

An underwater photograph showing a large school of sharks swimming over a vibrant coral reef. The water is clear and blue, with sunlight filtering through from above. The coral reef is densely packed with various types of coral, appearing in shades of green and brown. Numerous smaller fish are scattered throughout the scene, some swimming near the surface and others closer to the reef.

Reef Fish Research Across the Pacific: an overview of the Coral Reef Ecosystem Division's Fish TEAM

**Jill Zamzow, PhD
Senior Reef Fish Researcher**



Photo: NOAA/CRED library, Paula Ayotte, Alamagan Island



Mr. Ivor Williams, "Da Boss"



lylyn McCoy





Paula
Ayotte



Kevin Lino





Photo: Paula Ayotte

Dr. Adel
Heenan



Jake Asher



Andrew
Gray



Photo: Paula Ayotte





Dr. Kelvin Gorospe



MP: Reef Assessment & Monitoring Program



FISH TEAM
BENTHIC TEAM
INSTRUMENTATION TEAM
TOW TEAM
ECOSPATIAL INFORMATION TEAM
Mapping/GIS/Data

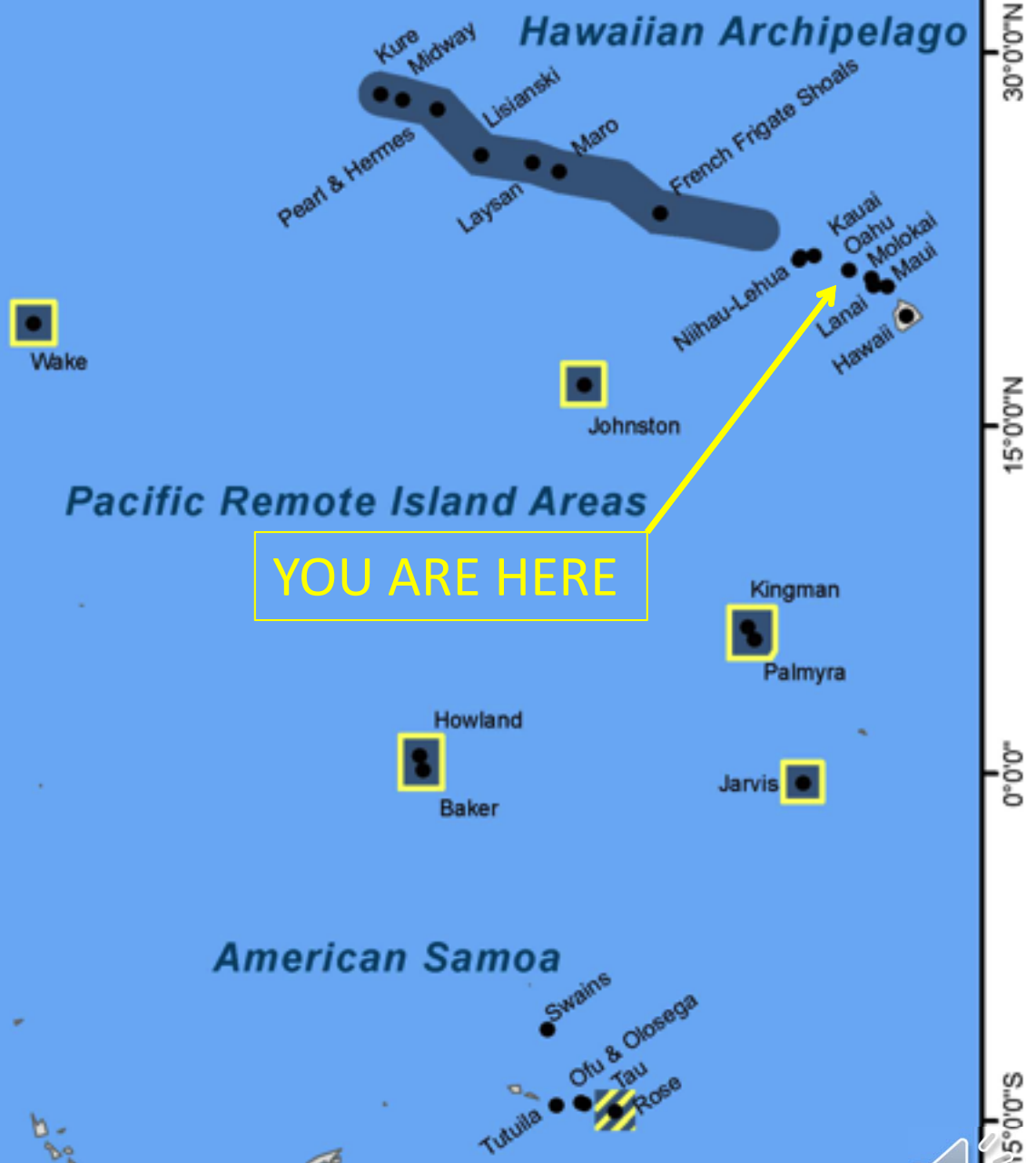
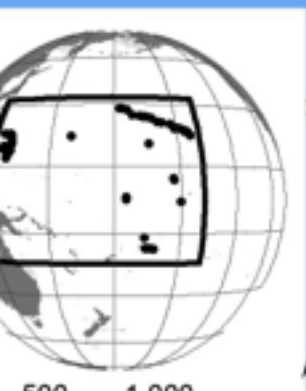
here We Work:

ianana Archipelago

- Farallon de Pajaros
- Maug
- Asuncion
- Agrihan
- Pagan
- Alamagan
- Guguan
- Sarigan
- Saipan
- Tinian
- Aguijan
- Rota
- Guam

Marine Monument Boundary

- iana Trench
- fic Remote Island
- e Atoll
- ahānaumokuākea



Pacific Remote Island Areas

YOU ARE HERE

American Samoa

Survey Platforms – *Hi'ialakai* & *Oscar Elton Sette*



A day in the life...



Photo: Ray Boland



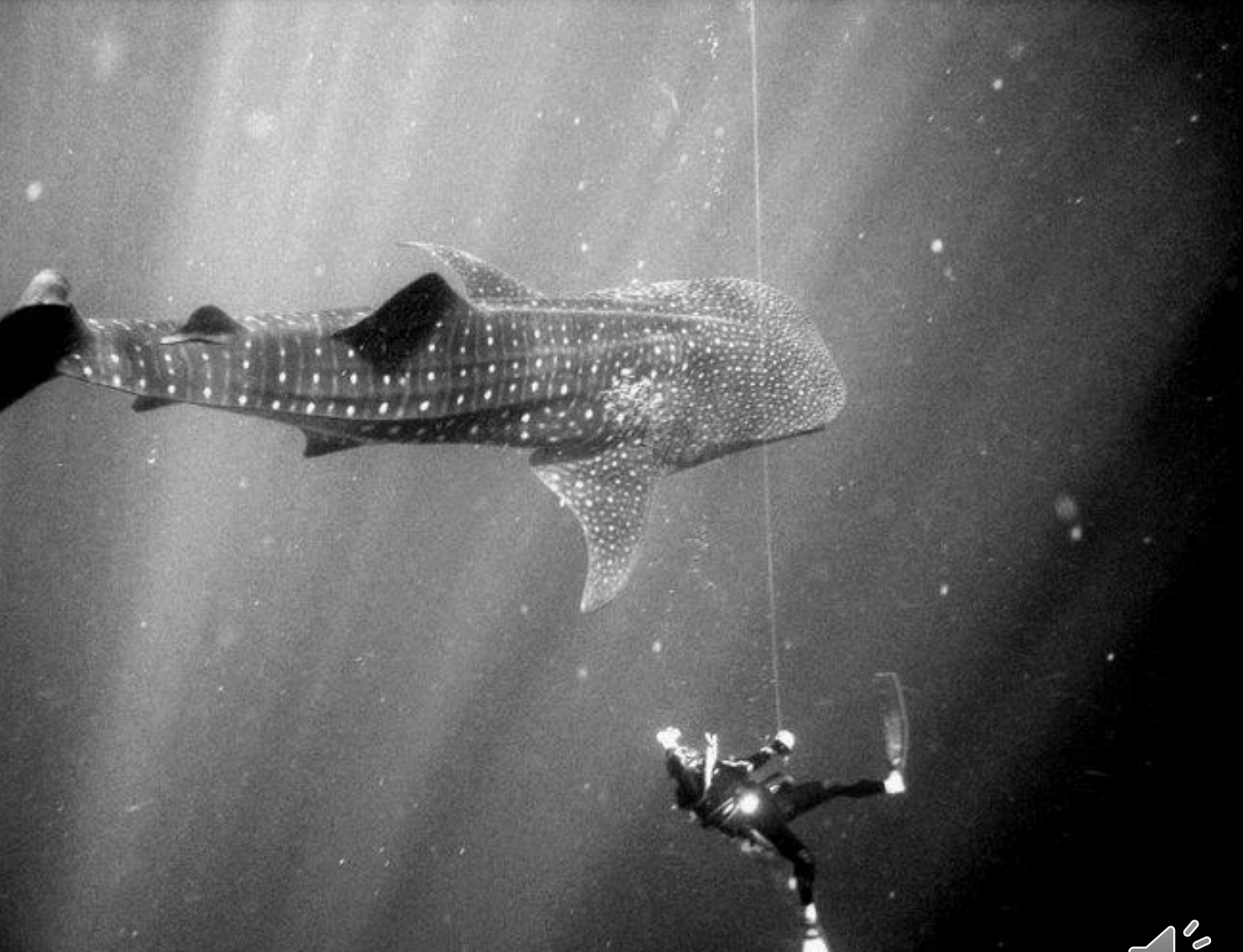
Photo: Ray Boland



Photo: Jill Zamzow



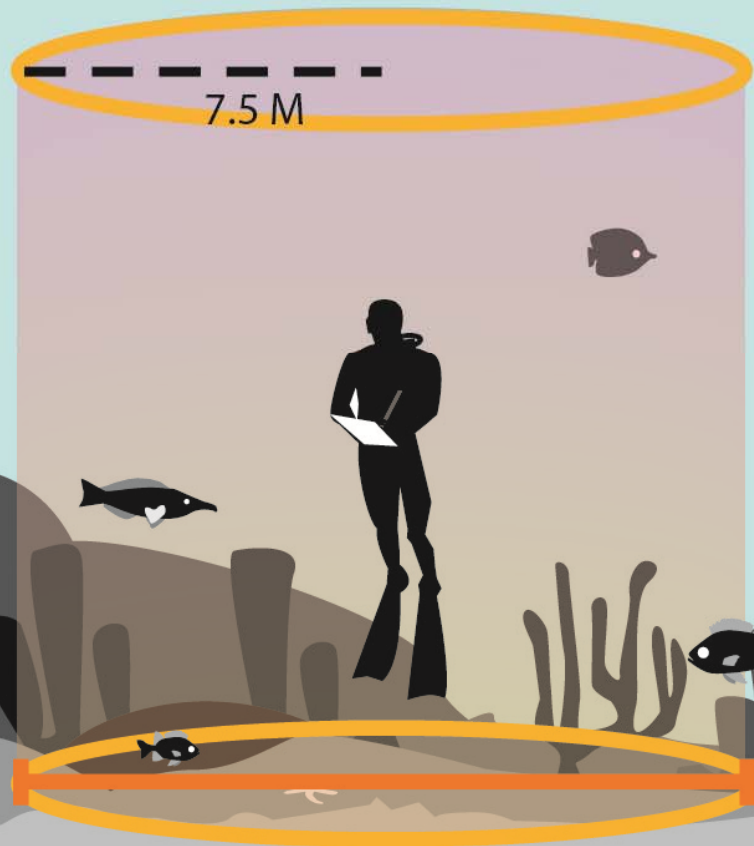




Team REA Methods – Fish & Benthos

SCALE & UNITS: RANDOM REA SURVEY

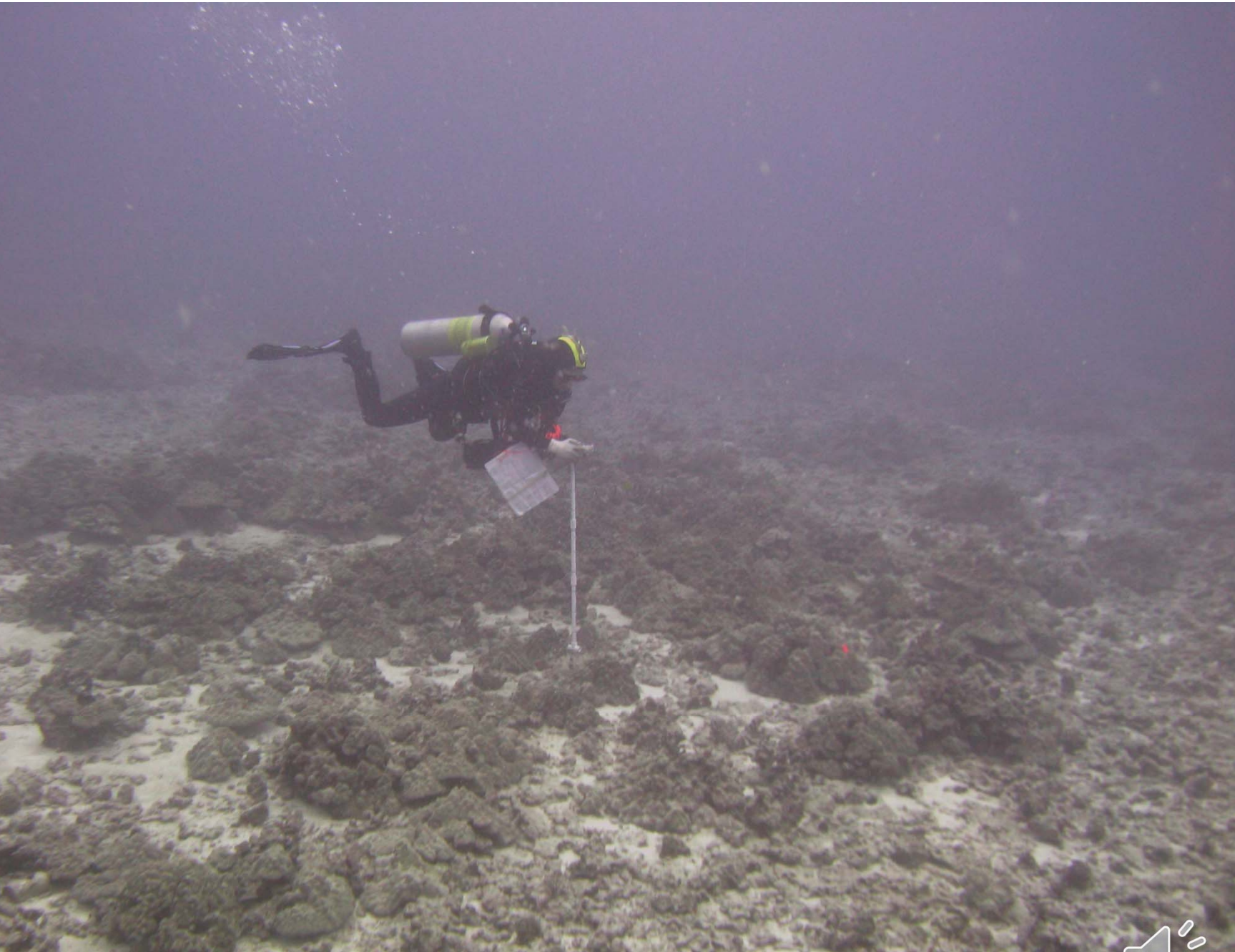
view



- RANDOMIZED HARD-BOTTOM LOCATION WITHIN 0-30 M DEPTHS
- PAIRED 15-M-DIAMETER CYLINDERS
- PHOTOGRAPHS OF BENTHOS TAKEN ALONG TRANSECTS
- STATIONARY-POINT-COUNT SURVEYS OF FISHES

