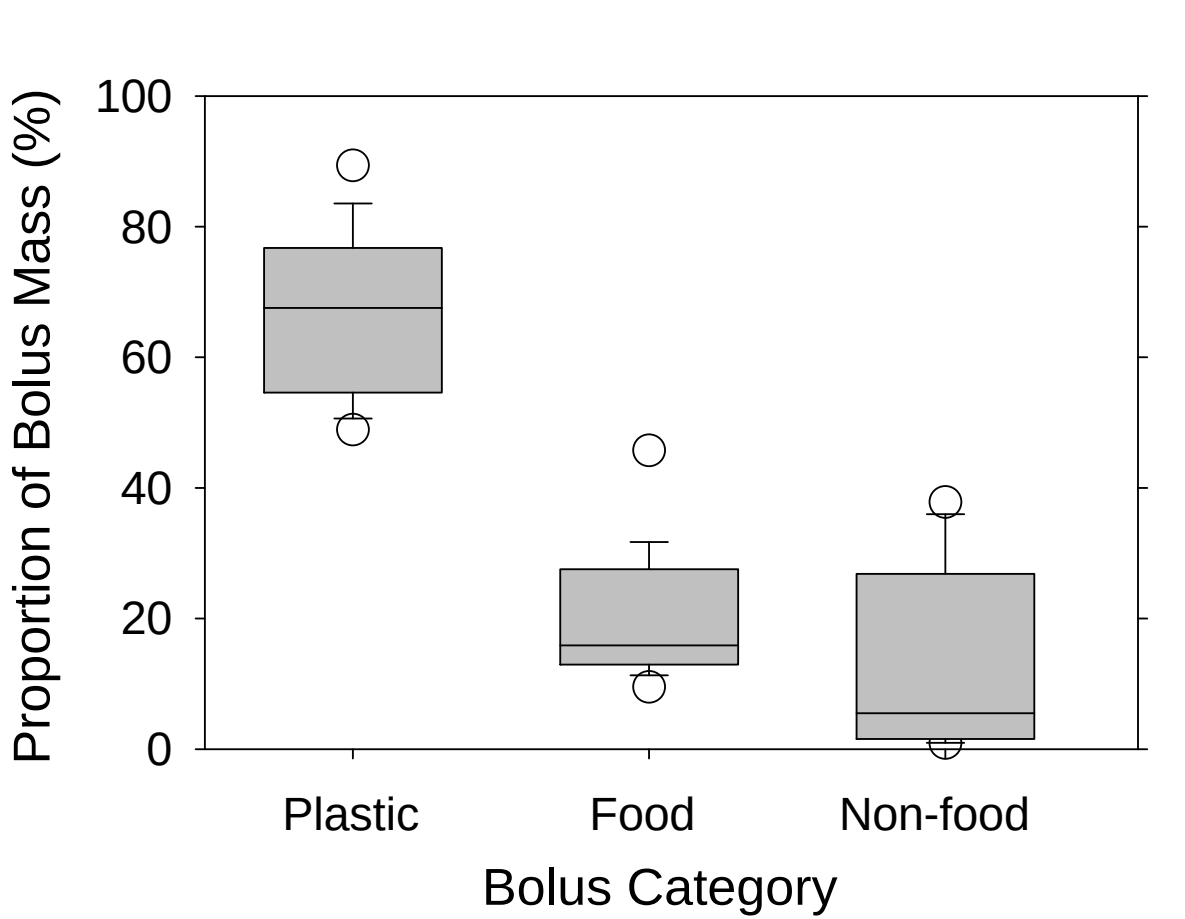
Fragments, Foam,
Line and Sheet

- Fragment

Size / Color

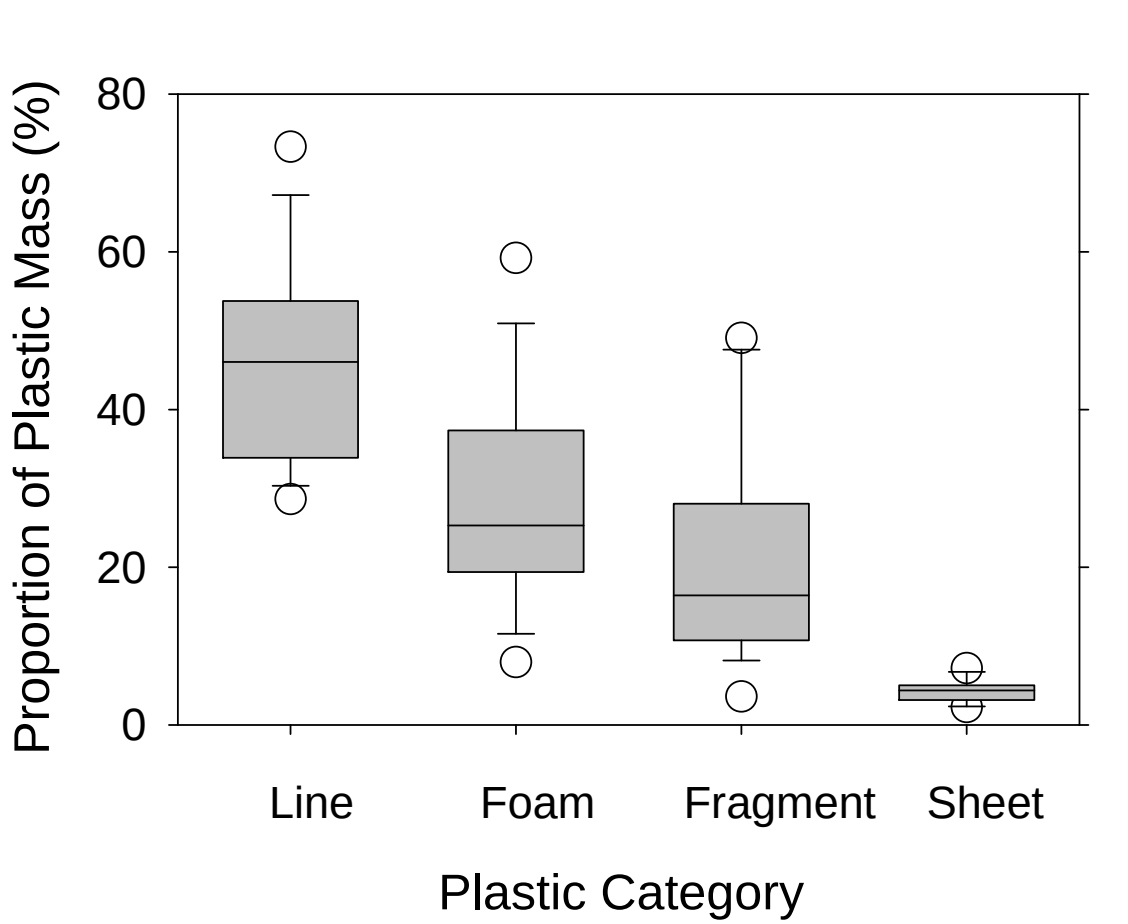
Results - Bolus Mass

- Every bolus contained plastic (100 %)
- Plastic accounts for 70 % of bolus mass