5-30 sites per island, with larger N at more populated/larger islands





: 5-6 sites/boat/day



Photo: Jake Asher

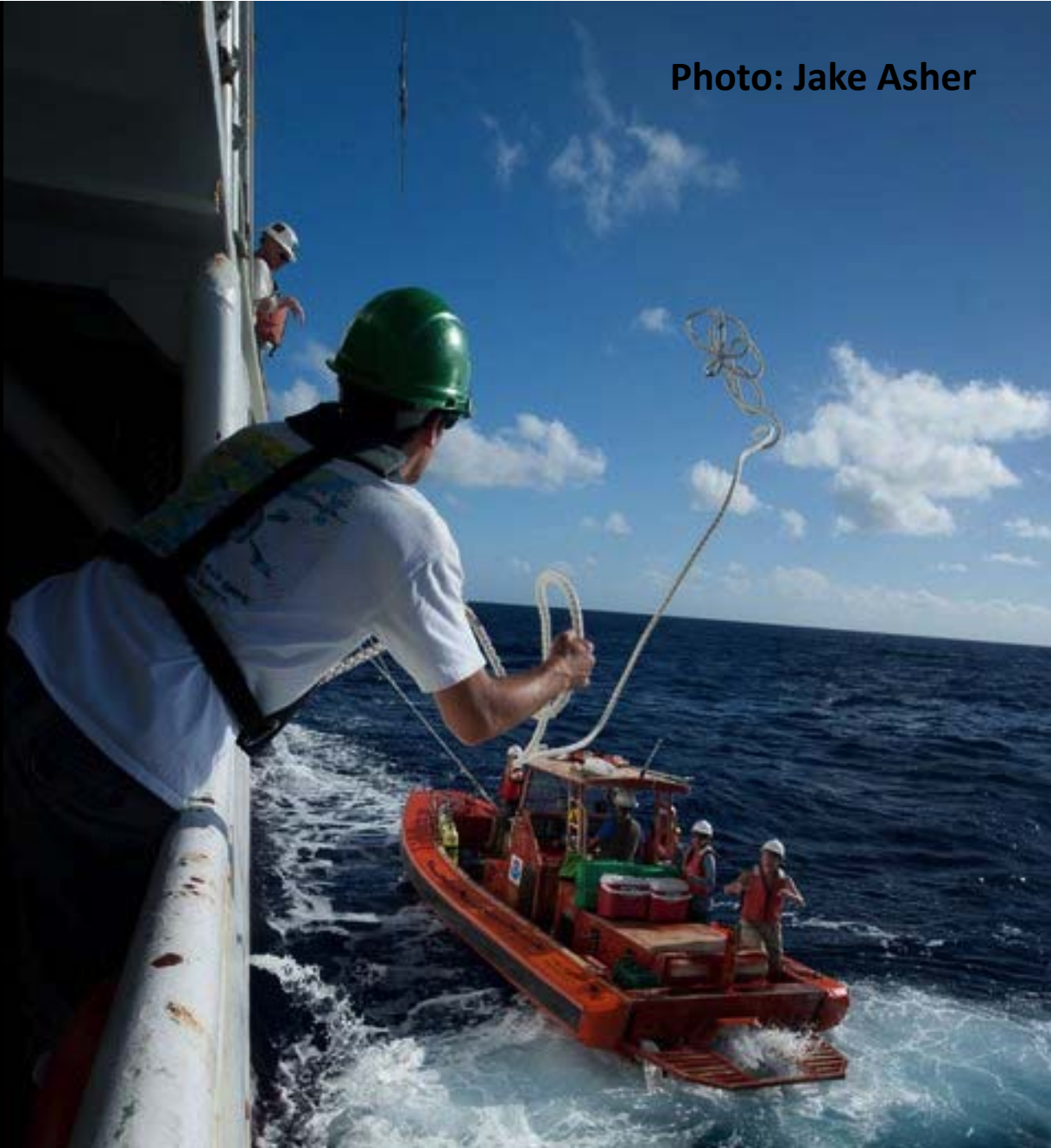


Photo: Jason Kehn





Photo: Ray Boland

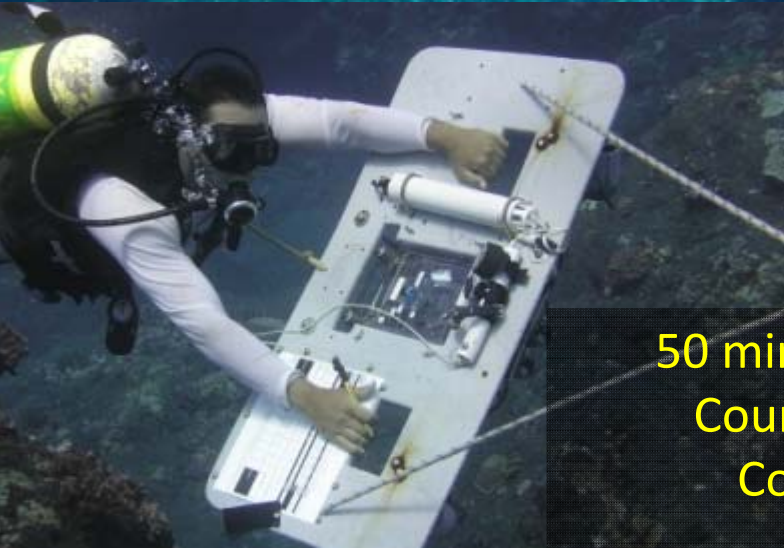
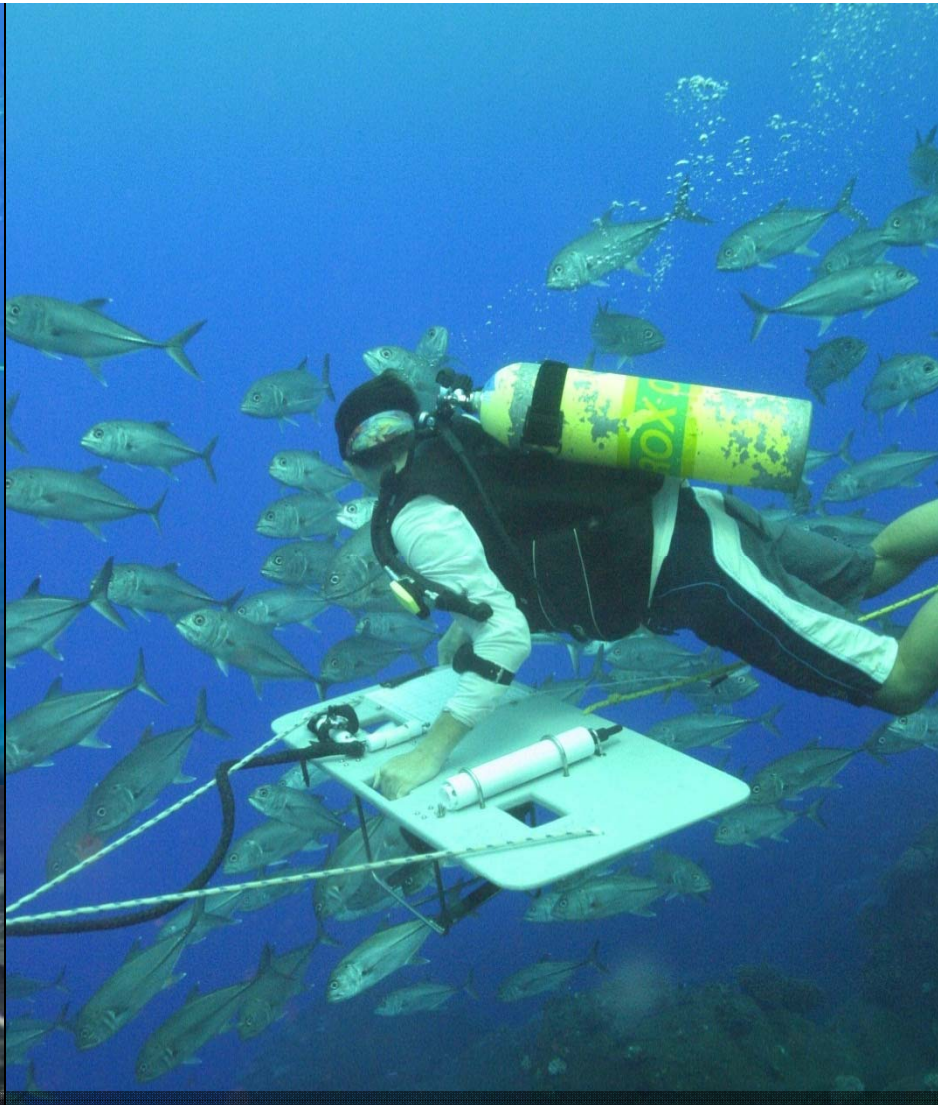
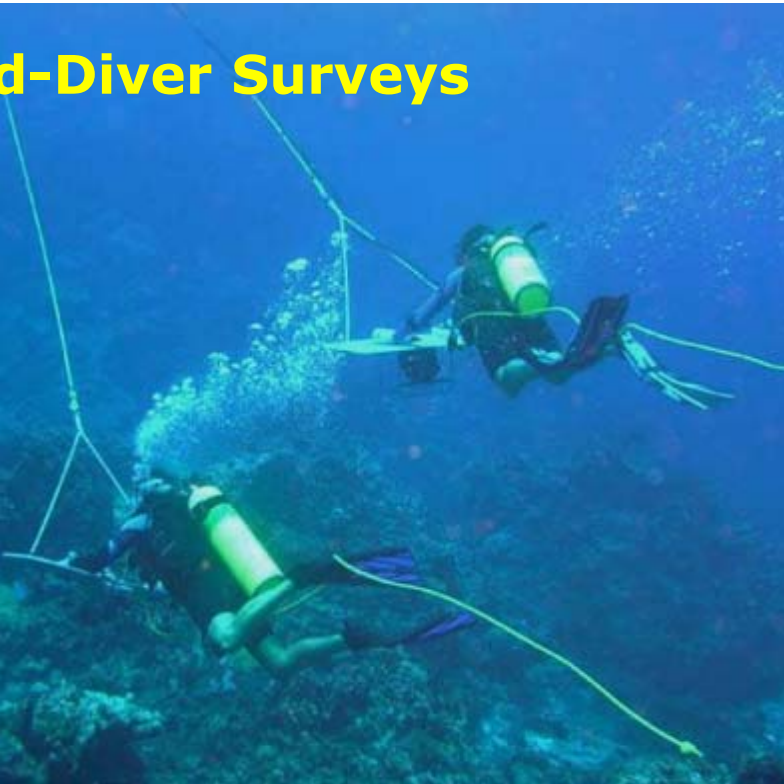


ES: ALWAYS LOOKING OVER YOUR SHOULDER AT WORK



Photo: Darla White

and-Diver Surveys



50 min. tows, ~2 km x 10m wide, ~15-20m depth
Counts: #, size, ID of fishes > 50 cm total length
Continuous: salinity, depth, temperature, GIS
Data recorded per 5 min "segment" of tow

Stereo-video technology

921_T3b.avi : 20110423R_051916_T3b.avi

Stereo About

1

Frame 12002 (23.5928 mins) Frame 12731

Species	Code	Number	Stage	Activity	Comment	Filename	Frame	Time (mins)	Period	Period time (mins)	Length (mm)	X (mm)	Y (mm)	Z (mm)	Range (mm)	RMS (mm)	Precision (mm)
forsteni	SCFO	1	AD	Passing		20110423_051921_T3b.avi	10031	22.4978				760.996	-954.265	-5546.779	5679.480	16.037	12.355
meyeni	TAME	1	AD	Passing		20110423_051921_T3b.avi	12002	23.5928			764.862	1000.238	-780.667	-5954.193	6087.884	9.157	27.758
lugubris	CALU	1	AD	Passing		20110423_051921_T3b.avi	16845	26.2833			507.588	3172.653	1821.918	-8798.155	9528.518	46.655	53.031
lugubris	CALU	1	AD	Passing		20110423_051921_T3b.avi	16845	26.2833			388.078	1116.278	2116.406	-9964.265	10247.528	58.901	86.997
lugubris	CALU	1	AD	Passing		20110423_051921_T3b.avi	16997	26.3678			387.881	1339.953	1115.429	-5397.593	5672.183	17.334	9.100
rubroviolaceus	SCRU	1	AD	Passing		20110423_051921_T3b.avi	17182	26.4705			334.445	477.235	-204.872	-6930.776	6950.208	18.562	15.296
forsteni	SCFO	1	AD	Passing		20110423_051921_T3b.avi	24836	30.7227			321.946	107.403	-177.174	-2573.441	2581.767	7.519	4.769
rubroviolaceus	SCRU	1	AD	Passing		20110423_051921_T3b.avi	25252	30.9539			333.523	374.348	-651.778	-3663.306	3739.621	18.528	5.282
Chelonia sp	TURT	1	AD	Passing		20110423_051921_T3b.avi	26309	31.5411				-42.476	640.030	-16496.792	16509.257	65.329	87.584
argus	CEAR	1	AD	Passing		20110423_051921_T3b.avi	28373	32.6877			322.223	1042.938	834.791	-4801.061	4983.450	11.303	13.787
bohar	LUBO	1	AD	Passing		20110423_051921_T3b.avi	29472	33.2983			418.045	299.868	-452.041	-3815.263	3853.634	6.179	12.314
forsteni	SCFO	1	AD	Passing		20110423_051921_T3c.avi	2969	35.4000				979.360	-107.988	-4099.959	4216.689	164.765	6.752
bohar	LUBO	1	AD	Passing		20110423_051921_T3c.avi	5615	36.8700			336.206	-794.263	-1551.867	-7916.334	8106.016	29.736	20.504
		1	AD	Passing	Dummy3	20110423_051921_T3c.avi	6749	37.5000				-145.836	-268.471	-3331.402	3345.382	11.771	4.313
rubroviolaceus	SCRU	1	AD	Passing		20110423_051921_T3c.avi	8205	38.3089			319.841	972.894	-282.899	-3414.141	3561.308	19.876	4.613
forsteni	SCFO	1	AD	Passing		20110423_051921_T3c.avi	8469	38.4555			315.379	-774.827	56.363	-3047.819	3145.272	14.048	5.392
louti	VALO	1	AD	Passing		20110423_051921_T3c.avi	19581	44.6288			325.296	331.936	-1126.829	-5977.061	6091.403	10.971	19.217

Points visible in both cameras are accurately placed in a 3D (X,Y,Z) coordinate system

o: Jake Asher



Remote Underwater Video (RUV), or Baited RUVs = BRUVs



Stereo-Video = Accurate, precise sizing

Deeper surveys (> 30m)

Diver-independent surveys

Time consuming analysis (go, Jake, go!!)





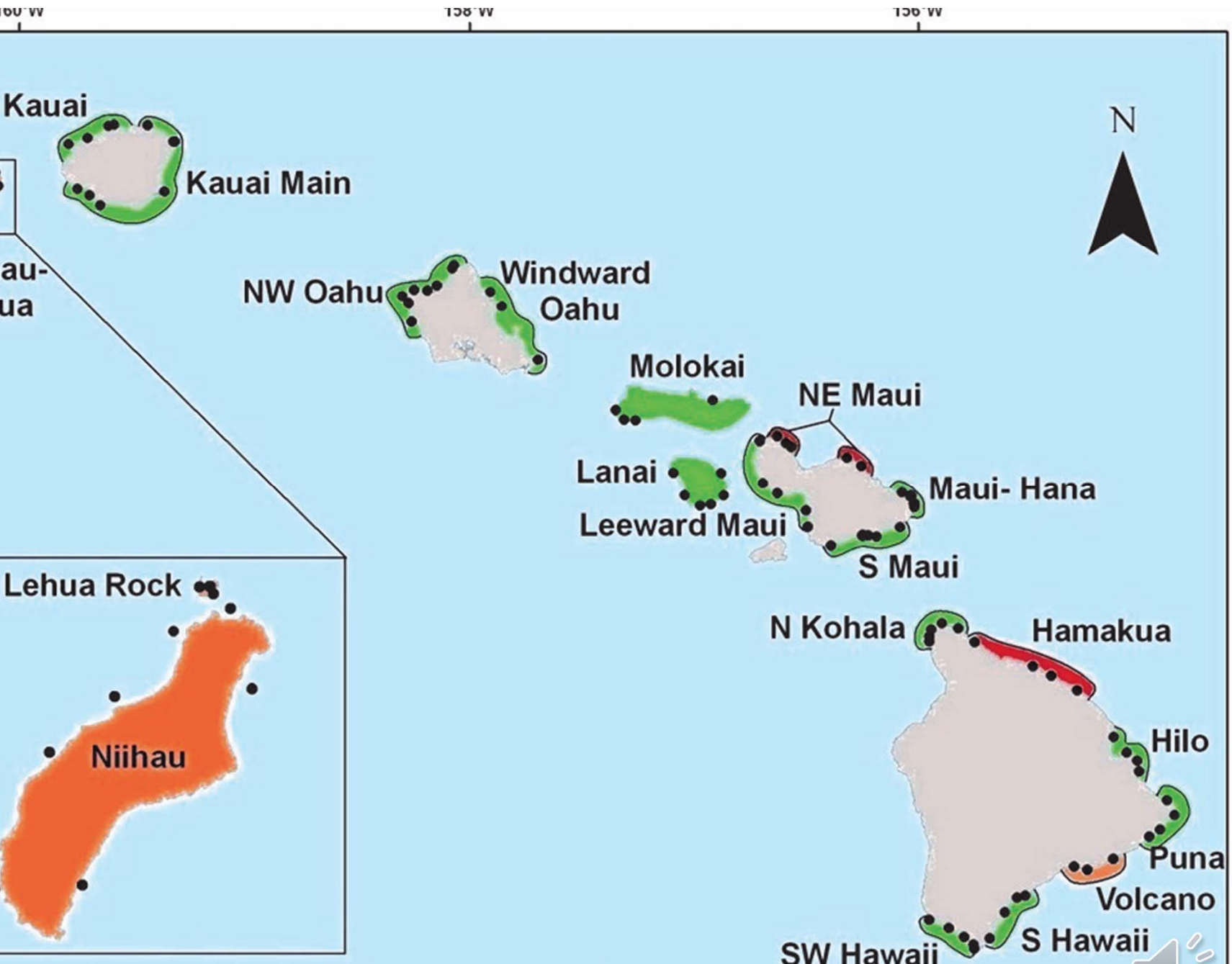
urvey design



Hawaii Sampling Design

N





NUMBER OF SURVEYS PER YEAR BY REGION

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013-15
			67		72		66		177		354		400*
					73	57		186		194		163	850*
58		63	62	57		64	117	147	182	118	141	180	
	30	34		48		80		138		179		274	
		43		59		62		113		282		253	400*

Increasing N is due to:

more trained divers

switch to stratified-random and SPC

intensive shore-based missions

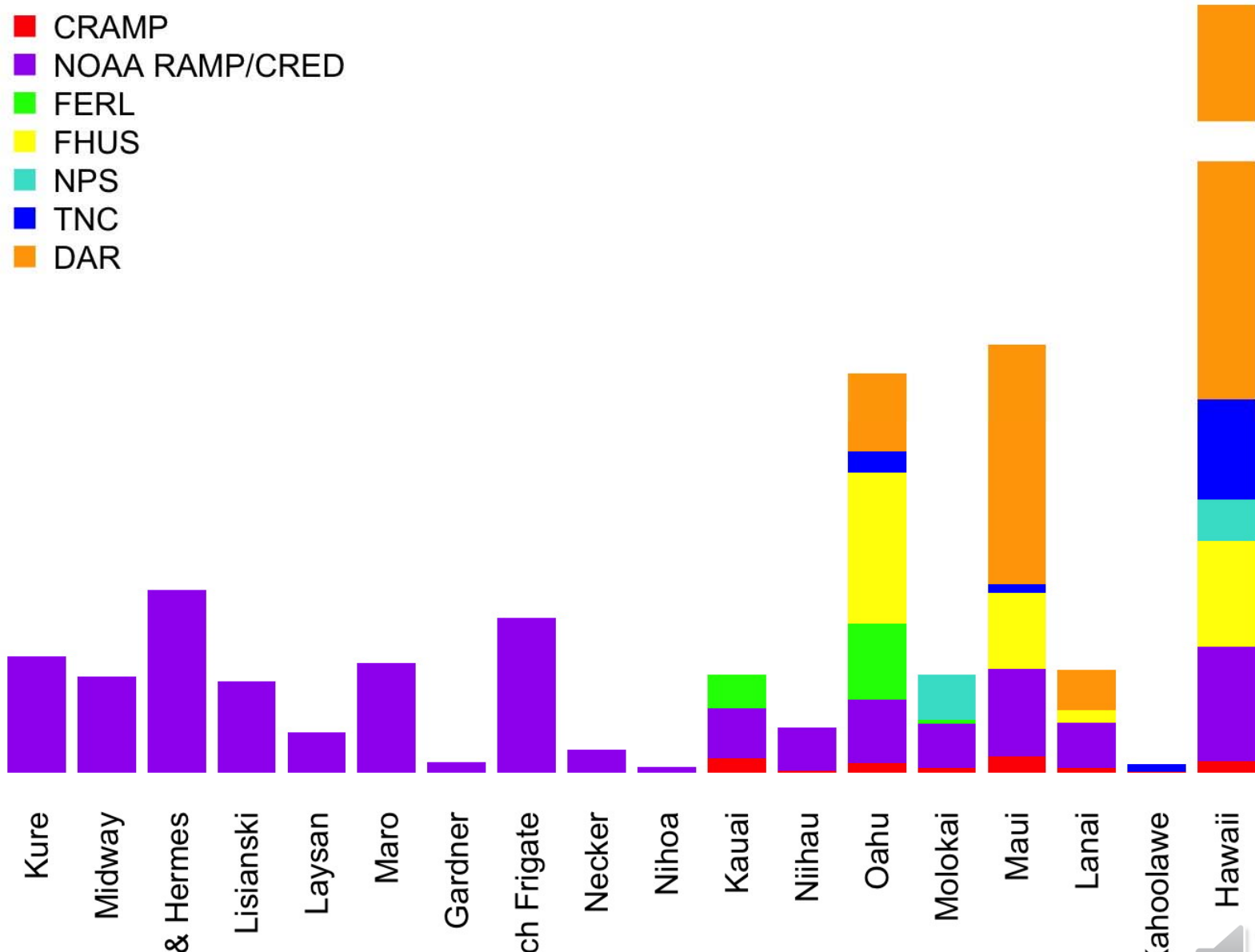
dedicated reef fish survey cruises

estimated



Graphic courtesy Mary Donovan, UH

- CRAMP
- NOAA RAMP/CRED
- FERL
- FHUS
- NPS
- TNC
- DAR



Results/Products:



Photo: ???