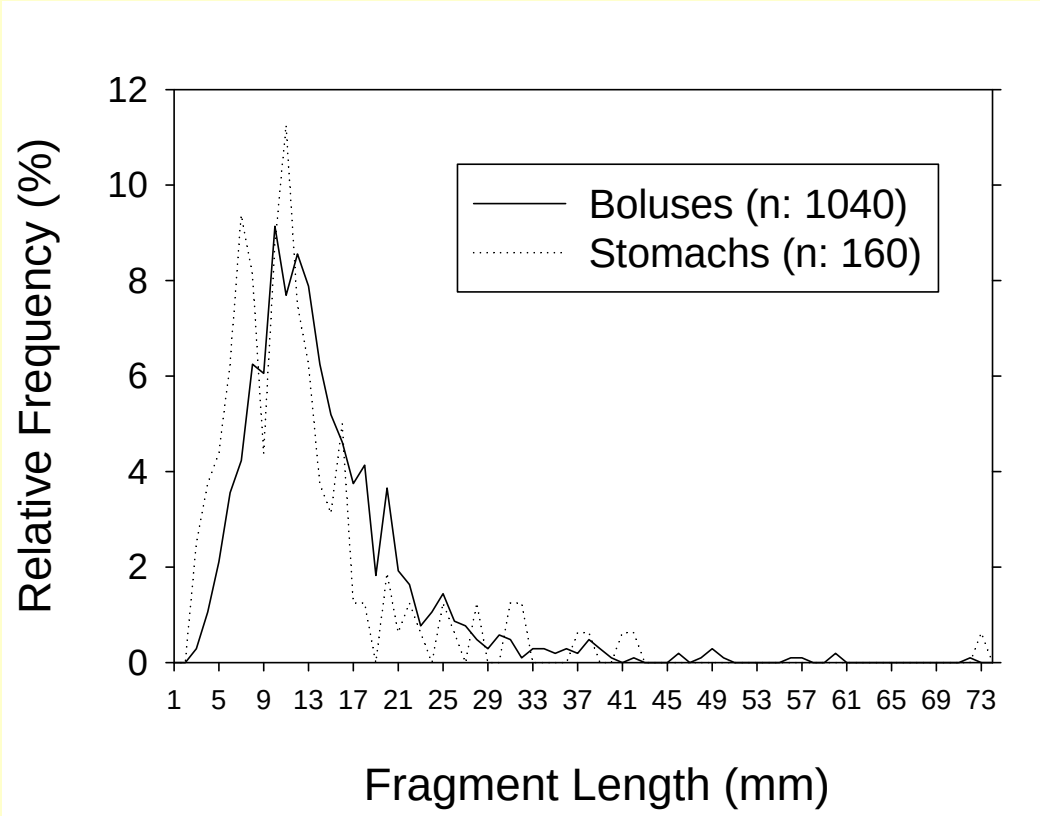
Results - Bolus Mass

- Line and foam are most abundant plastic types

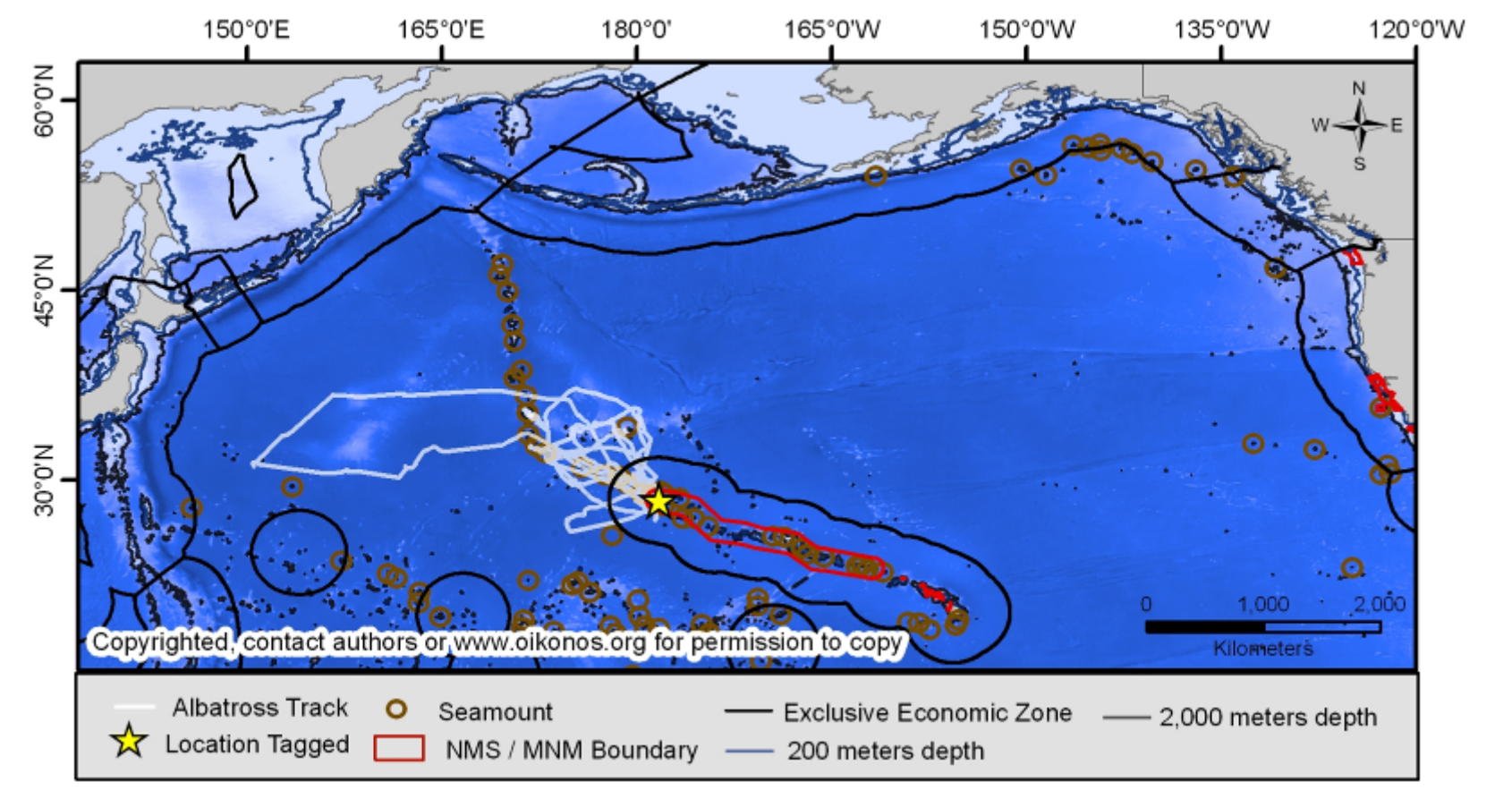


Results: Plastic Mass

- Fragment size distribution from 20 boluses and 5 chick stomachs. Wide range: from 1 to 73 mm

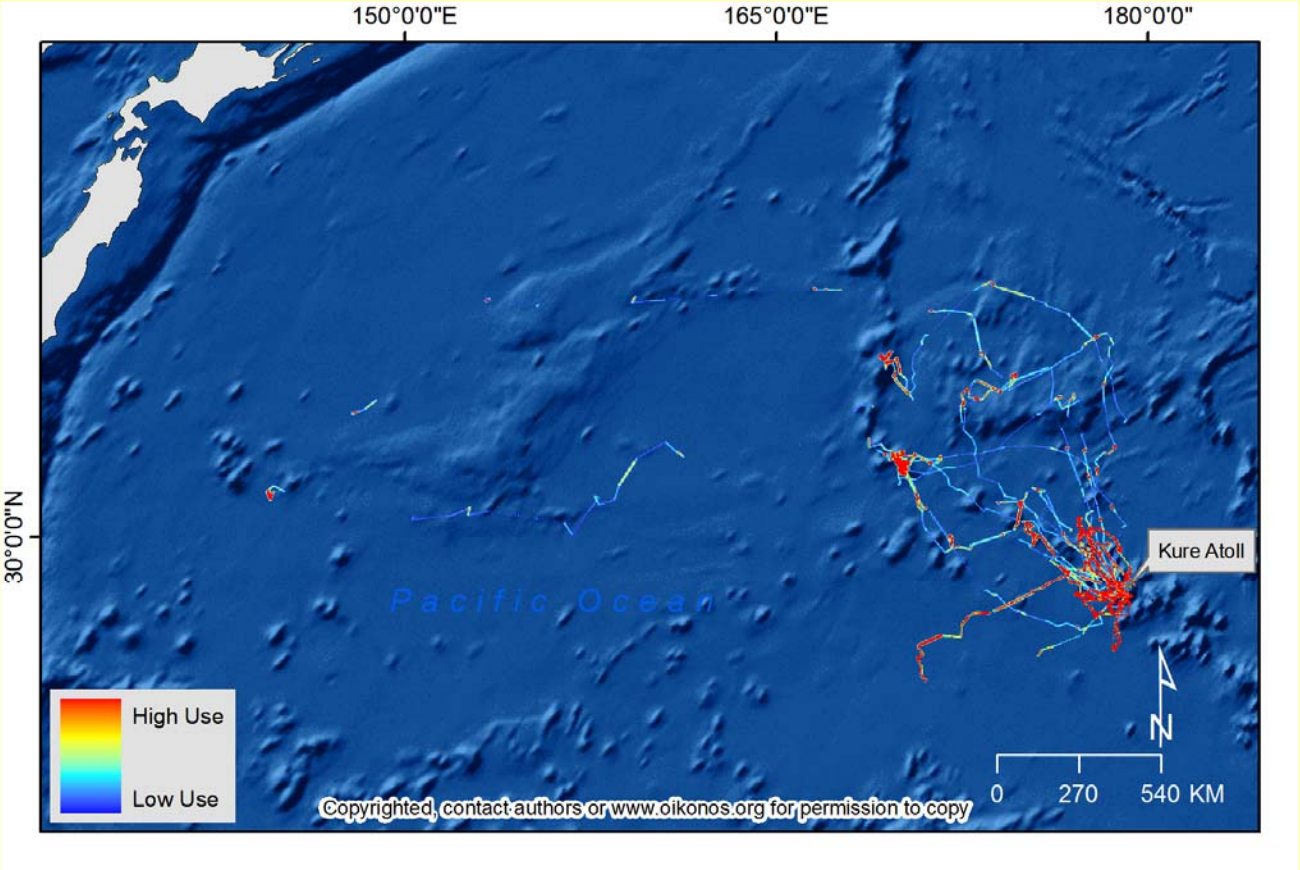


Satellite Tracking - Kure Atoll 2008



Tracks of 14 complete foraging trips by 7 BFAL tagged at Kure Atoll (star) during chick-rearing period (May – June) of 2008. Tracks are superimposed on extent of management jurisdictions and ETOPO 1-minute bathymetry (highlighting seamount locations).

Habitat Use - Kure Atoll 2008



Mean (+/- SD) proportional time BFAL spent within distinct bathymetric domains, from ETOPO 1-min relief data within 2.3 km radius from interpolated locations