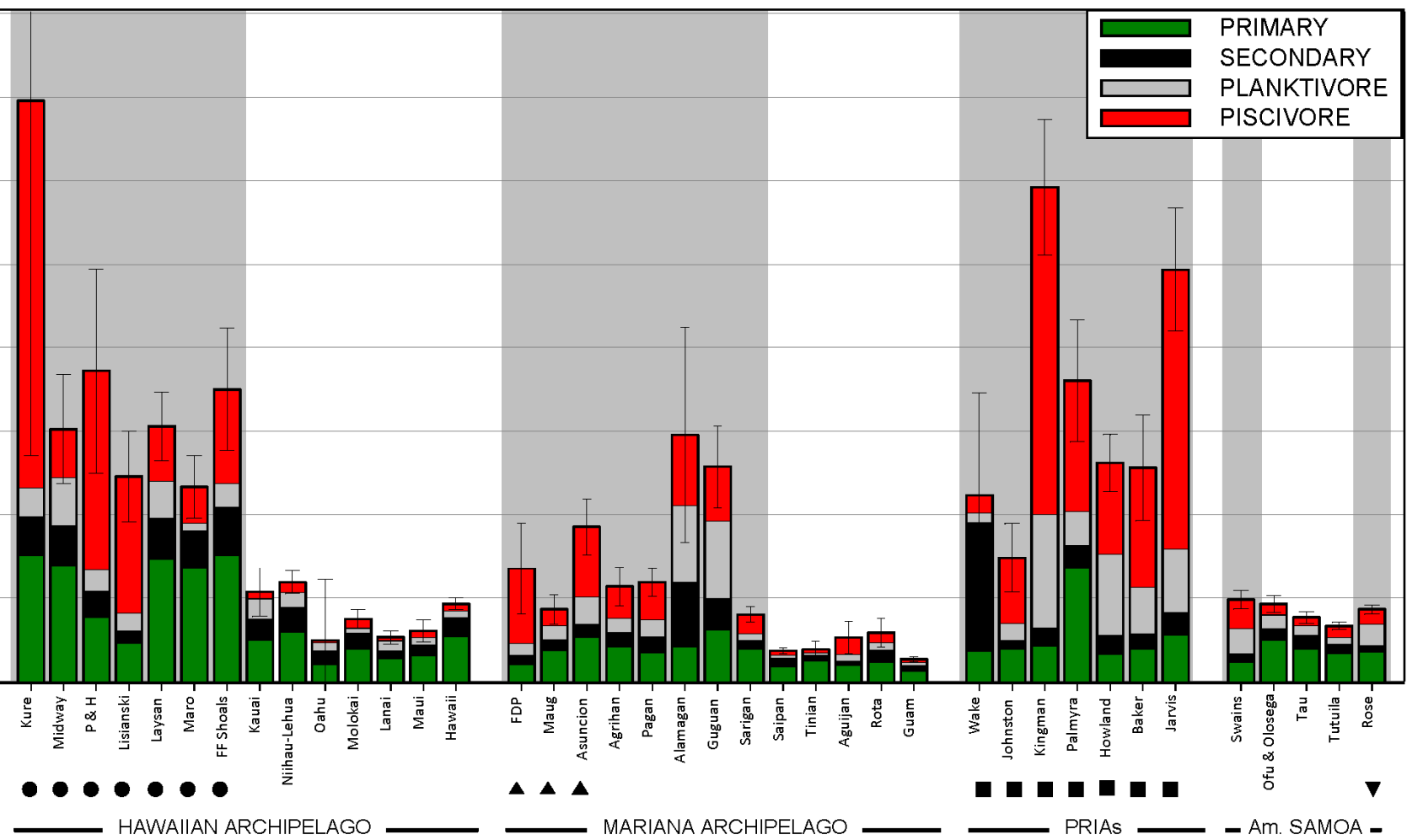


Photo: Jason Leonard



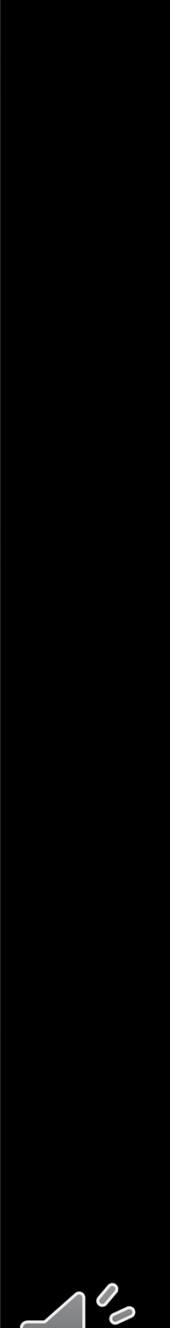
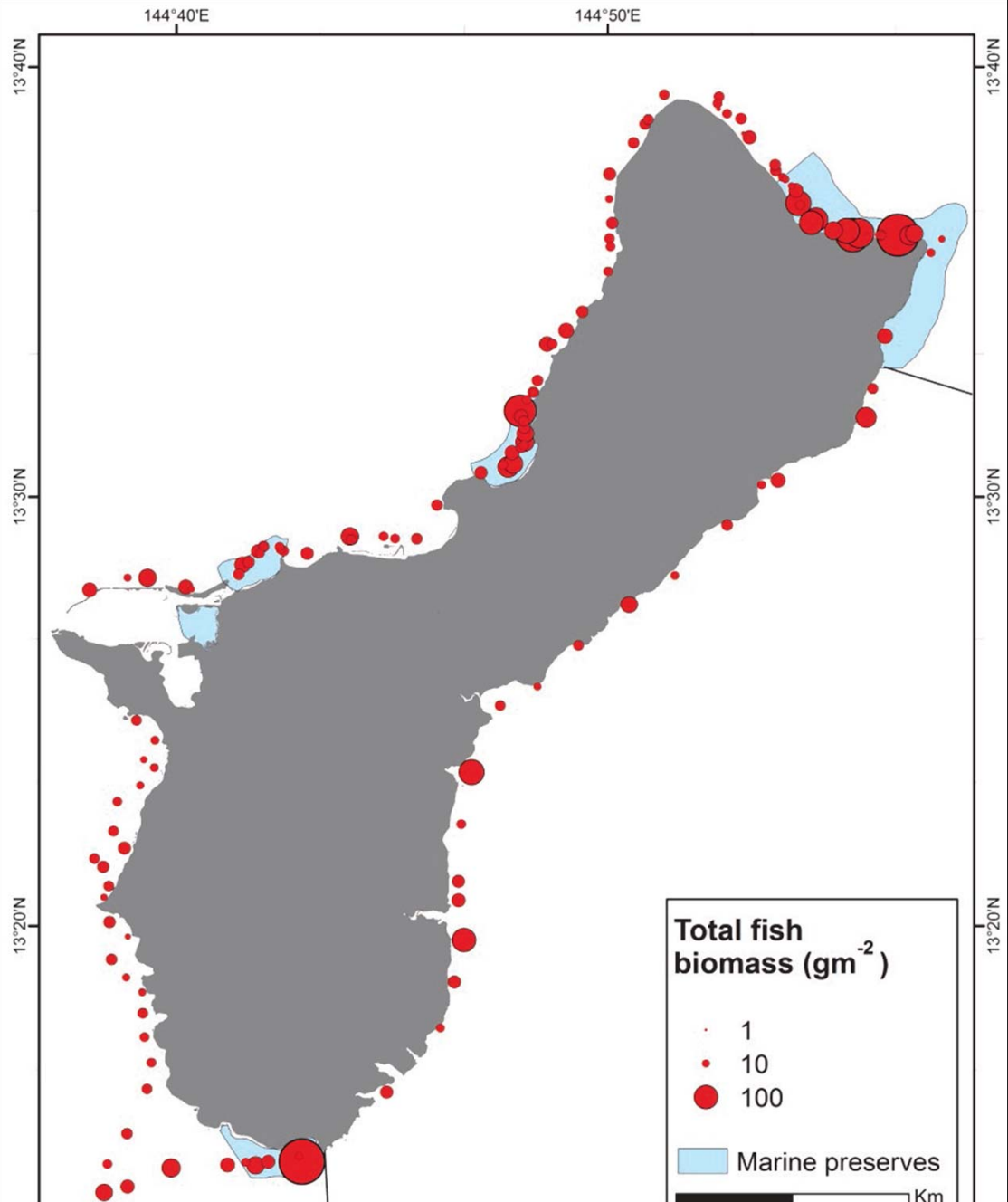
Photo: Jill Zamzow

RAMP Results – Fish Biomass By Consumer Group



consistent survey methods, design & personnel allow for meaningful comparison in islands, regions, archipelagoes, and at Pacific-wide scales

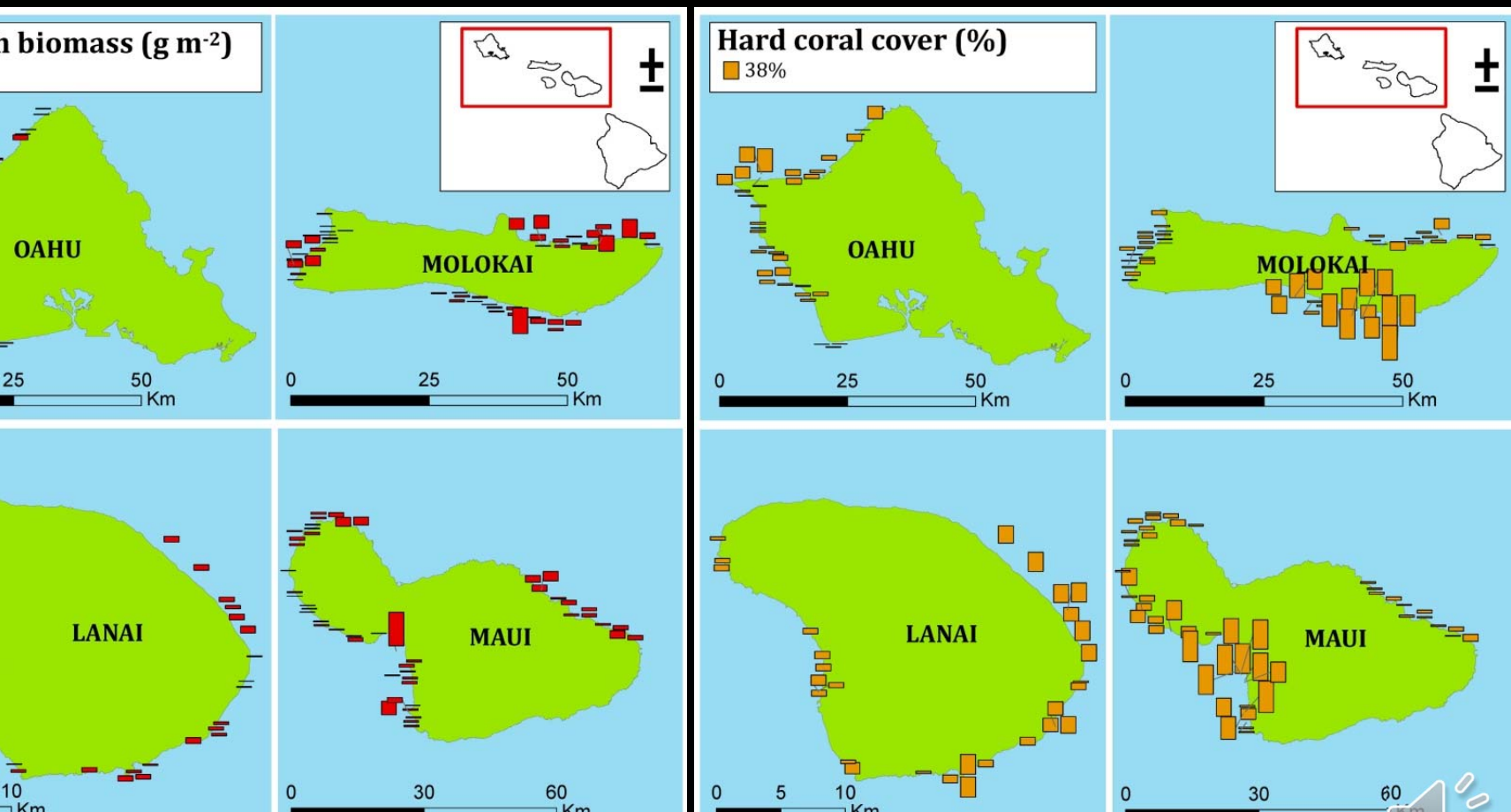
S
I
D
E
P
R
O
J
E
C
T
S



Reef Fish Survey (RFS) Cruises

Aug Sept 2012, PIFSC-NMFS supports "Reef Fish Survey" cruises (fish REA & BRUV)
MHI 09/12; possibly 25-day MHI 09/14
increased n => lowered CV and ability to generate size distributions for rare stuff

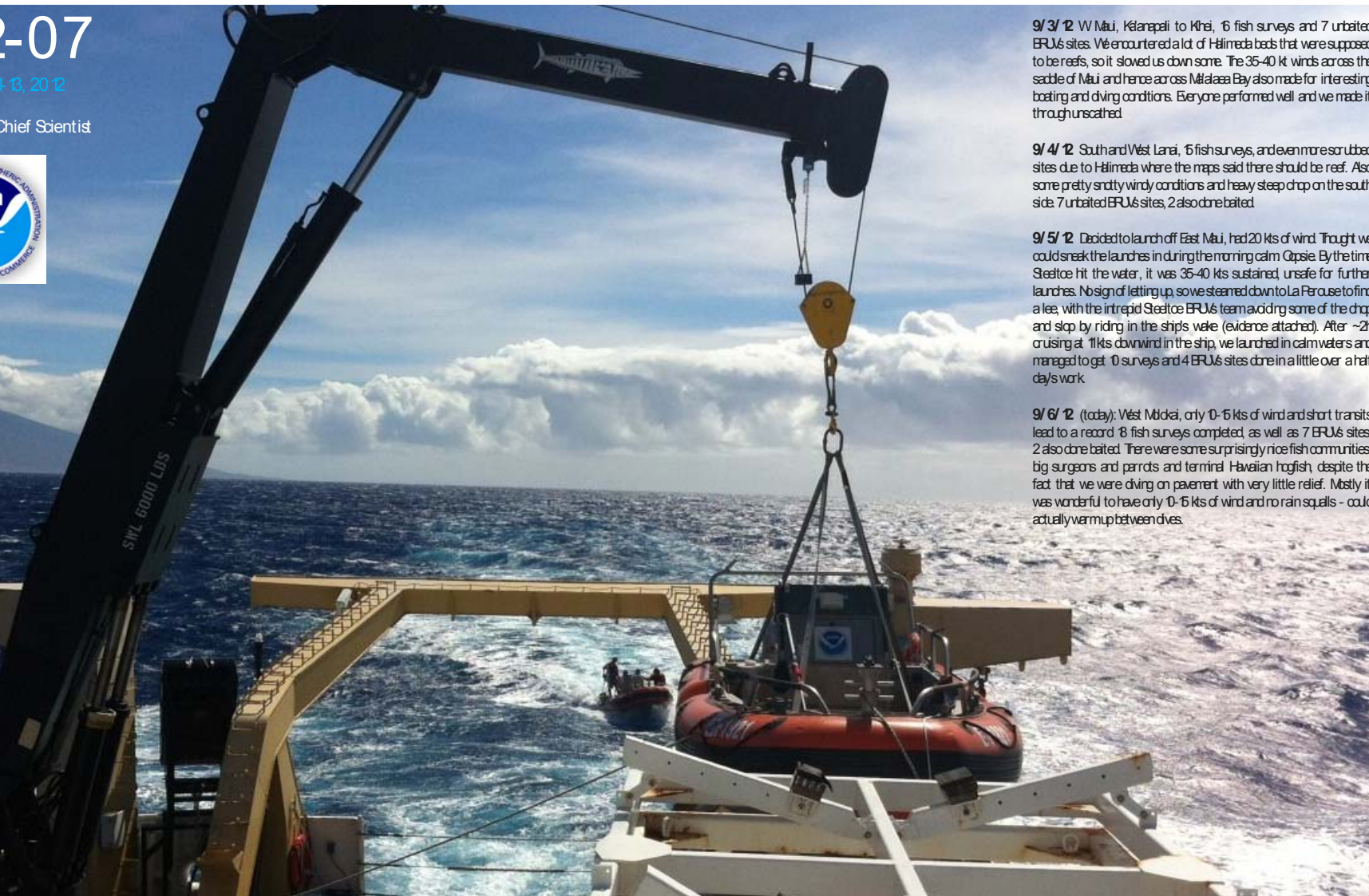
Example data overview: MHI September 2012 cruise, n=163 sites



2-07

4-13, 2012

Chief Scientist



9/3/12 W Maui, Kélanepali to Khei, 6 fish surveys and 7 unbaited BRU&s sites. We encountered a lot of Hāliuā beds that were supposed to be reefs, so it slowed us down some. The 35-40 kt winds across the saddle of Maui and hence across Mālaeā Bay also made for interesting boating and diving conditions. Everyone performed well and we made it through unscathed.

9/4/12 South and West Lanai, 6 fish surveys, and even more scrubbed sites due to Hāliuā where the maps said there should be reef. Also some pretty snotty windy conditions and heavy sleep chop on the south side. 7 unbaited BRU&s sites, 2 also done baited.

9/5/12 Decided to launch off East Maui, had 20 kts of wind. Thought we could sneak the launches in during the morning calm. Opsie. By the time Sealice hit the water, it was 35-40 kts sustained, unsafe for further launches. No sign of letting up, so we steamed down to La Perouse to find a lee, with the intrepid Sealice BRU&s team avoiding some of the chop and stop by riding in the ship's wake (evidence attached). After ~2h cruising at 11kts downwind in the ship, we launched in calm waters and managed to get 10 surveys and 4 BRU&s sites done in a little over a half day's work.

9/6/12 (today): West Mākae, only 10-15 kts of wind and short transits lead to a record 18 fish surveys completed, as well as 7 BRU&s sites, 2 also done baited. There were some surprisingly nice fish communities, big surgeons and parrots and terminal Hawaiian hogfish, despite the fact that we were diving on pavement with very little relief. Mostly it was wonderful to have only 10-15 kts of wind and no rain squalls - could actually warmup between dives.

surveys, 352 person-dives, and 30,863 fishes counted. Not bad for 11.5 days.



Total fish biomass (g m²)

- 1
- 10
- 50
- 100

■ Marine protected areas

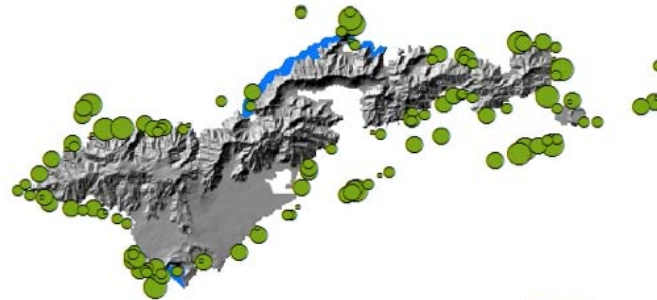


Generic fish richness

- <15
- 15-20
- 20-25
- >25

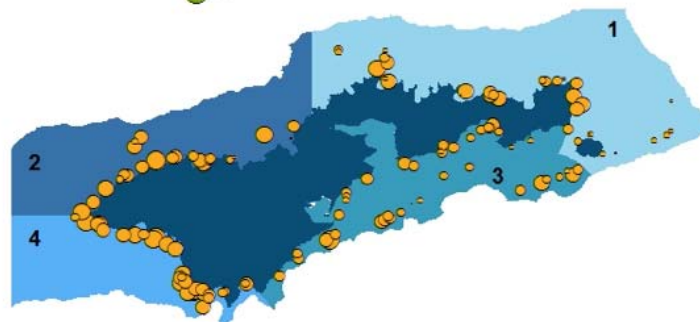
■ Marine protected areas

■ Elevation (high to low)



Coral cover (%)

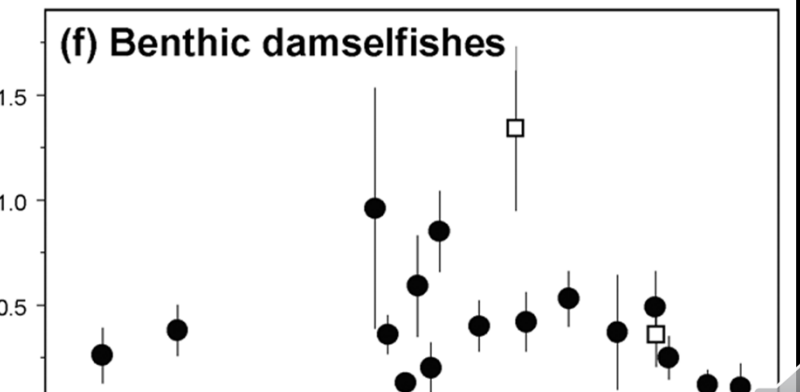
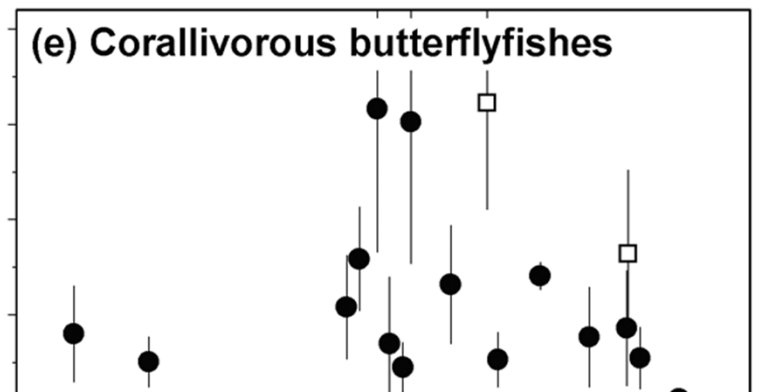
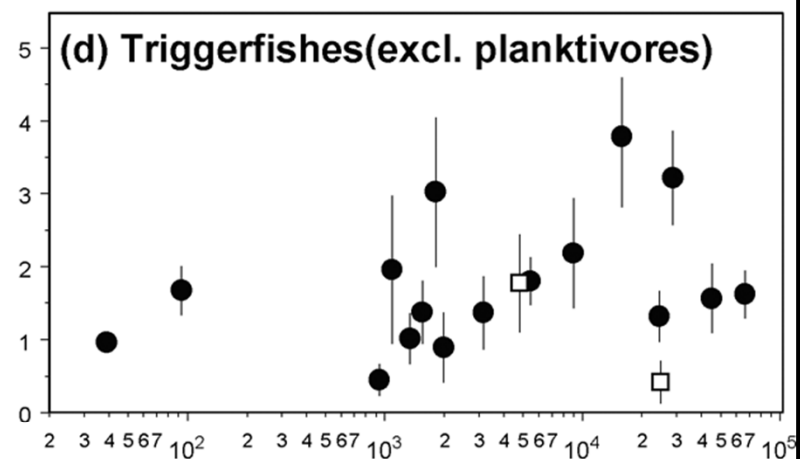
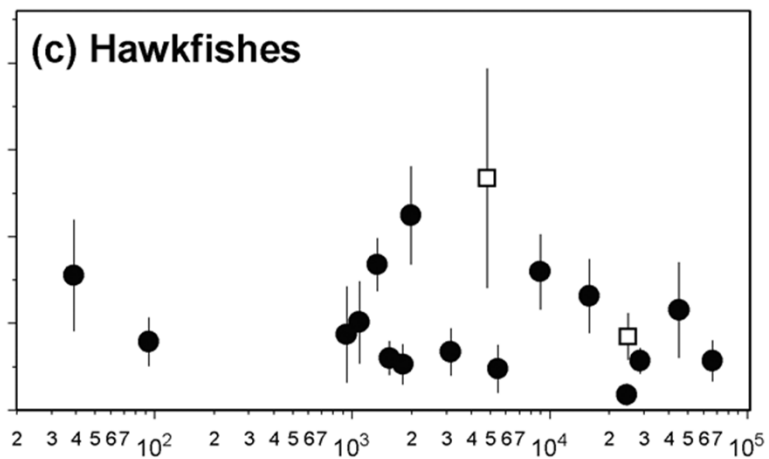
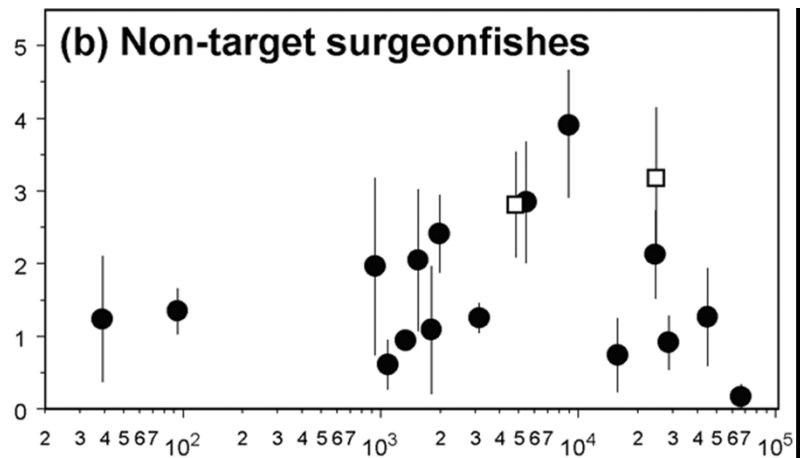
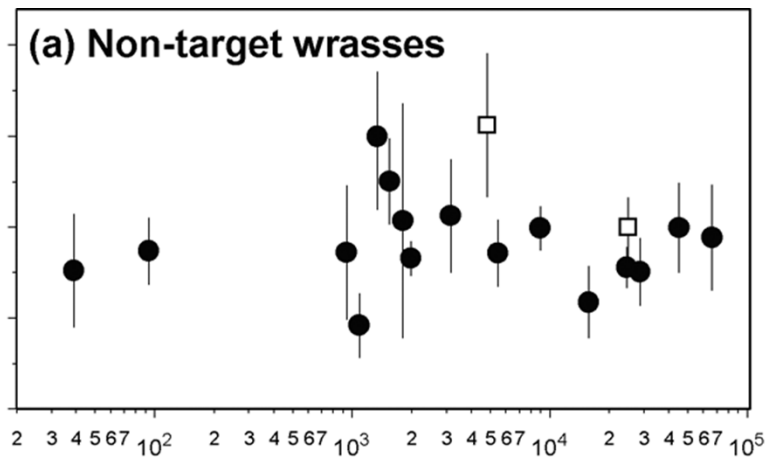
- 1
- 10
- 50
- >70

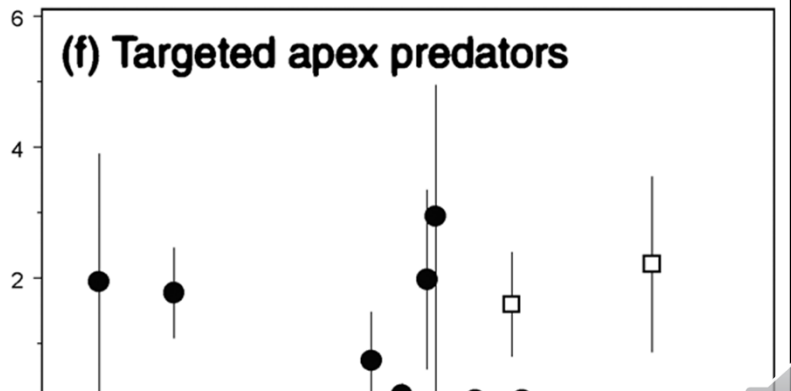
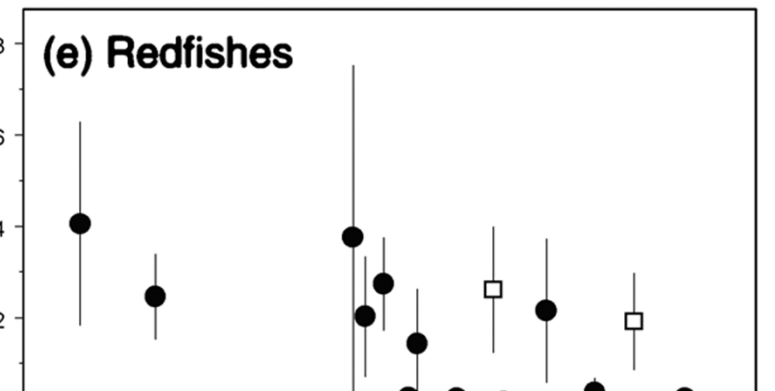
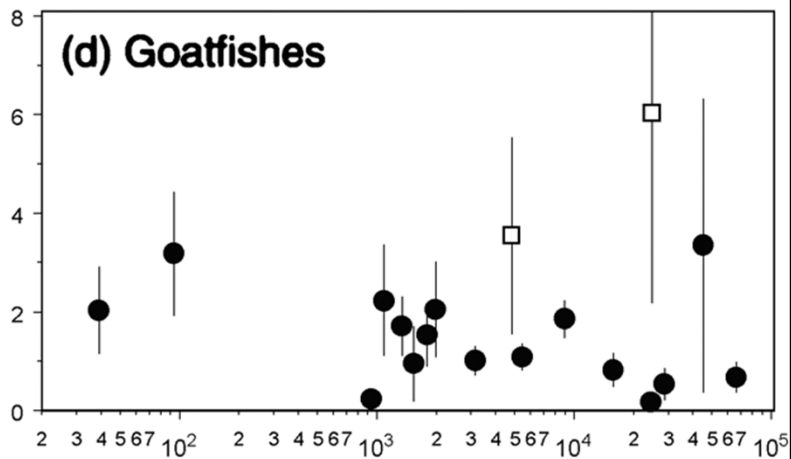
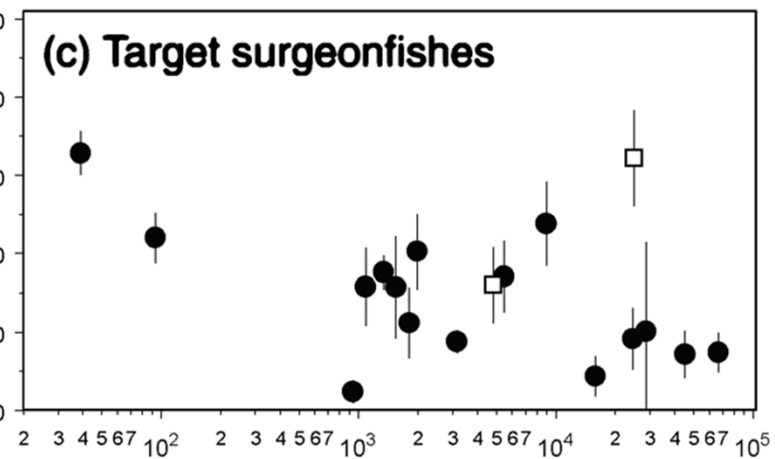
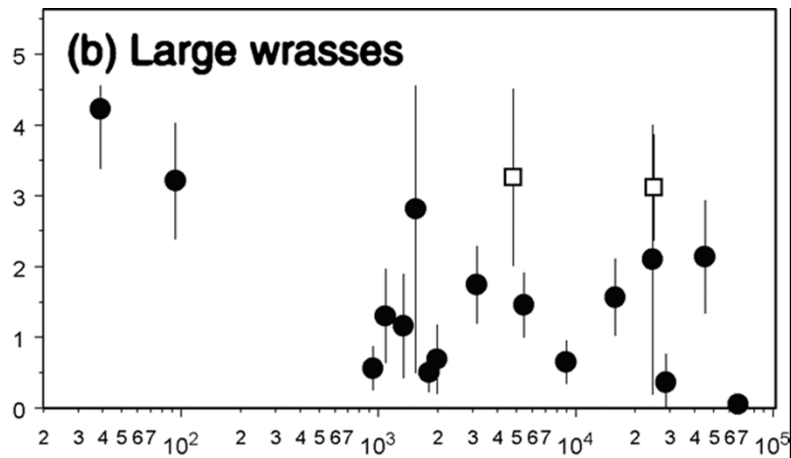
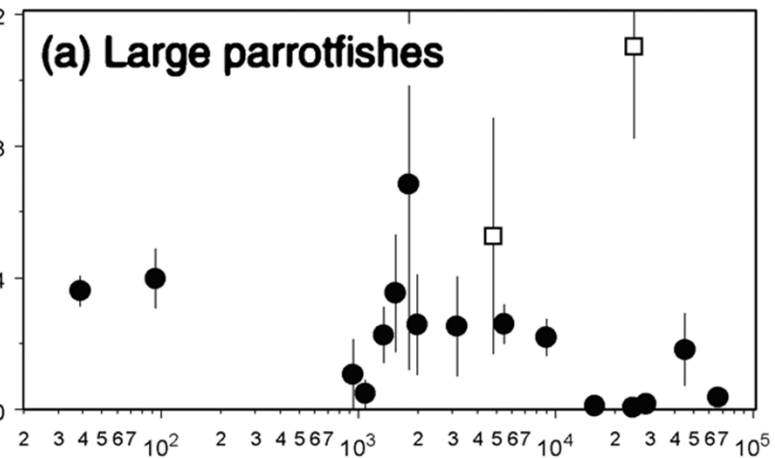


Benthic substrate ratio

- <1
- 1-3
- 3-6
- 6-11



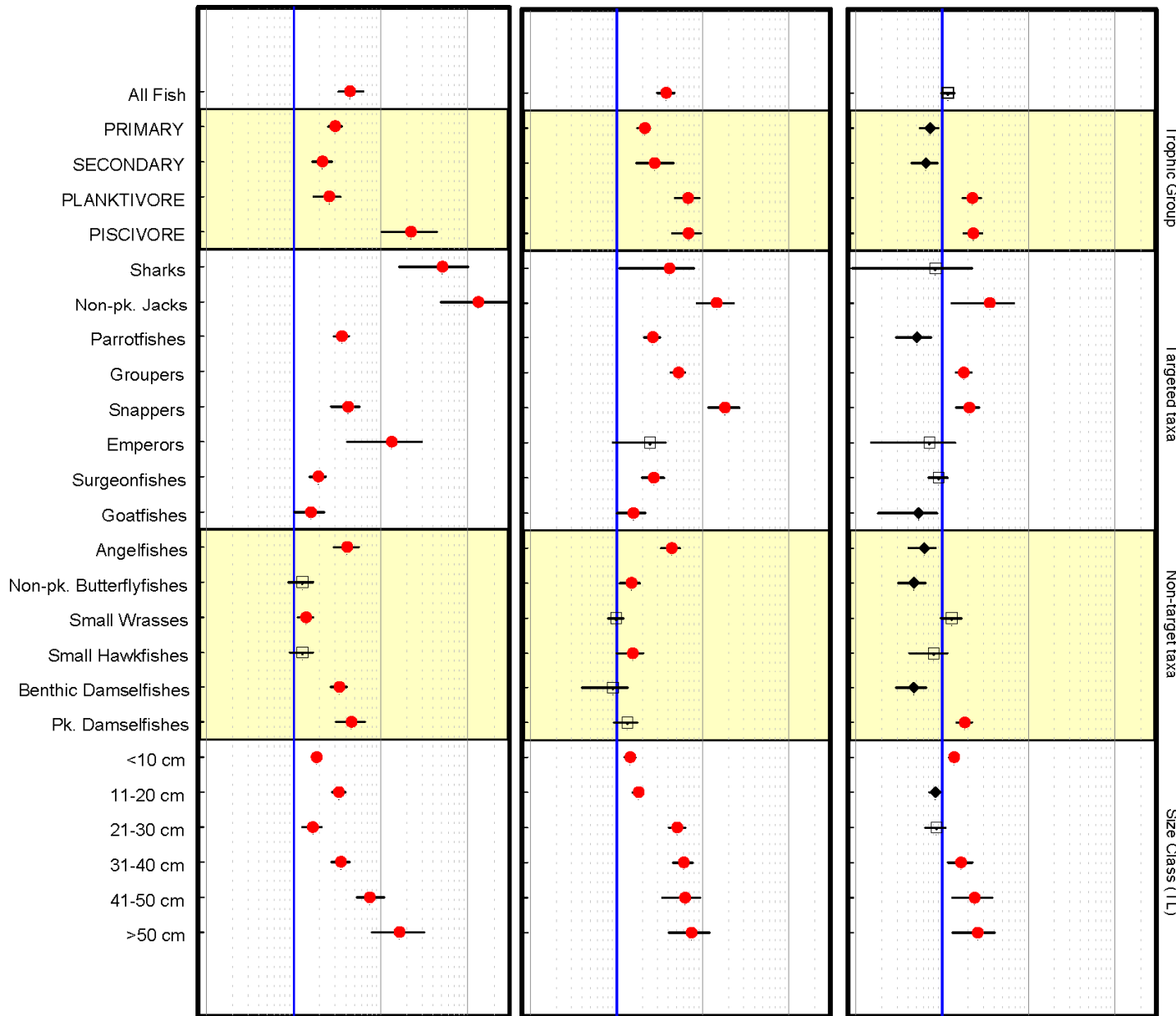




Hawaiian Archipelago

Mariana Archipelago

American Samoa

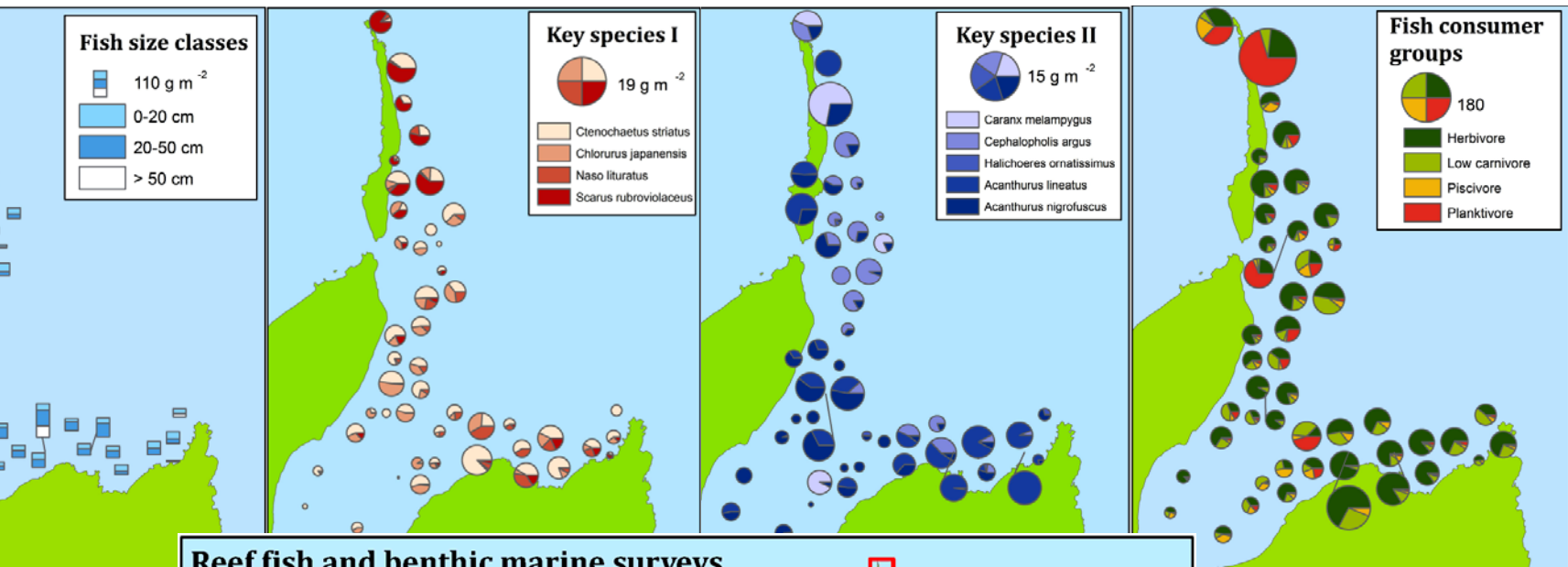


Trophic Group

Targeted taxa

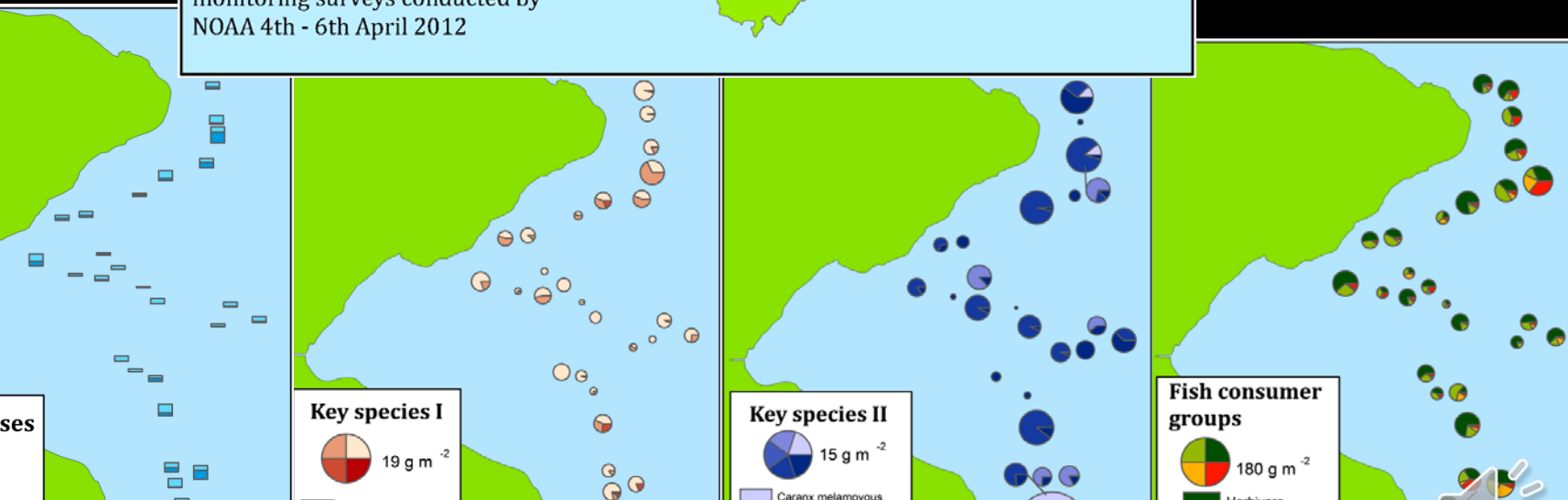
Non-target taxa

Size Class (TL)



**Reef fish and benthic marine surveys
in Faga'alu and Vatia watersheds,
Tutuila, American Samoa**

Depth-stratified random biological
monitoring surveys conducted by
NOAA 4th - 6th April 2012



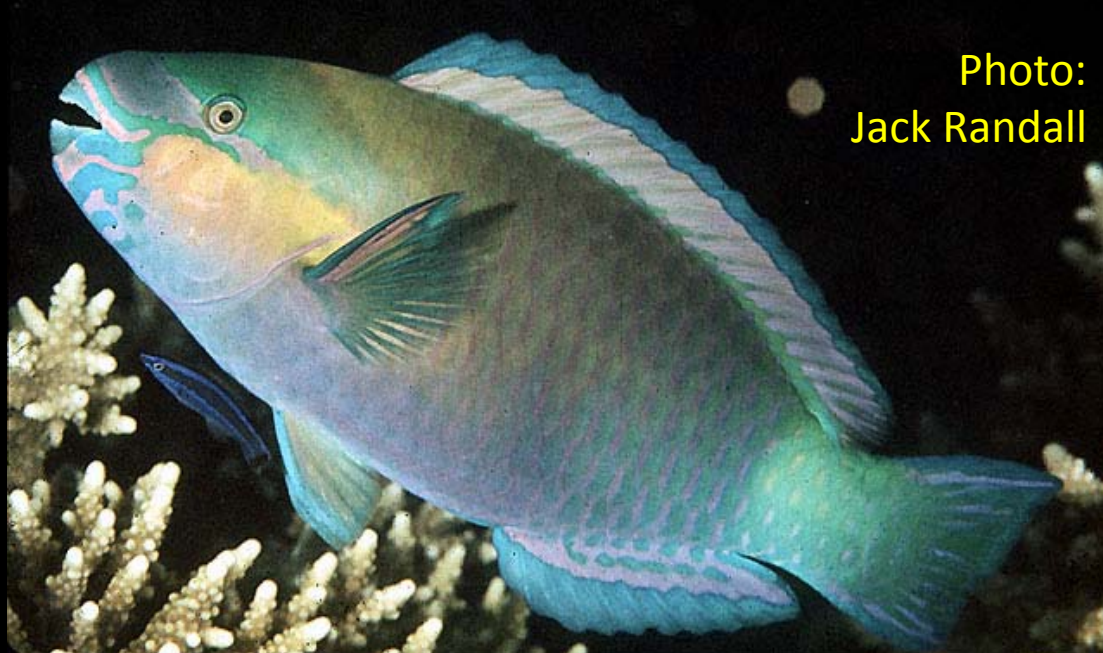
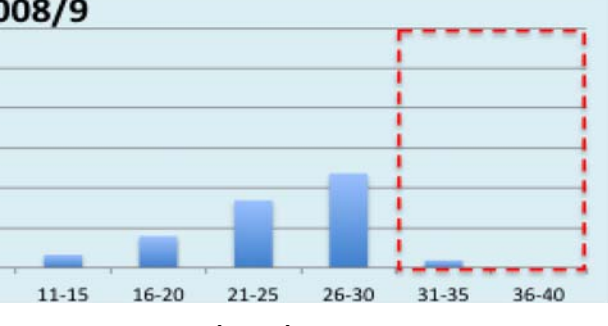
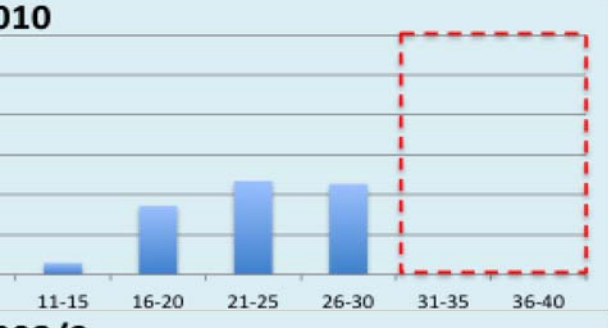
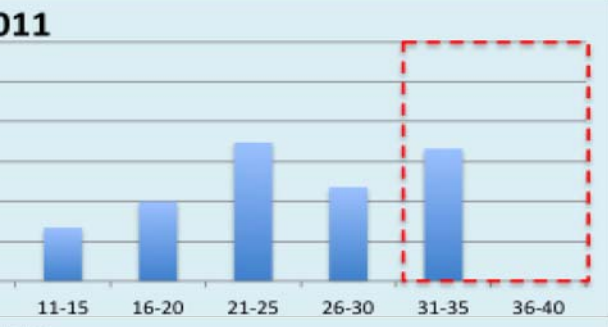
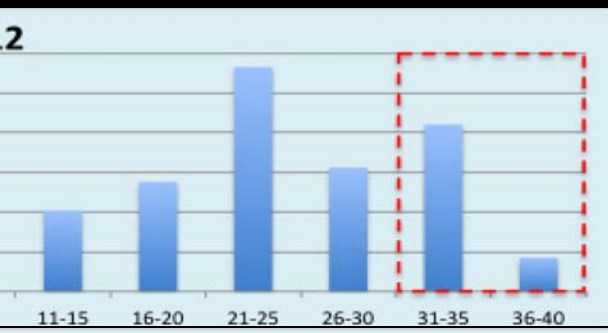
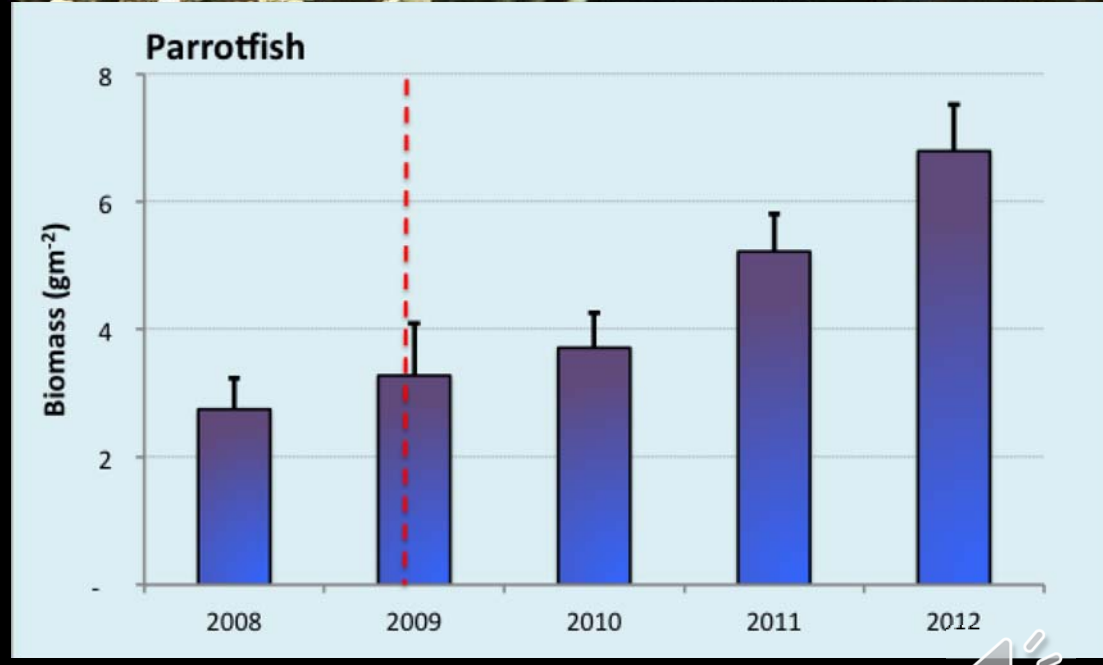