Seamounts
(< 200m)
10.83 +/- 9.37

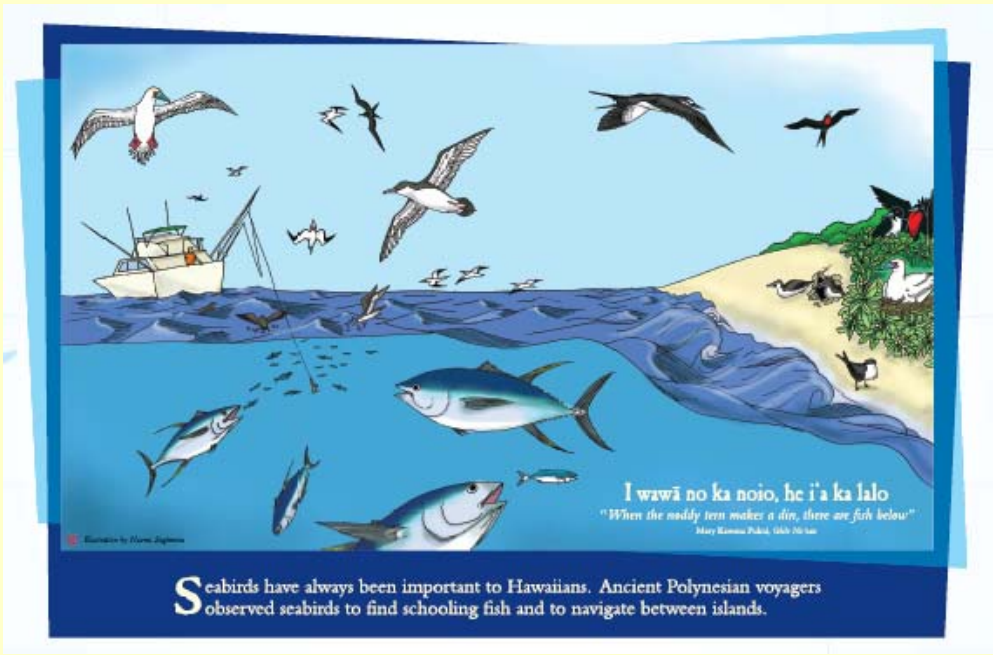
Pelagic
(> 2000m)
89.17 +/- 9.37

Implications - Plastic Metrics



- Kure Black-footed Albatross collect plastic from the Western North Pacific
- Plastic incidence in boluses not a sensitive metric
- Need to focus analysis on plastic loads / types
- Efforts to document size / color / origin