Photo:
Jack Randall

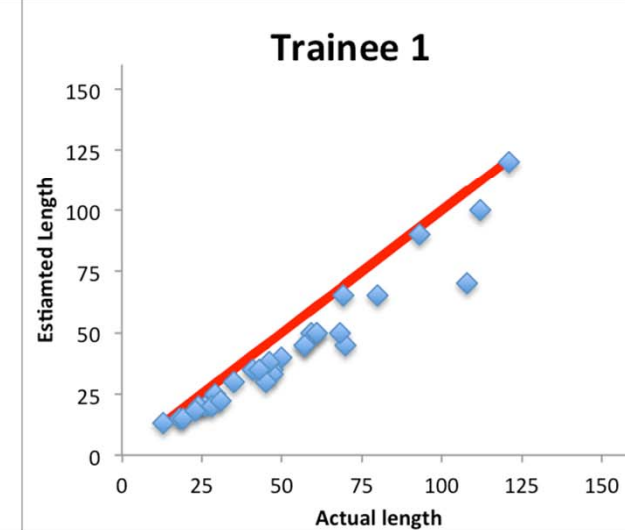
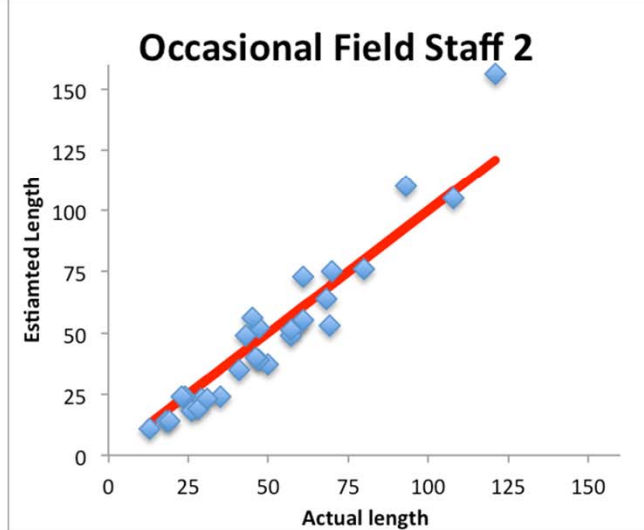
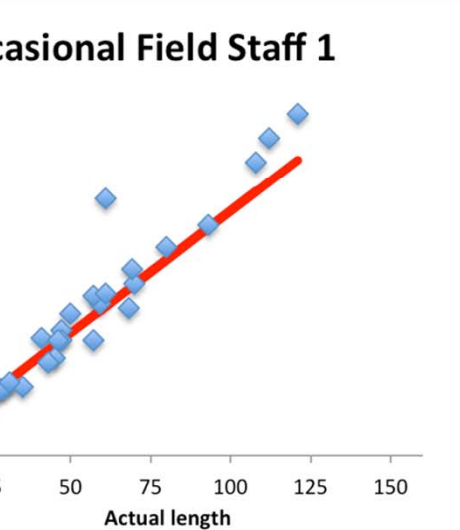
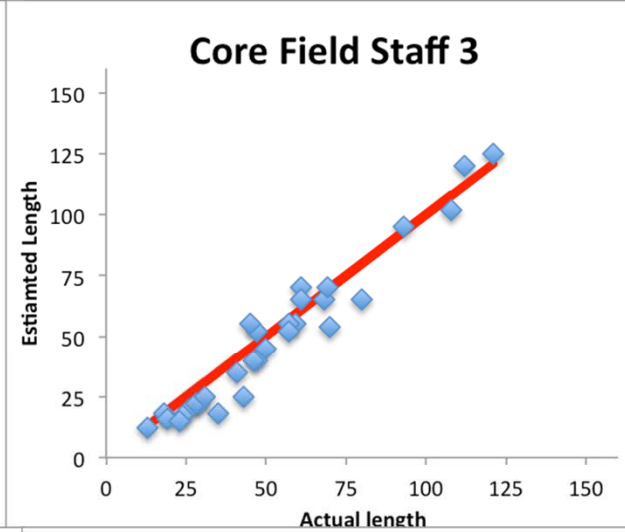
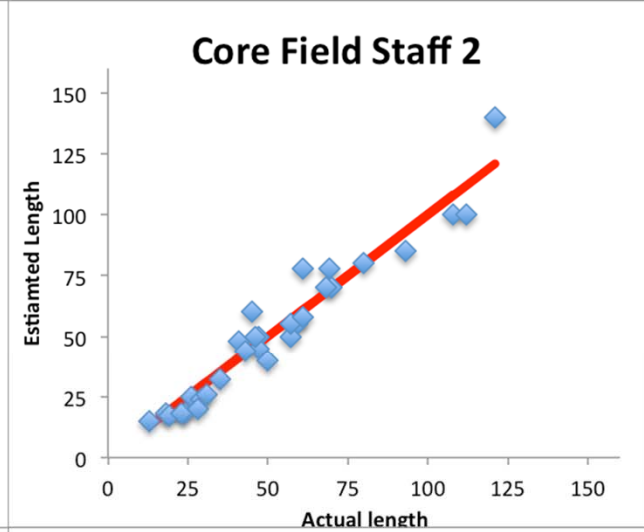
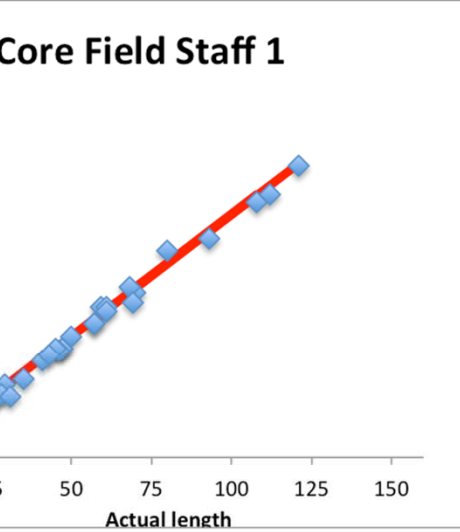


ing & Quality Control

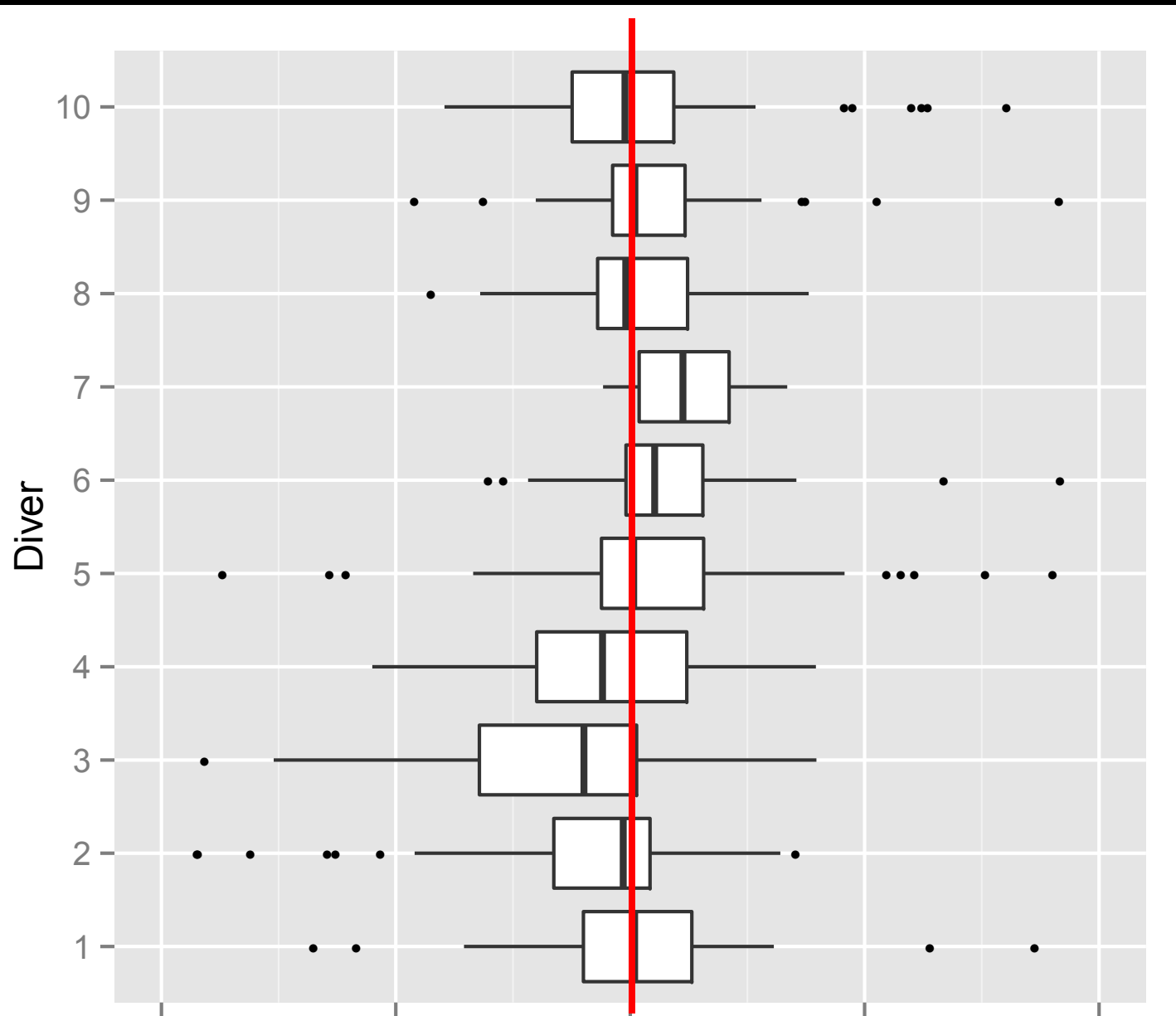
utine Size Estimation Training
Using Fish Models



Estimation Test Results

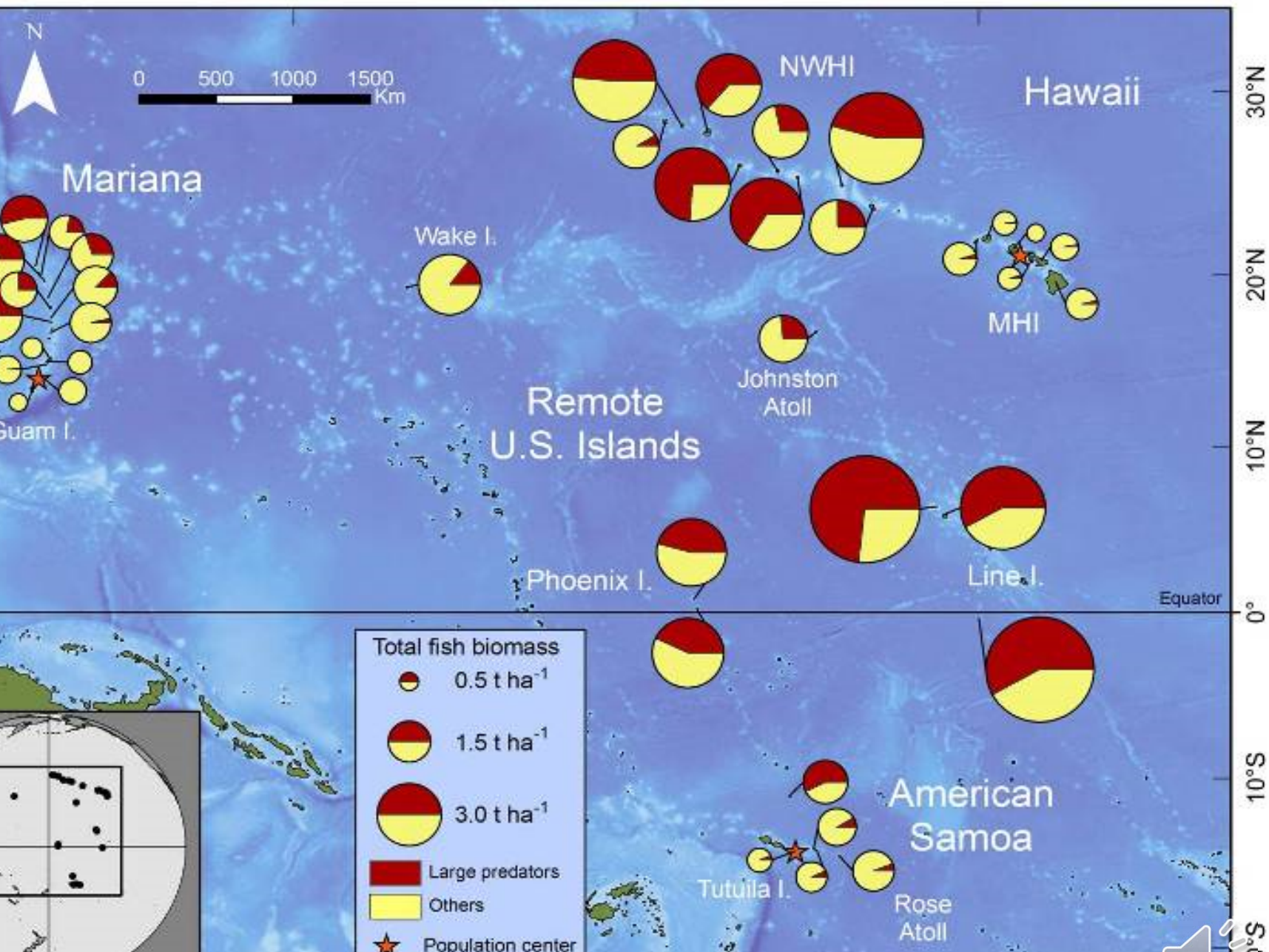


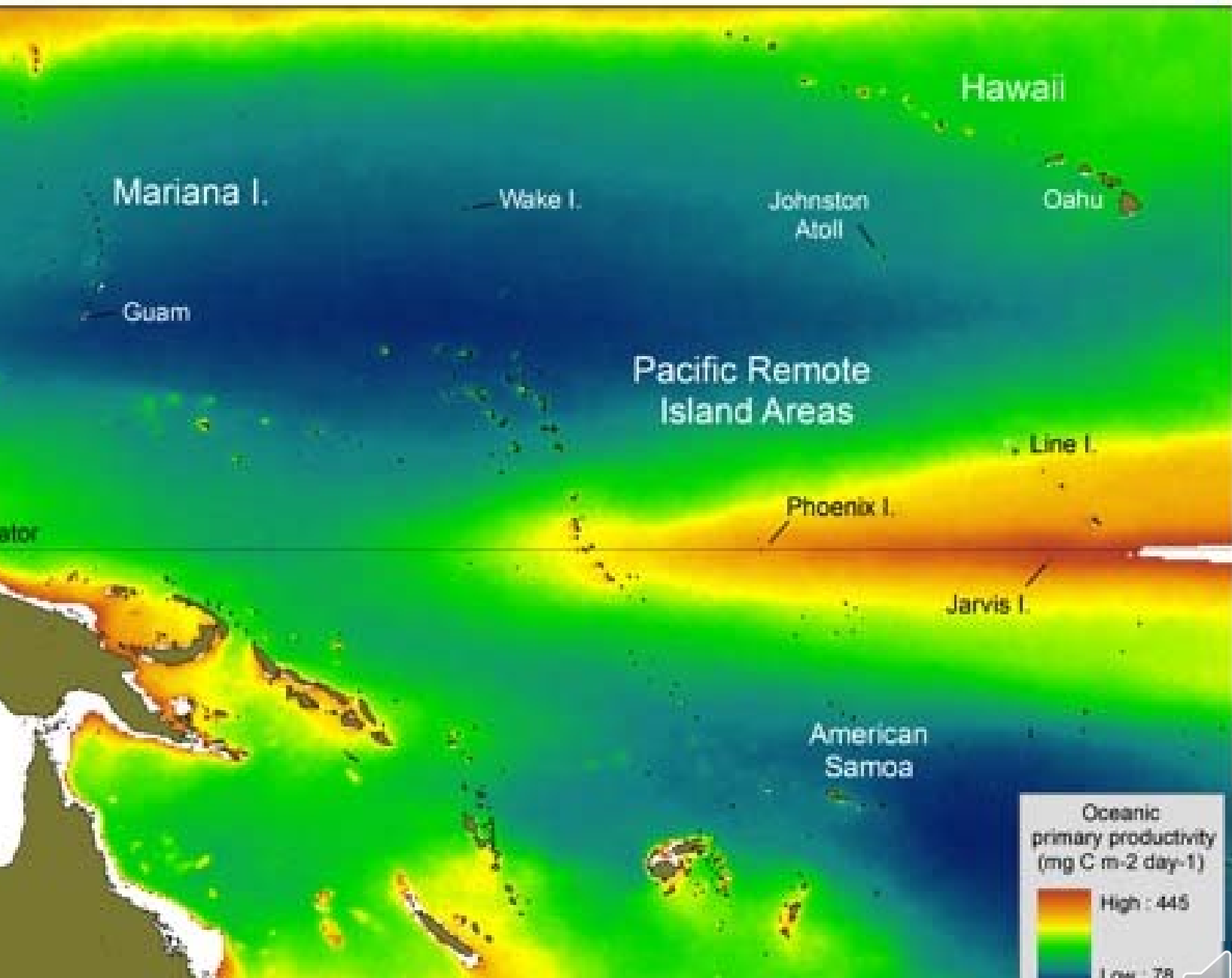
observer (Buddy-buddy) comparisons:



TOW

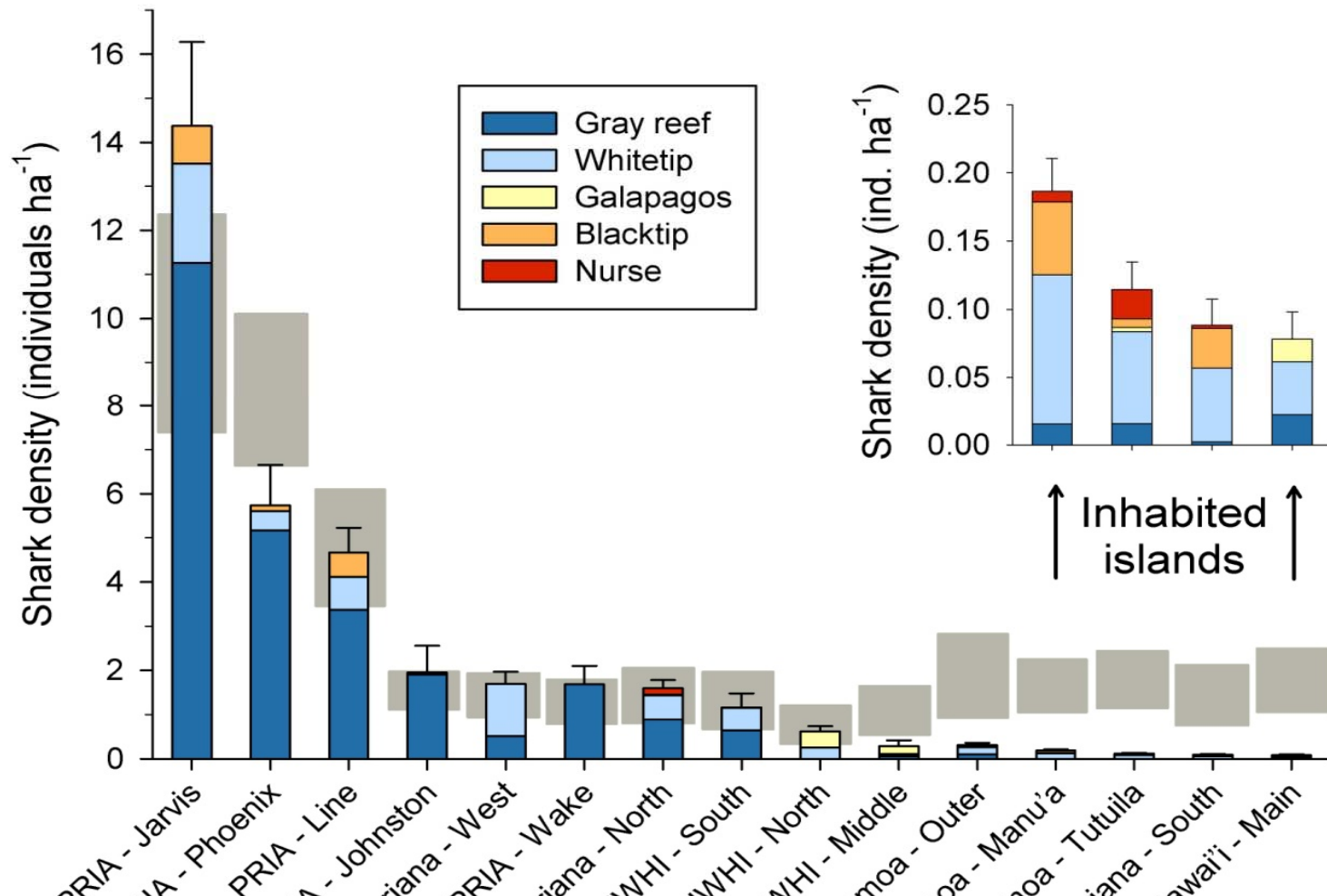




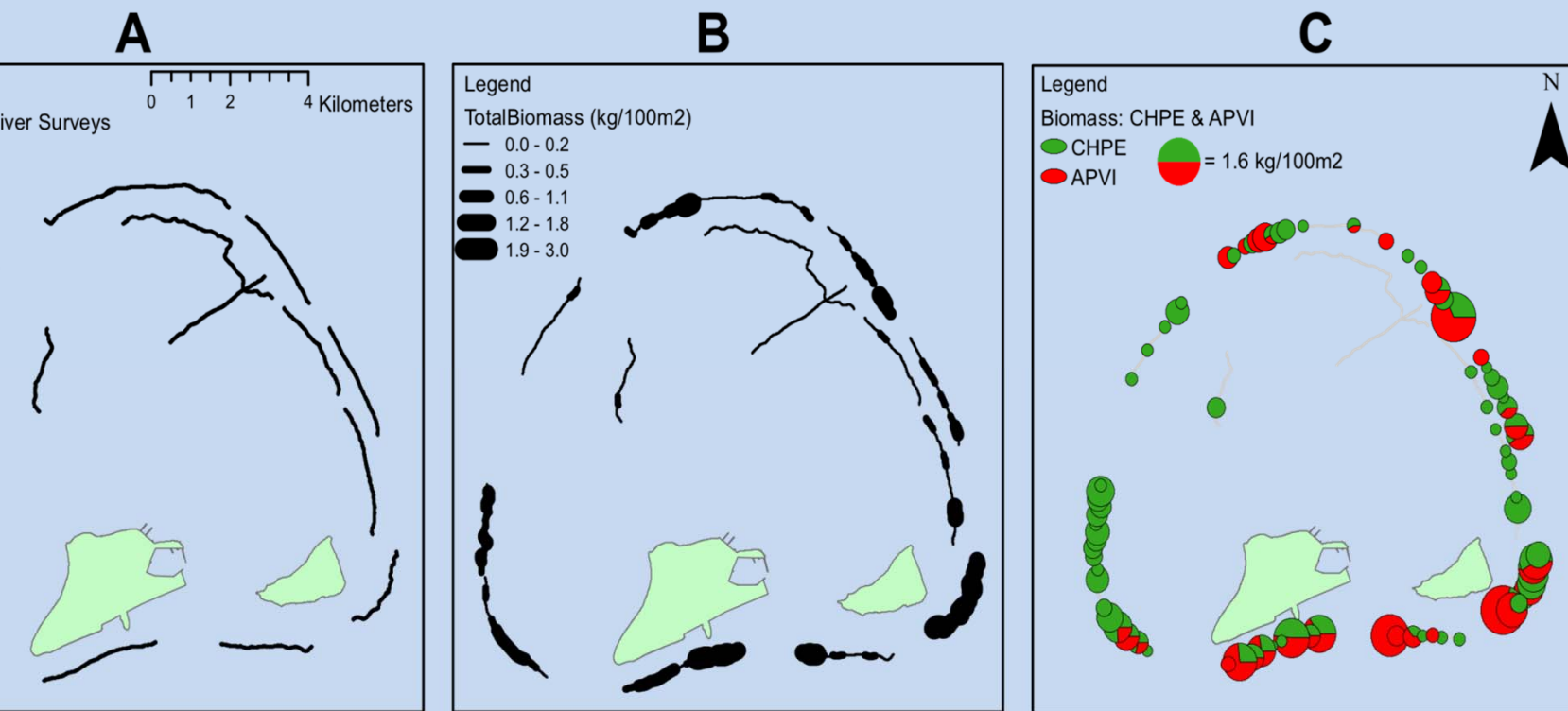


Towed Diver Data to Reconstruct Reef Shark Baselines

Shark densities near population centers <10% of modeled density without humans
Productivity also very important



Red-Diver Surveys May – Papahānaumokuākea Marine National Monument



Tow methods paper: Richards et al, 2011, PLOS ONE 7(2): e31374

JILL,
BILL & TED'S
EXCELLENT
ADVENTURE



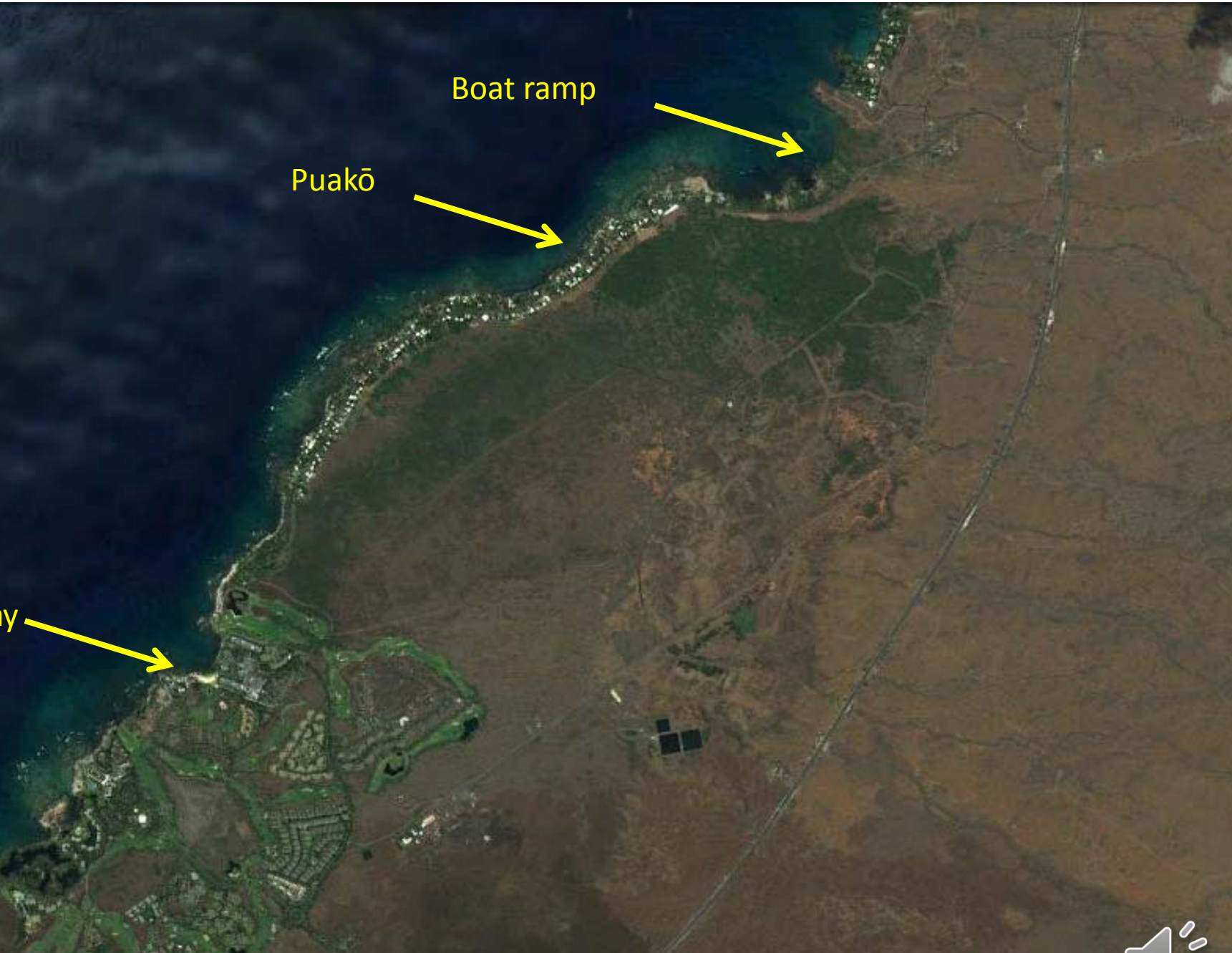
WHAP Study Sites

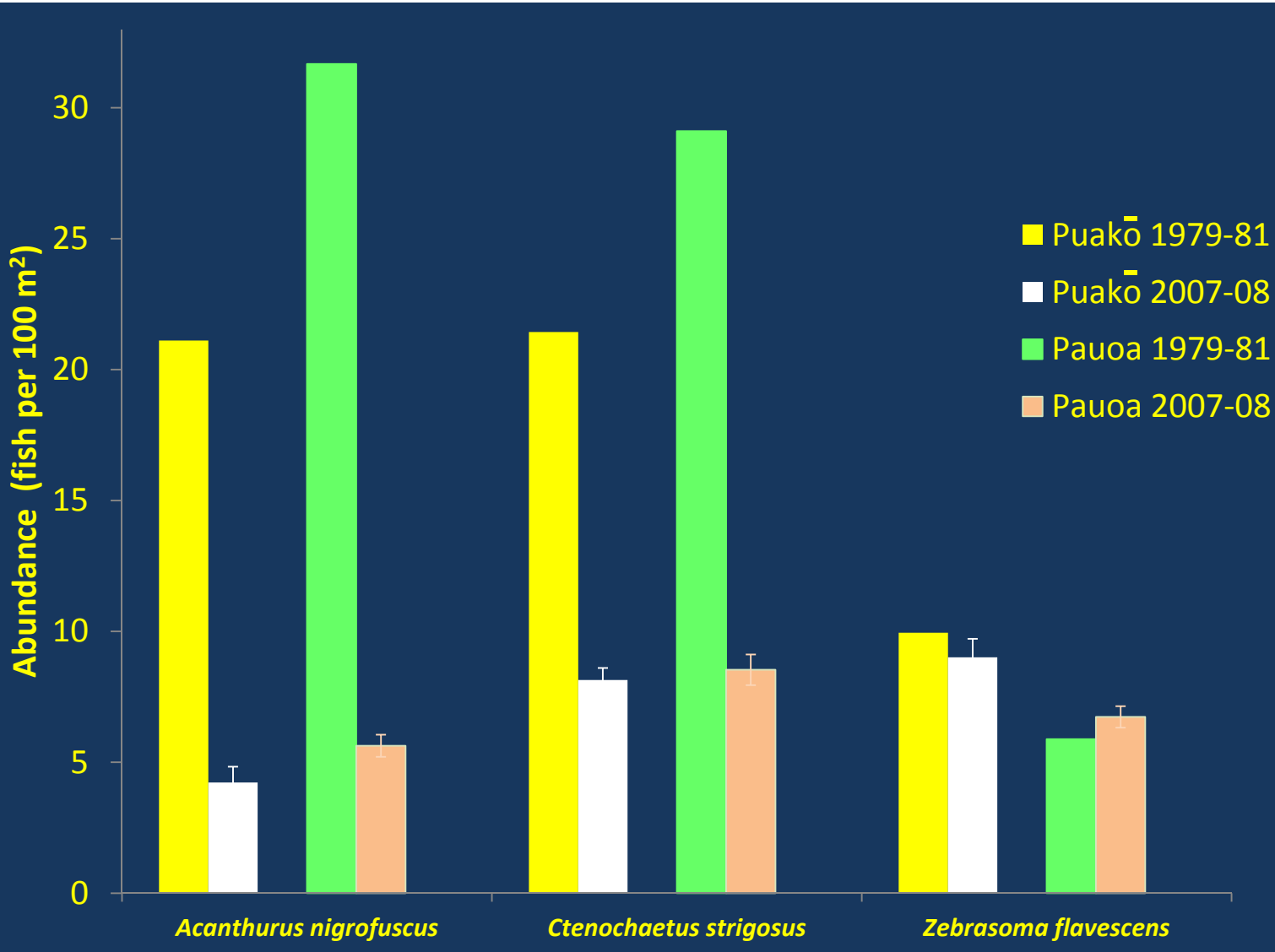
- Open Sites
- MPA Sites
- FRA Sites
- ∧ 100 Fathom Contour
- Fish Replenishment Areas



Map Projection: UTM Zone 4 1:600,000
Scale: 1:600,000









Kealakekua Bay

e'ei
& Walsh)

mano Point
(son basalt)

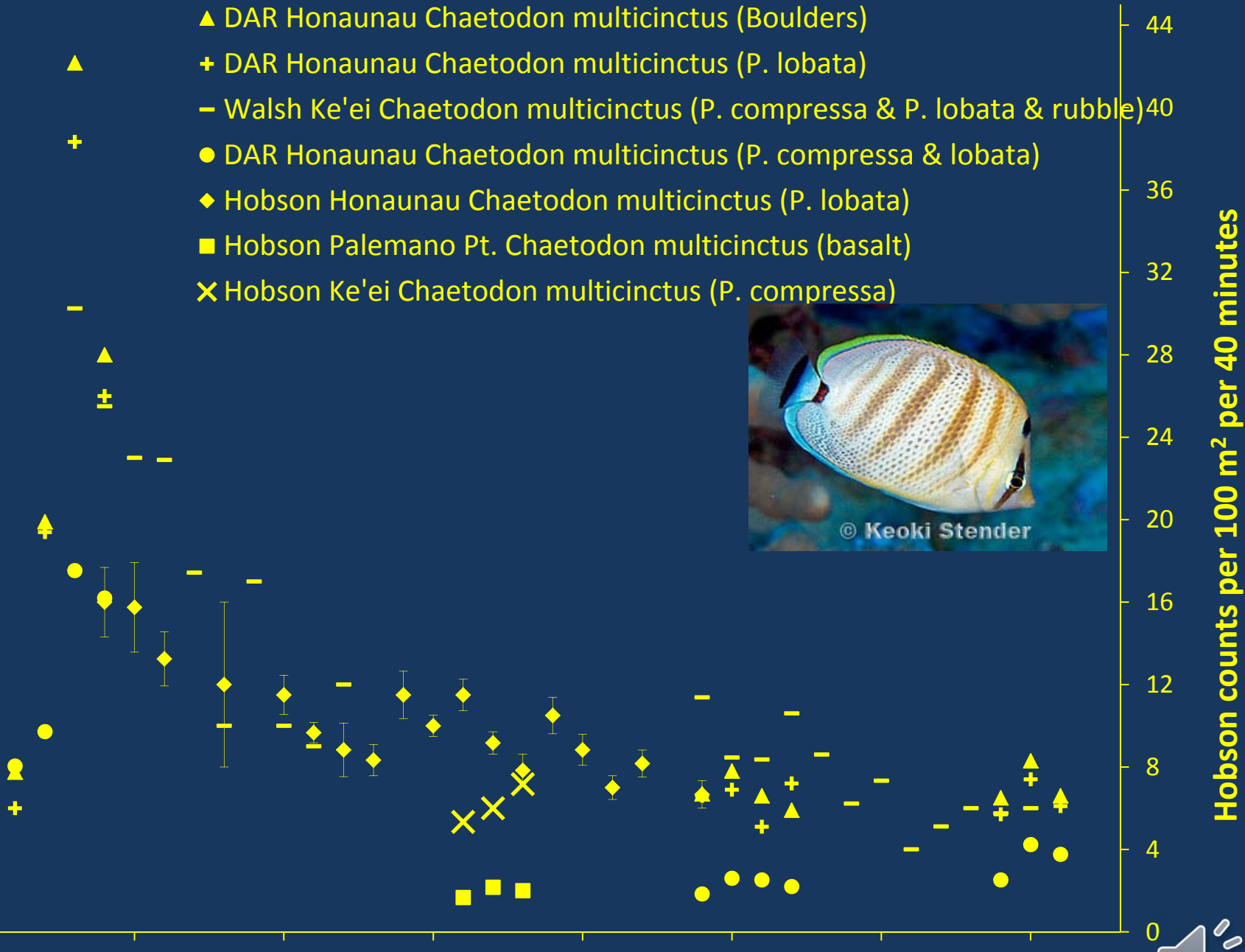
= ~4.5 km

onaunau
(son & DAR)