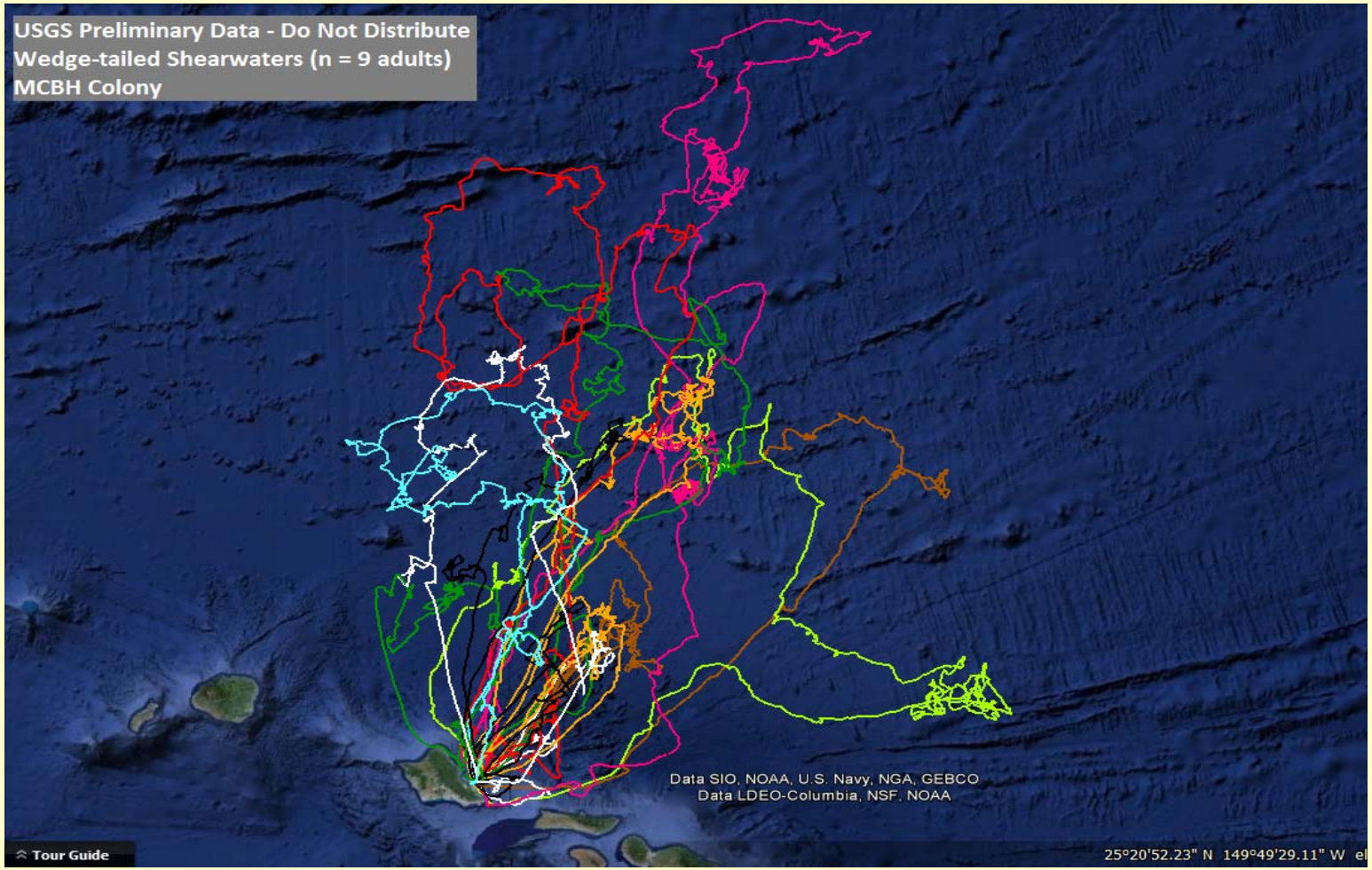
IIIc. Case Study 3: Local Metric



Dominant in feeding flocks with subsurface predators (skipjack tuna, aku)

(Hebshi et al., 2008)

Wedge-tailed Shearwater Foraging



Ray Boland

Breeding Wedgies forage within 200 miles of their colonies in Main Hawaiian Islands

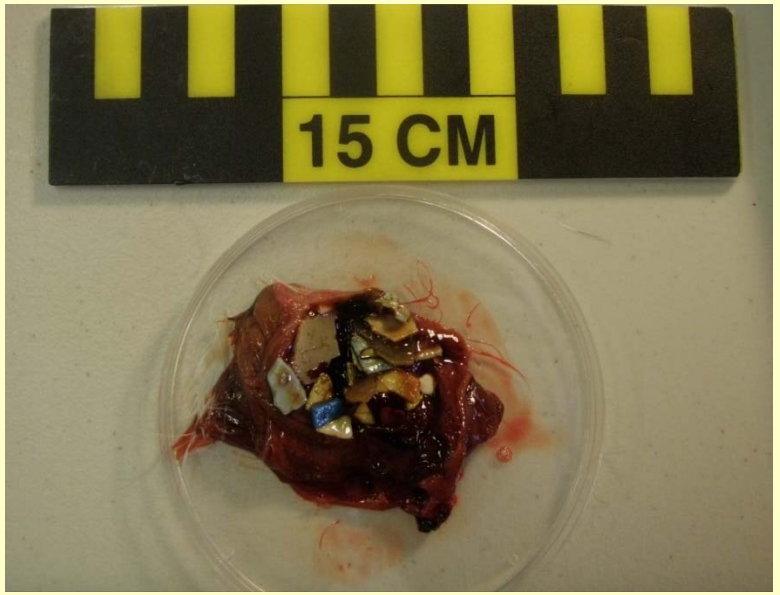
(USGS, Adams et al. in prep)

Approach – Opportunistic Collections

Oceanic Institute
Sea Life Park
Hawai'i Pacific University

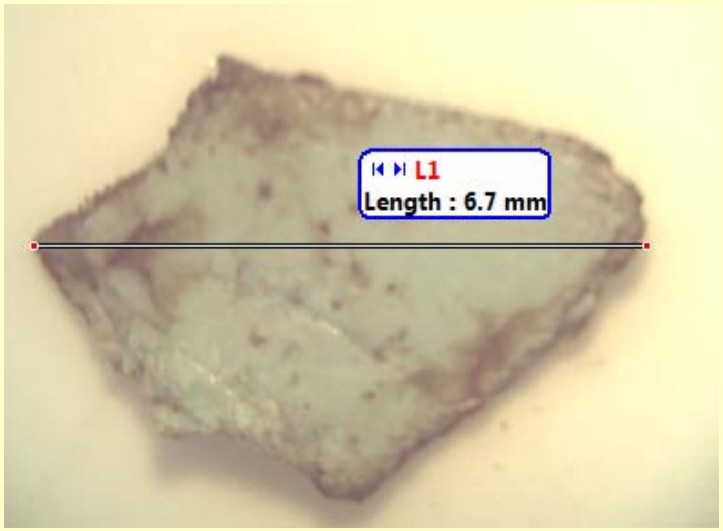
SEABIRD NECROPSY PROGRAM
O'AHU, HAWAII

- 142 chicks necropsied (2009 and 2010)
- Quantified incidence and mass of ingested plastic (proventriculus / gizzard)
- Sampled tissues for isotopic diet and pollutants



Methods - Quantifying Ingested Plastic

- Plastic Incidence & Mass – by stomach chamber
- Plastic Type & Size – by stomach chamber
- Number of Squid Beaks – by stomach chamber
- Other Prey Items – by stomach chamber



Fragment Size
Range: 0.3 – 7.7 mm

Squid beaks and lenses

Results – Incidence: % of birds ingesting

GIZZARD

year	n	%plastic	%beaks
2009	70	52.9	94.3
2010	72	75.0	97.2

PROVENTRICULUS

year	n	%plastic	%beaks
2009	70	28.6	74.3
2010	72	44.4	75.0

Is probability of finding plastic influenced by ?

- what organ you study (stomach / gizzard): YES (higher in gizzard) (p = 0.006)

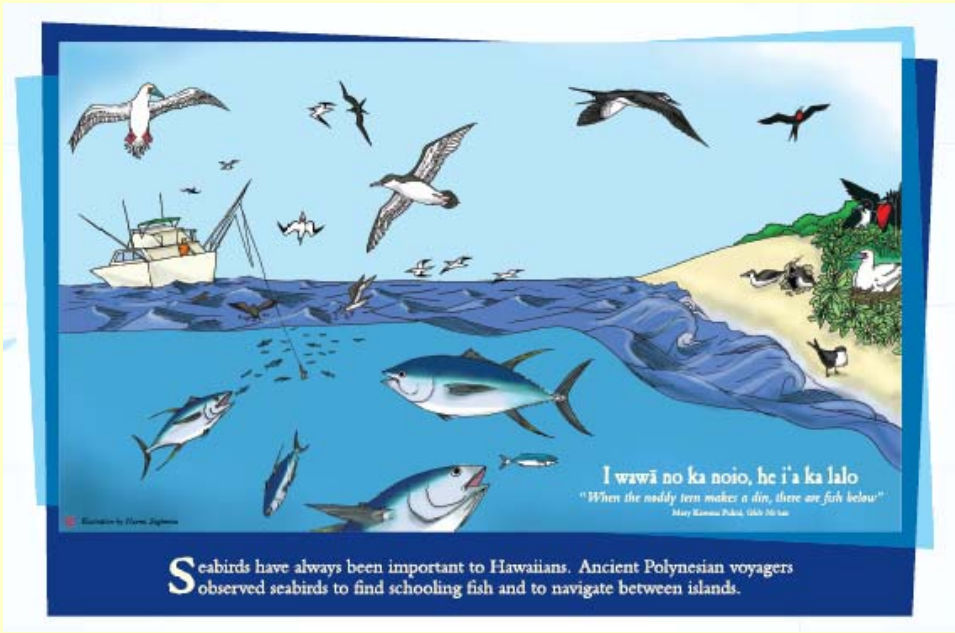
- what year you study (2009 / 2010): YES (higher in 2010) (p = 0.02)

Wedge-tailed Shearwater: Plastic Incidence

Sample	Age Class	Years	N	Source	Mean Plastic Incidence (%)
Fry et al.	Breeding Adults	1984	20	Collected	60.0
Robinson et al.	Breeding Adults	2014	28	Dog Kill	71.4
Lyday et al.	Fledging Chicks	2009-10	142	Opportunistic	72.5
Dwyer et al.	After Hatch-Year	2010-15	45	Opportunistic	62.2

- Increase in adult incidence since 1980s
- Chicks have higher ingestion rates than adults

Implications - Plastic Metrics



- Breeding Wedge-tailed Shearwaters collect plastics from vicinity of their colonies (200 miles)
- Next steps: focus on interannual variability
- Questions: links with prey (secondary ingestion?)

IV: Emerging Issues – New Species

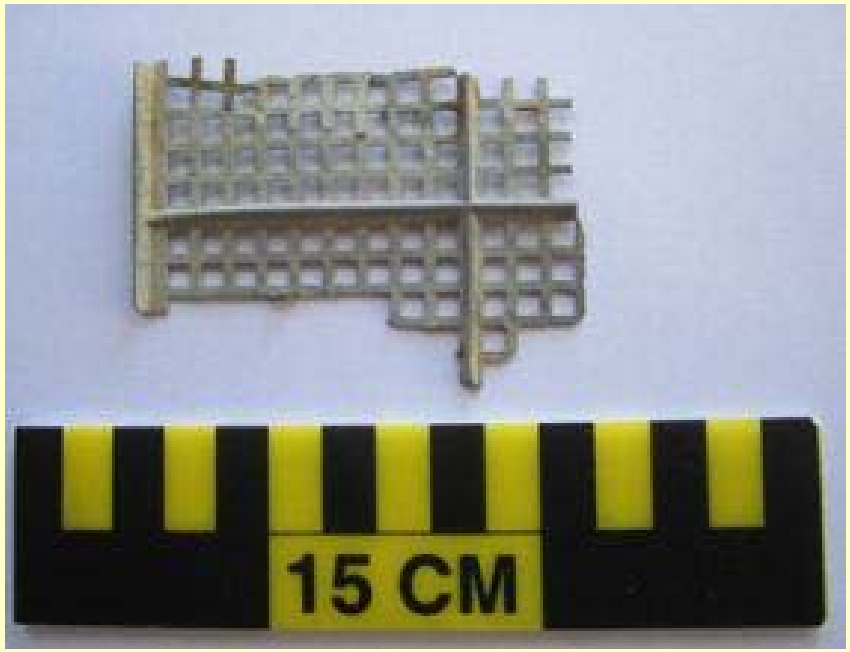
Large plastic fragment (14.5 cm x 3.25 cm) ingested by a White-tailed Tropicbird (O'ahu)