unau" Boulder transect

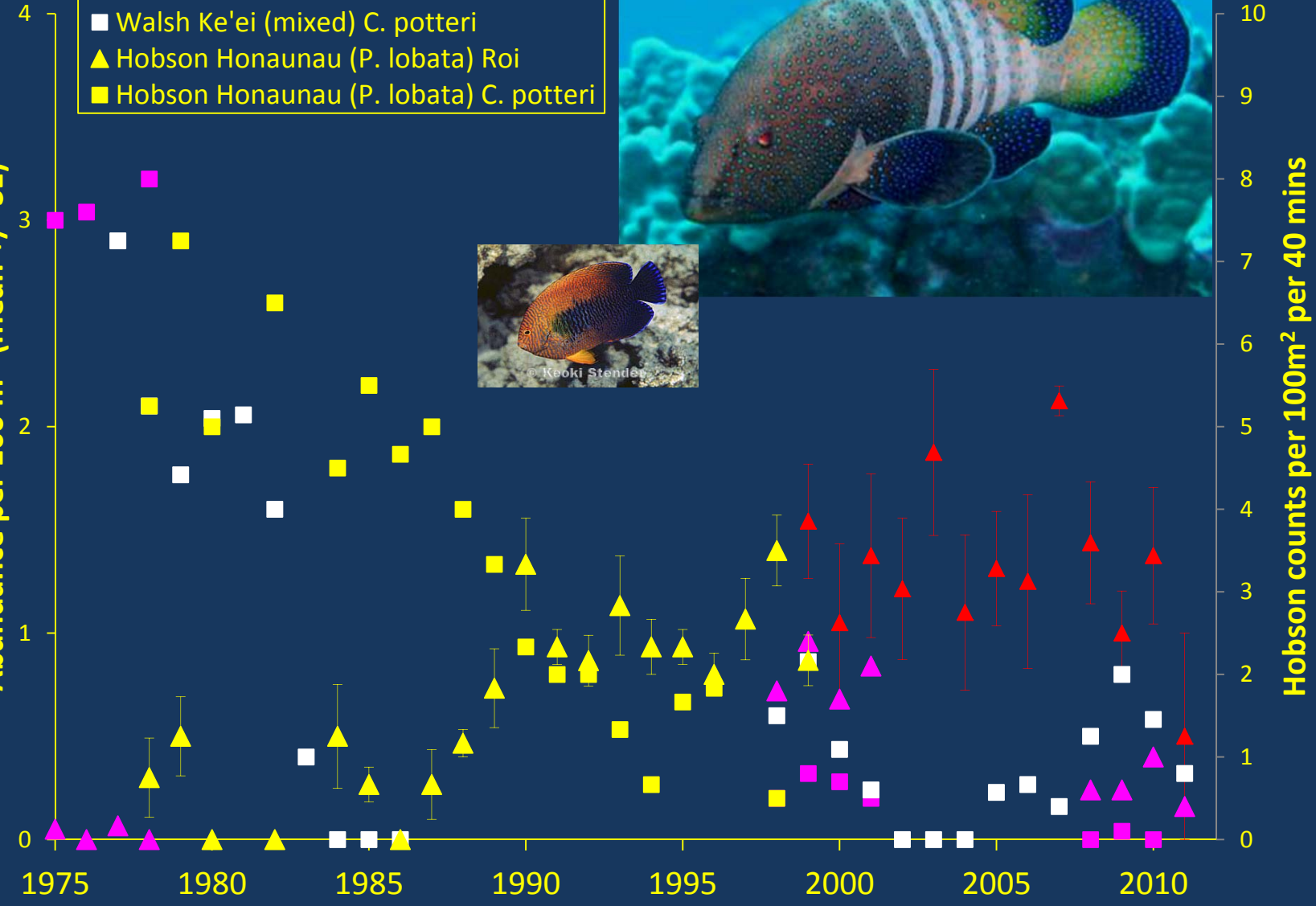


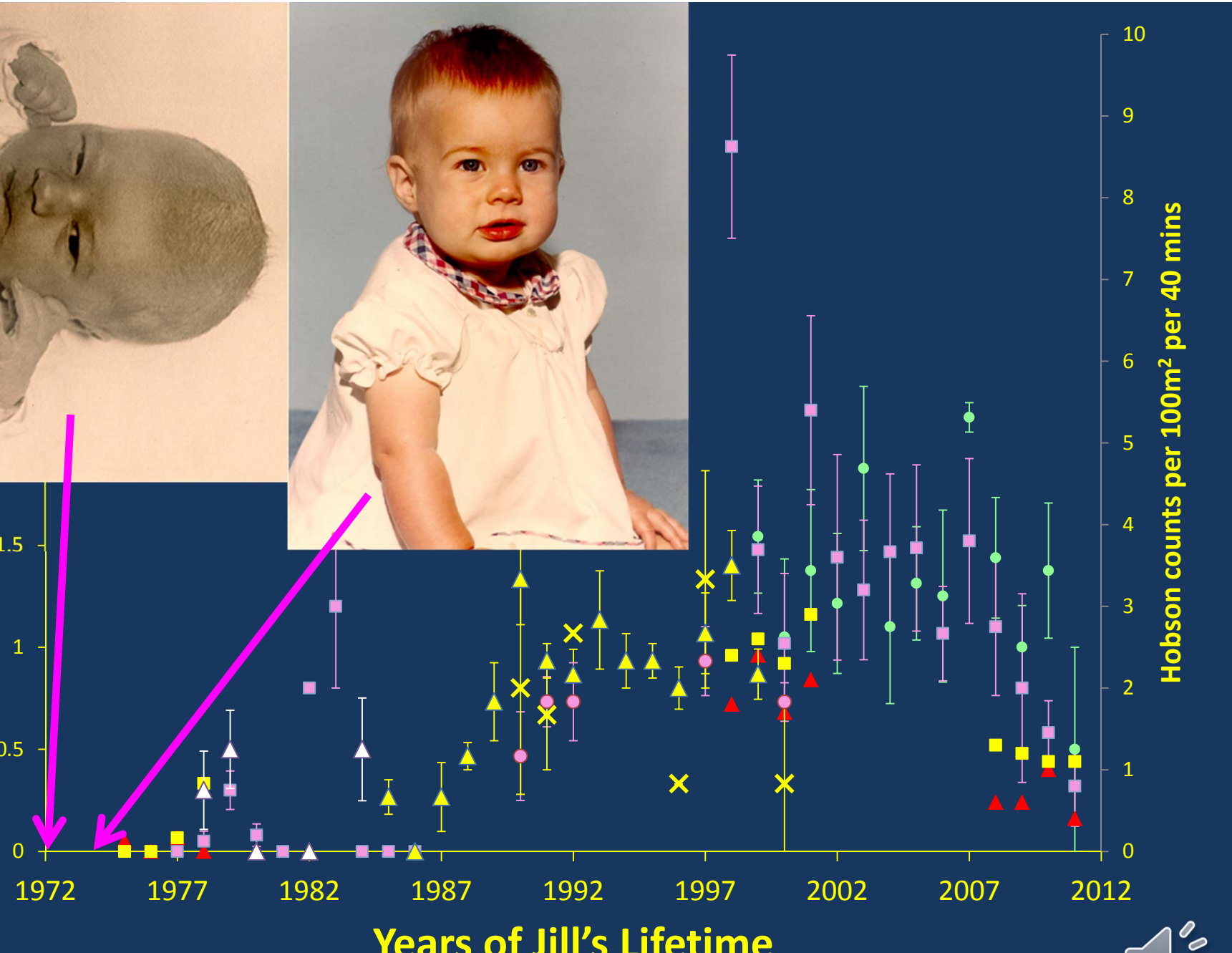
- ▲ DAR Honaunau Chaetodon multinctus (Boulders)
- + DAR Honaunau Chaetodon multinctus (P. lobata)
- Walsh Ke'ei Chaetodon multinctus (P. compressa & P. lobata & rubble)
- DAR Honaunau Chaetodon multinctus (P. compressa & lobata)
- ◆ Hobson Honaunau Chaetodon multinctus (P. lobata)
- Hobson Palemano Pt. Chaetodon multinctus (basalt)
- × Hobson Ke'ei Chaetodon multinctus (P. compressa)



Hobson counts per 100 m² per 40 minutes

- DAR Honaunau (*P. lobata*) *C. potteri*
- ▲ DAR WHAP (*P. compressa*) Roi
- ▲ DAR Honaunau (*P. lobata*) Roi
- Walsh Ke'ei (mixed) *C. potteri*
- ▲ Hobson Honaunau (*P. lobata*) Roi
- Hobson Honaunau (*P. lobata*) *C. potteri*

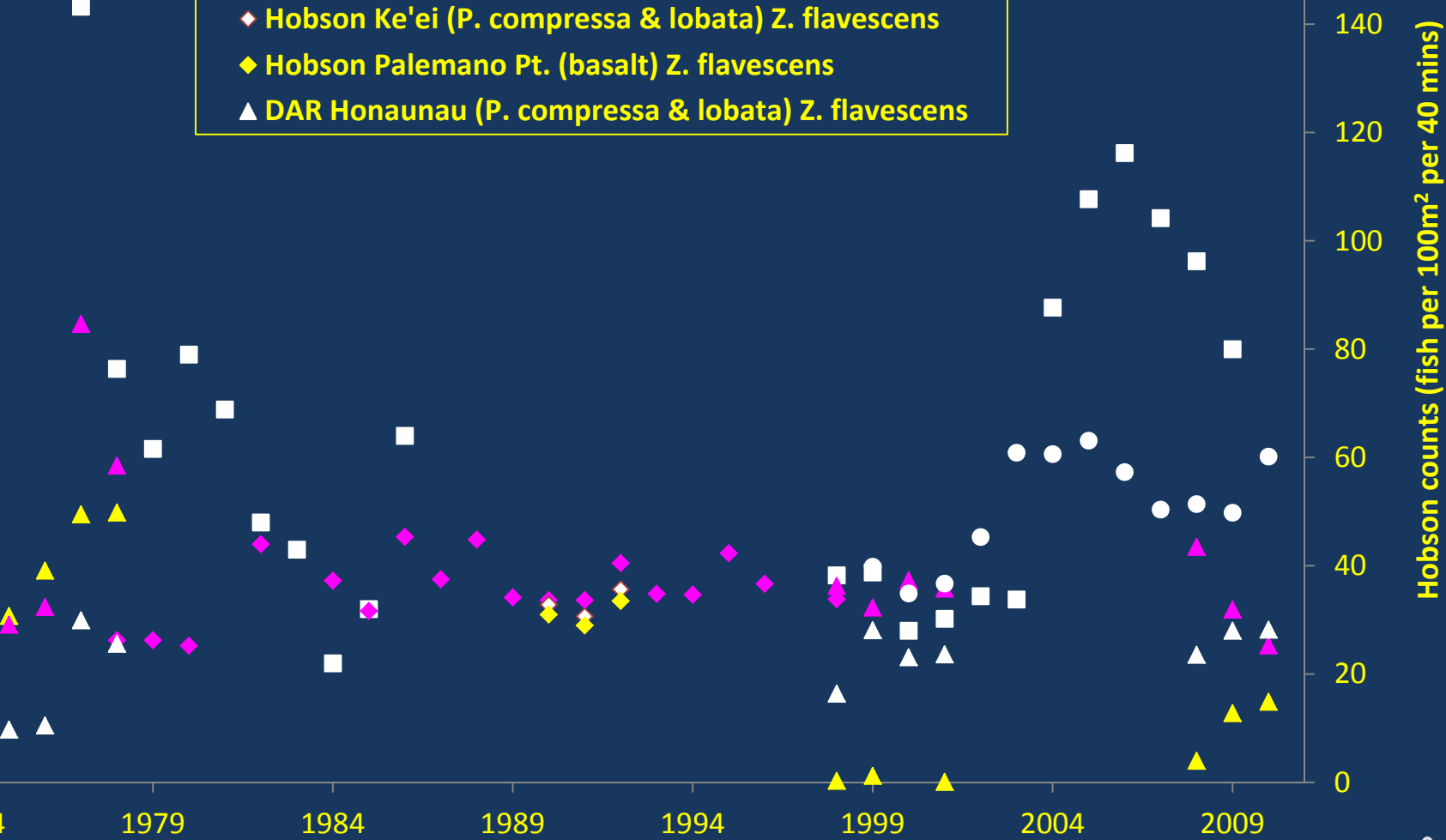


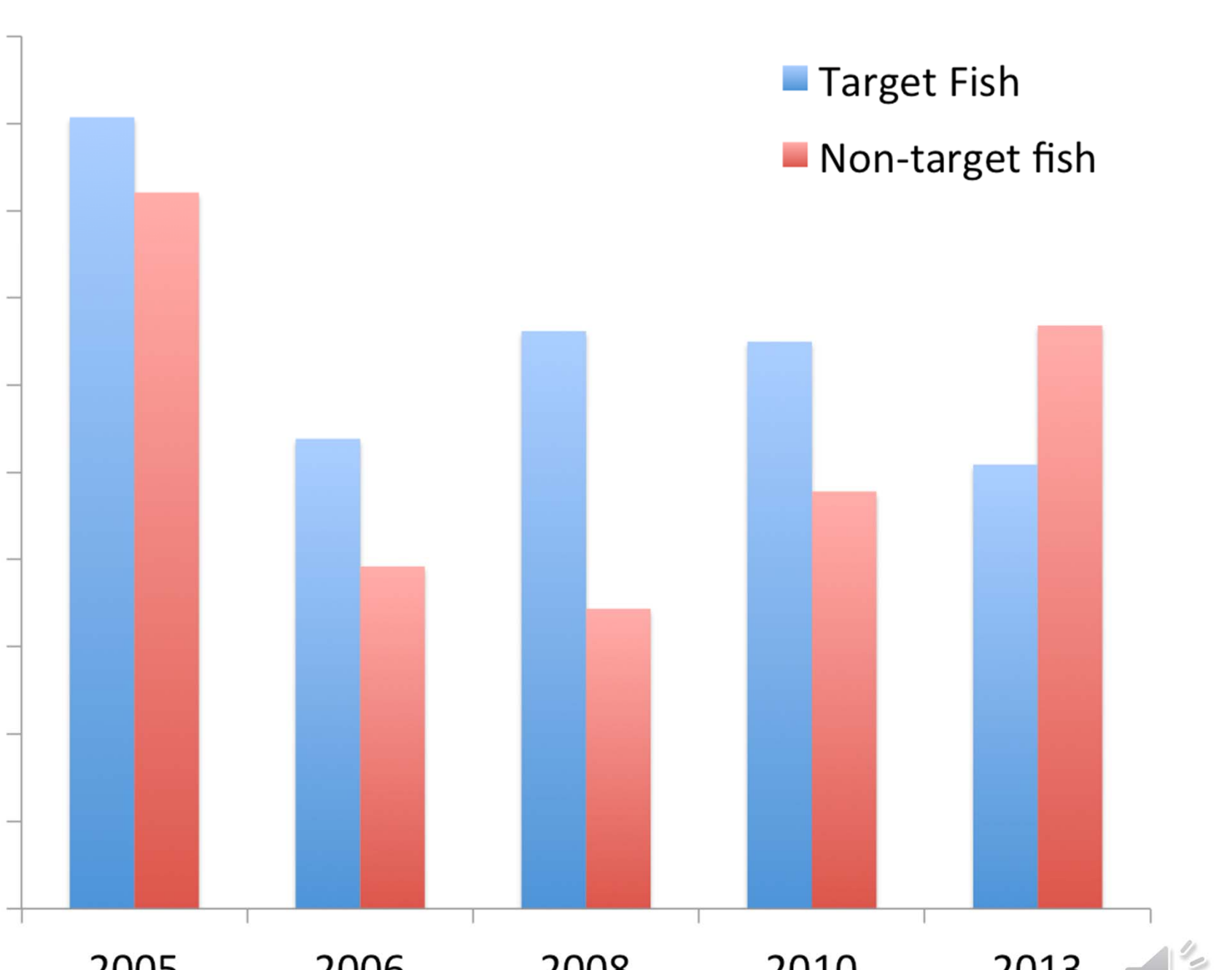


Years of Jill's Lifetime

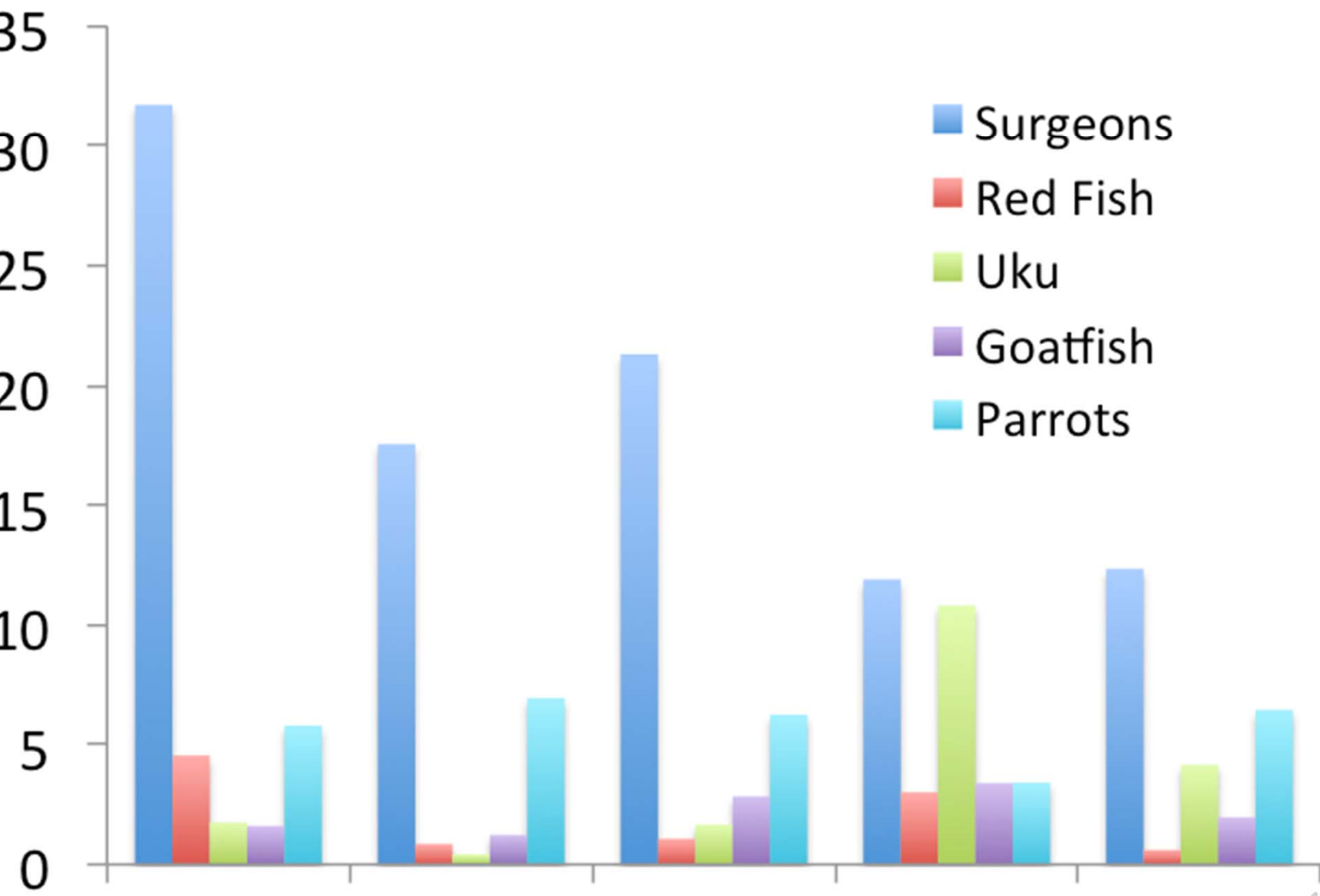


- Walsh Ke'ei (mixed) *Z. flavescens*
- ▲ DAR Honaunau (boulders) *Z. flavescens*
- ▲ DAR Honaunau (*P. lobata*) *Z. flavescens*
- DAR WHAP sites (*P. compressa*) *Z. flavescens*
- ◆ Hobson Honauanau (*P. lobata*) *Z. flavescens*
- ◆ Hobson Ke'ei (*P. compressa* & *lobata*) *Z. flavescens*
- ◆ Hobson Palemano Pt. (basalt) *Z. flavescens*
- ▲ DAR Honaunau (*P. compressa* & *lobata*) *Z. flavescens*





Ni'ihau Fish Trends







NOAA CORAL REEF CONSERVATION PROGRAM

ADMINISTRATION

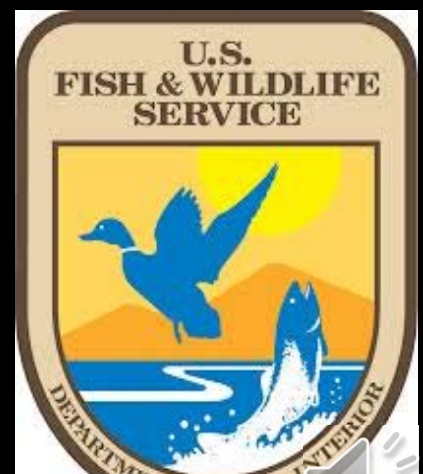




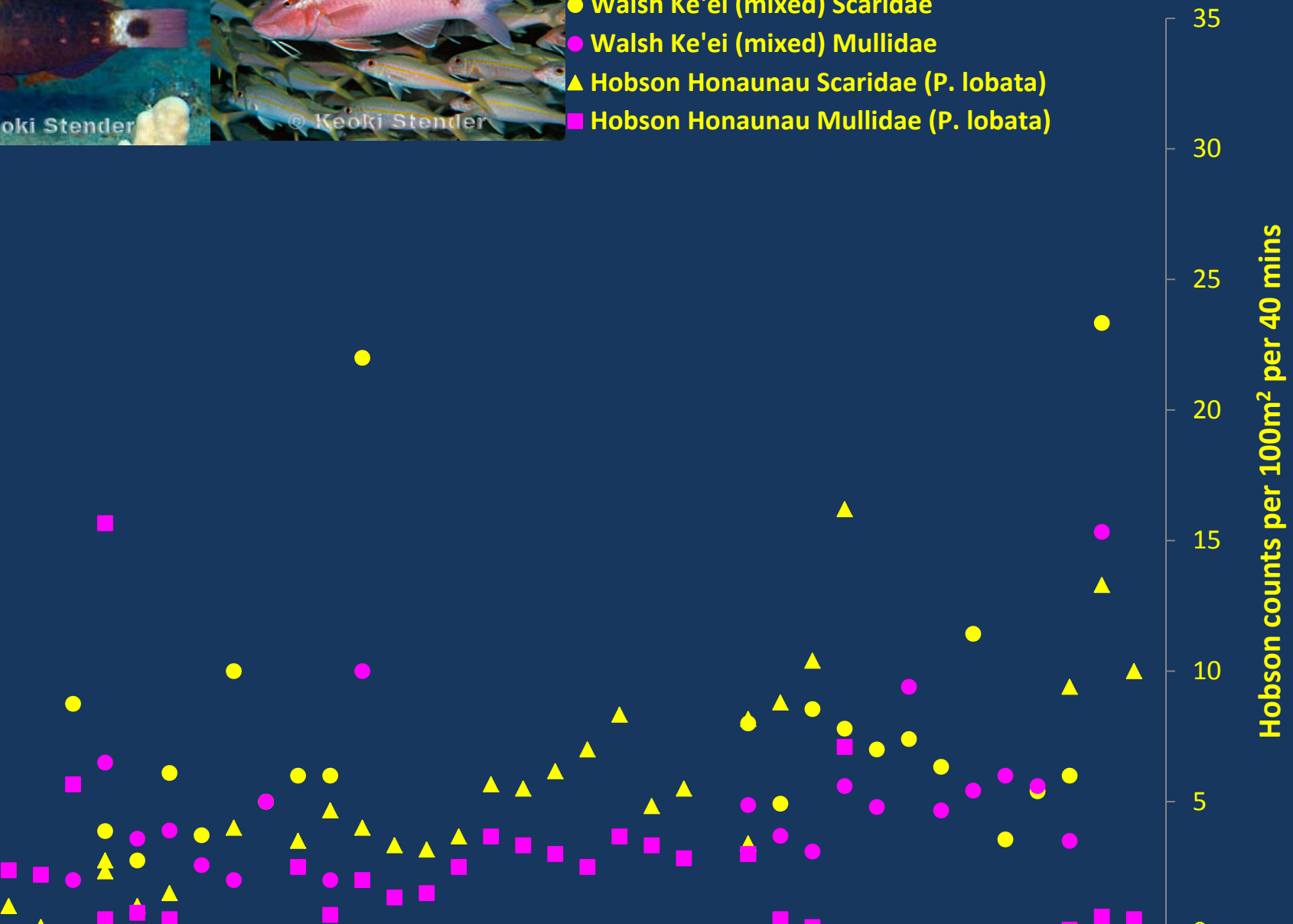
Photo: Jill Zamzow



EXTRA SLIDES FOLLOW



- DAR Honaunau Mullidae (*P. compressa* & *P. lobata*)
- ▲ DAR Honaunau Scaridae (*P. compressa* & *P. lobata*)
- Walsh Ke'ei (mixed) Scaridae
- Walsh Ke'ei (mixed) Mullidae
- ▲ Hobson Honaunau Scaridae (*P. lobata*)
- Hobson Honaunau Mullidae (*P. lobata*)