(Hyrenbach et al. 2013)

Aku: 60% (n = 10)

Mahi-mahi: 12.5% (n = 8)

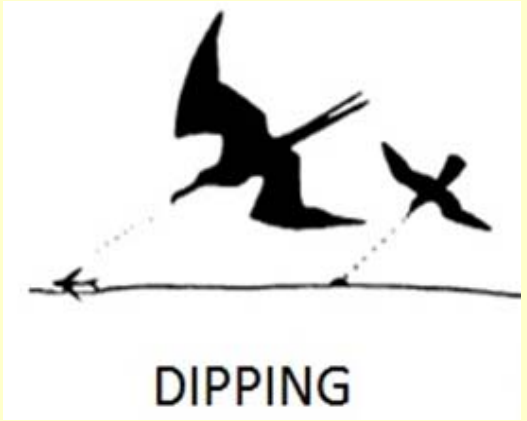
Example: Large plastic fragment (9cm x 6cm) ingested by Mahi-mahi



Plastic Ingestion Incidence – FFS 2006-13

Laysan Albatross:
93.1 %

Black-footed Albatross:
77.6 %

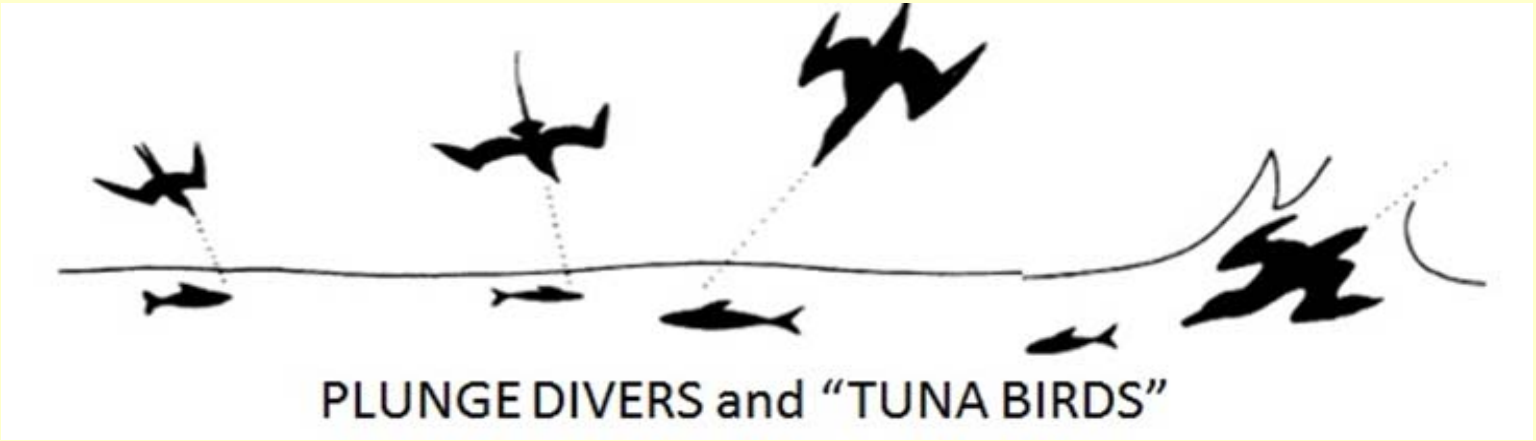


Greater Frigatebird:
38.4 %

Tristram's Storm-petrel:
100 %

Bonin Petrel:
100 %

Plastic Ingestion Incidence – FFS 2006-13



Brown Booby:
25.0 %

Wedge-tailed Shearwater:
75.0 %

Brown Noddy:
7.7 %

Red-tailed Tropicbird:
16.7 %

Sooty Tern:
0.0 %

Red-footed Booby:
4.5 %

Black Noddy:
0.0 %

Scope of Plastic Ingestion – Hawai'i

100% Hawaiian (Black-Footed, Laysan) albatross boluses have plastic (since 2008)

On average 70% of Black-footed albatross bolus mass (70% bolus volume) is plastic

72.5% of O'ahu Wedge-tailed Shearwater chicks contain plastic (2009 – 2010)

100% of Tern Island's Tristram's Storm-petrels contain plastic (2007-13)

New records: boobies, noddies, tropicbirds

Contaminants & Sub-lethal Effects

Acknowledgements

- **Funding:** National Fish & Wildlife Foundation marine debris program, Papahānaumokuākea Marine National Monument, Hawaii Pacific University, Oikonos – Ecosystem Knowledge

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  USFWS, State of Hawai'i – DOFAW

- **The Birds**


GRACIAS