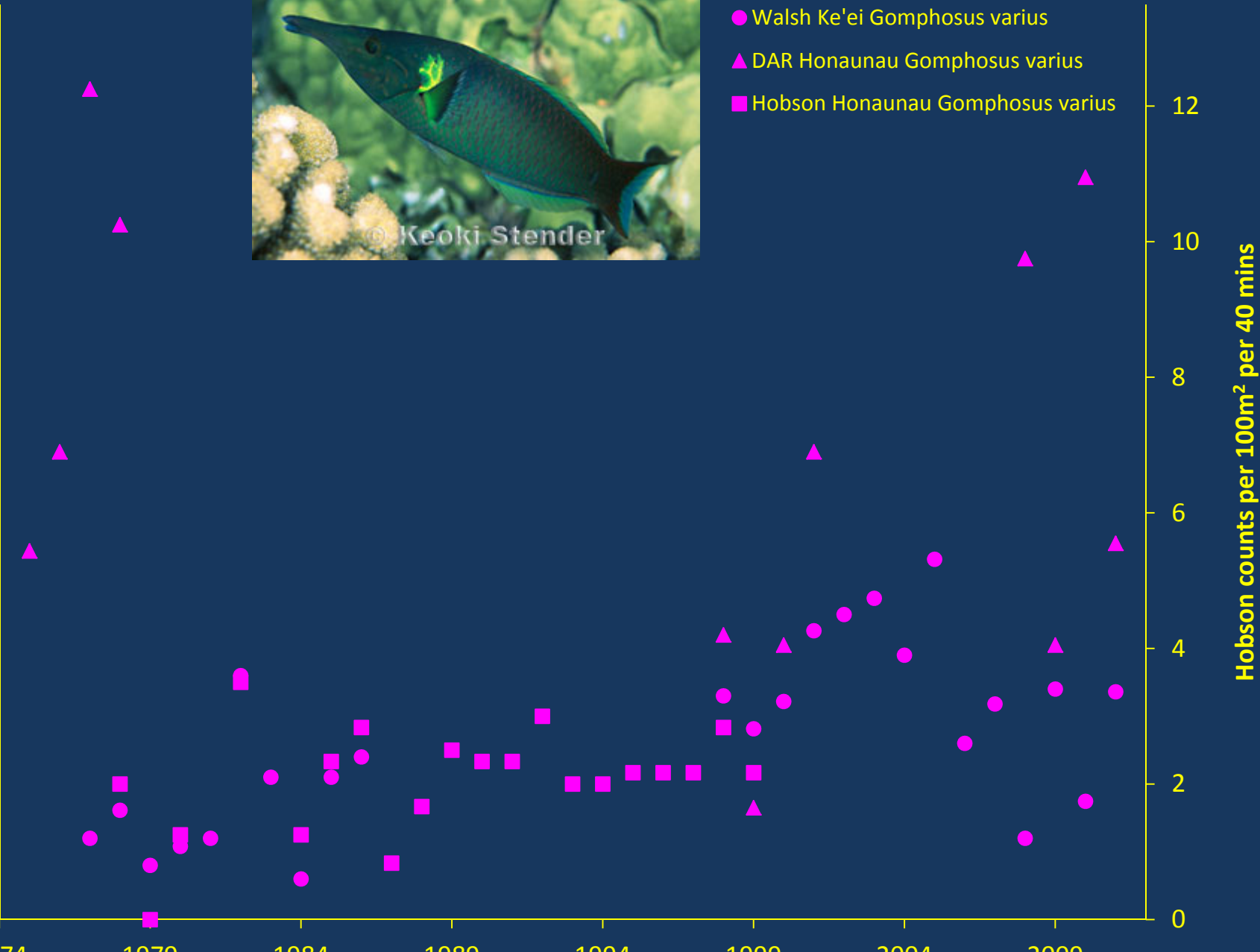


Hobson counts per 100m² per 40 mins

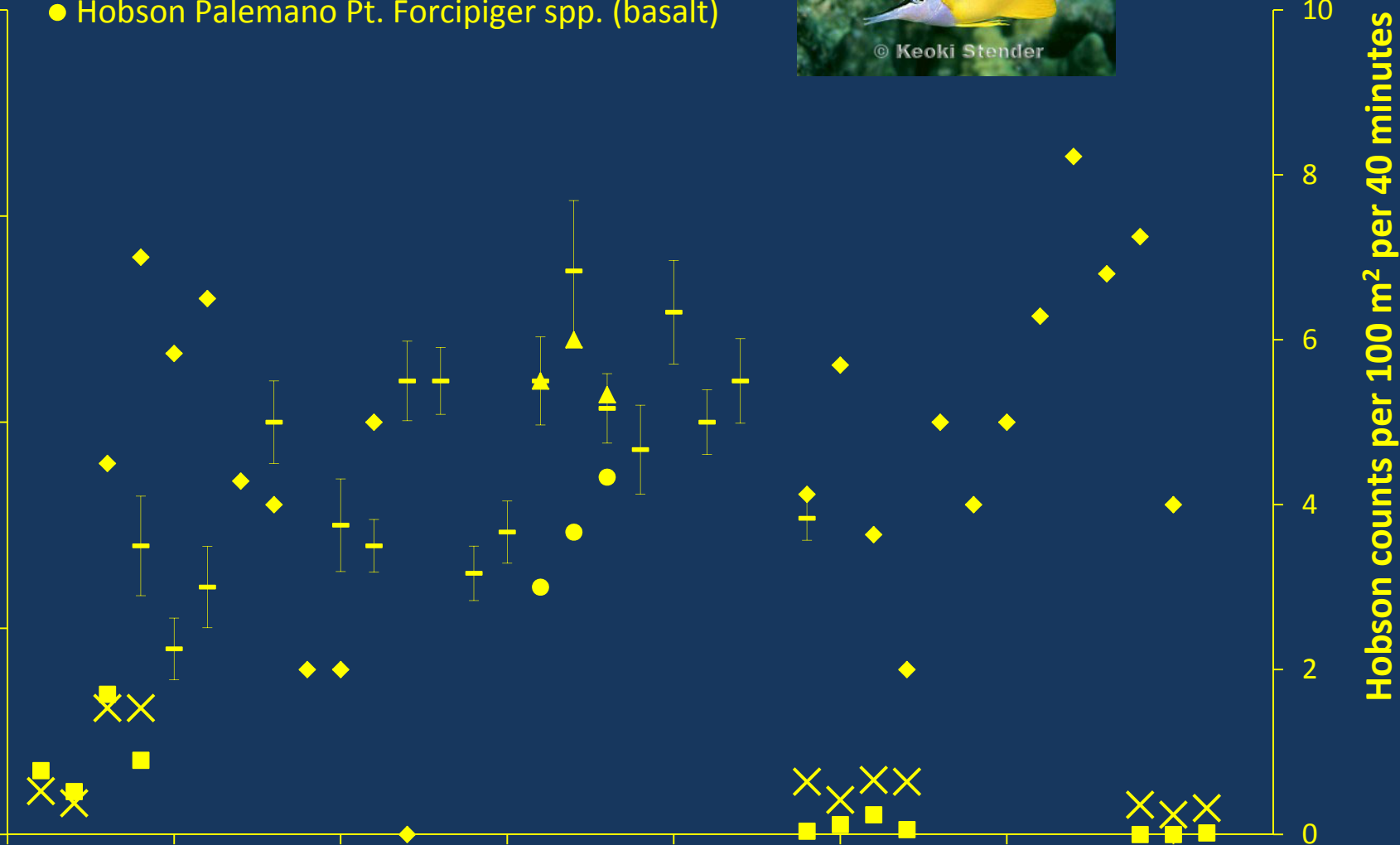


© Keoki Stender

- Walsh Ke'ei Gomphosus varius
- ▲ DAR Honaunau Gomphosus varius
- Hobson Honaunau Gomphosus varius



- × DAR Honaunau Forcipiger spp. (*P. compressa* & *lobata*)
- ◆ Walsh Ke'ei Forcipiger spp. (*P. compressa* & *P. lobata* & rubble)
- DAR Honaunau Forcipiger spp. (Boulders)
- Hobson Honaunau Forcipiger spp. (*P. lobata*)
- ▲ Hobson Ke'ei Forcipiger spp. (*P. compressa*)
- Hobson Palemano Pt. Forcipiger spp. (basalt)



Biomass Estimates (0-30m hardbottom) American Samoa

Area 0-30 m hardbottom		ESTIMATED POPULATION BIOMASS (kg)					
(n)	(Ha)	Emperor	Goatfish	Grouper	Jack	Parrotfish ¹	Reef Shark
(171)	4,888	42,513	20,678	43,491	25,614	271,926	7,111
(36)	1,003	8,575	3,191	27,534	5,399	60,795	2,929
sega (43)	1,055	8,339	2,674	25,310	9,304	86,402	10,354
(61)	558	4,087	2,411	10,307	8,597	13,142	14,682
(41)	281	1,055	293	7,580	10,033	5,450	4,154
(352)	7,785	64,569	29,246	114,222	58,947	437,716	39,231
	Rudderfish	Snapper	Squirrel/ Soldierfish	Wrasse ¹	Surgeonfish	Others	Total Fish Bio
	2,011	62,463	14,870	53,262	497,952	577,177	1,619,068
	4,705	29,547	11,921	17,378	111,952	90,894	374,821
sega	1,945	39,932	10,451	13,375	154,103	103,852	466,038
	29	12,534	6,262	10,167	24,203	21,669	128,091
	26	9,008	2,218	3,843	10,870	65,524	128,056
	8,716	153,484	45,721	98,025	807,079	859,116	2,716,074

Strengths & Limitations of CRED RAMP fish data for Development & Status Assessment

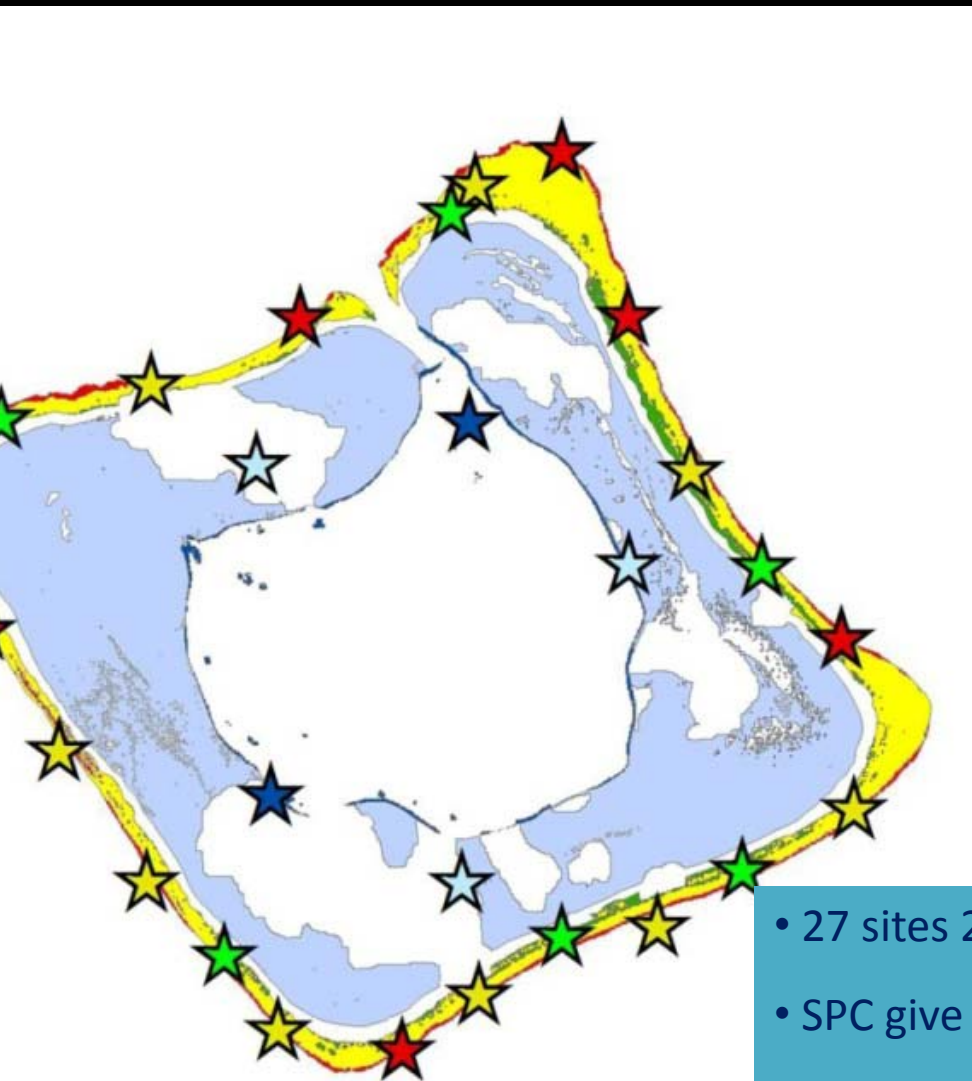
Strengths

- Wide spatial coverage & consistent methods, design, observers
- Data are representative of broad target domain (hard-bottom < 30m)
- Fish data paired with benthic and GIS data
- Reasonable data quality on common taxa when pooled at larger scales
- Size and spatial distributions from visual surveys offer potential for length-based assessment of stock
- High taxonomic resolution

Limitations

- Data gathered by SCUBA
 - Depth limited to 30m
 - Potential fish-behavior impacts from divers' presence
- Daytime surveys. Nocturnally active taxa undercounted (soldierfish)
- Hardbottom habitat only
- Non-trivial gaps in habitat & bathymetric data at some locations
- Limited replication
 - Sheer size of some regions relative to sampling density (NWHI, MHI)
 - Heavily clumped, rare, or very narrowly distributed species not well counted

Estimating Population Sizes to Support Reef Fish Assessments Atoll Example



- 27 sites 2008; 34 in 2010; 48 in 2012
- SPC give biomass density per strata
- Habitat/bathymetric data give area per strata

Biomass Estimates (0-30m hardbottom)

Example: Surgeonfish, Rose Atoll

Zone	(# survey sites)	Depth	Area ('000 m ²)	Mean Biomass density (gm ⁻²)	Estimated Biomass (kg)
Inshore	(2)	0-6 m	53.8	5.35	288
	(4)	6-18 m	100.6	1.79	180
Fore reef	(9)	0-6 m	3,660.9	2.42	8,853
		6-18 m	240.7	2.42 ¹	582
		18-30 m	10.7	2.42 ¹	26
Back reef	(13)	0-6 m	60.8	13.00	791
	(19)	6-18 m	827.2	11.79	9,755
	(14)	18-30 m	214.2	10.05	2,153
Channel		0-6 m	419.0	2.42 ¹	1,013
		0-6 m	9.3	13.00 ²	121
		6-18 m	31.3	11.79 ²	369
		18-30 m	7.2	10.05 ²	73
ROSE ATOLL TOTAL (kg)					24,203

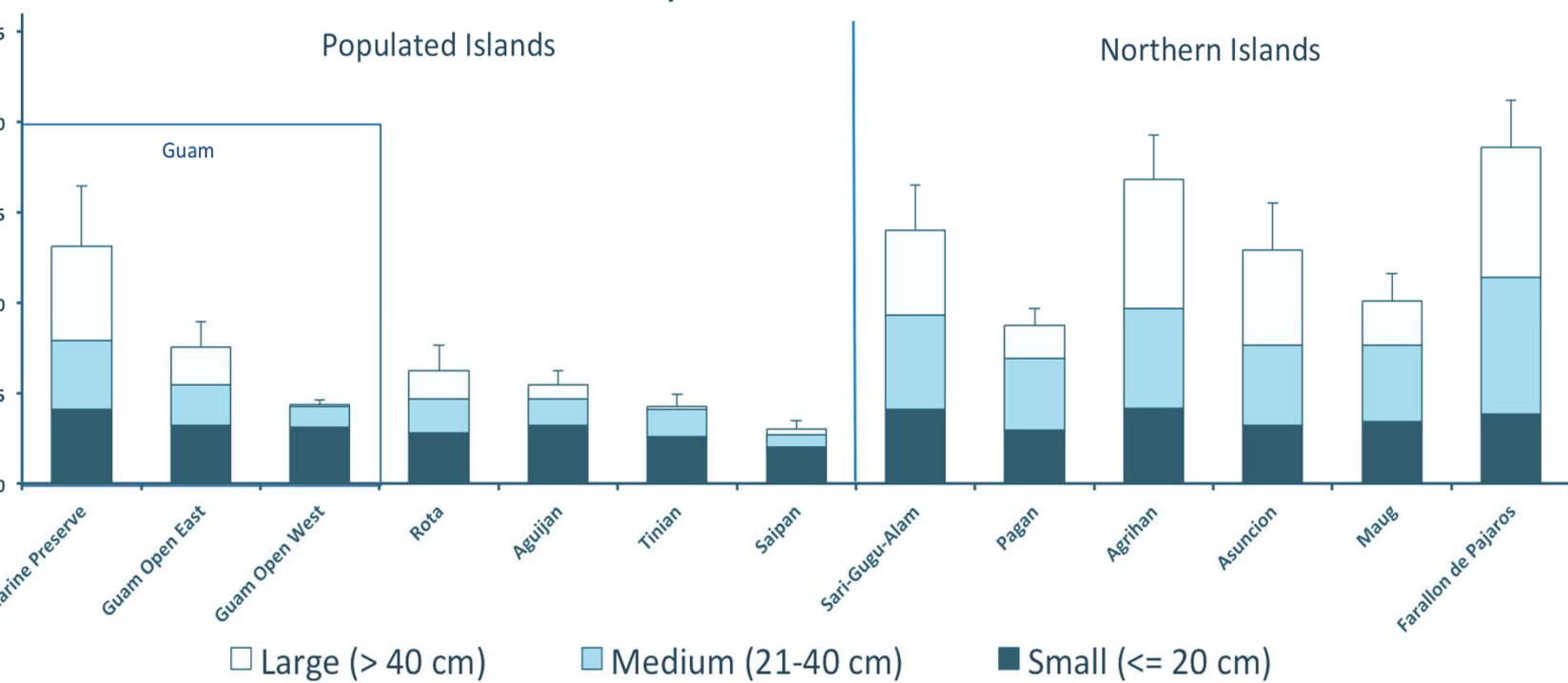
¹ Backreef shallow density estimate used for all backreef & crest strata;
² Forereef density estimates used for channel areas.

TABLE 1. Notes on potential for application of CRED RAMP data to coral reef species complexes

CREMUS Grouping	Comments
Acanthuridae (Surgeonfish)	Highly diverse group. Commonly represented in CRED RAMP data.
Atulai /Akule (scad)	Visual survey data likely to be very poor - Heavily clumped, highly seasonal, surface/mid-water/pelagic
Jacks (Carangidae) excl. scad	Significant deep water populations of most jack species.
Squirrelfish/soldierfish (Holocentridae)	Nocturnally and diurnally cryptic, hence daytime visual surveys likely to underestimate population size.
Rudderfish/Drummers (Kyphosidae)	Heavily clumped distributions.
Wrasse (Labridae) excluding napolean wrasse	Highly diverse group, including many small species (max size < 10 cm) that are lightly-targeted.
Emperors(Lethrinidae)	Previous studies indicate that lethrinids can be under-represented in visual surveys (Jennings and Polunin 1995)
Snappers (Lutjanidae)	Several lutjanid species have wide depth ranges (including important target species such as <i>L. kasmira</i> , <i>A. virescens</i>). It may therefore be difficult to meaningfully estimate population status from visual surveys in 0-30 m depths.
Mullet (Mugilidae)	CRED surveys of hardbottom reef areas do not cover habitats preferred by mullet.
Goatfish (Mullidae)	Commonly encountered, but heavily clumped daytime distributions.
Parrotfish (Scaridae) excluding Bumphead parrotfish	Commonly recorded during visual surveys.
Groupers (Serranidae)	Potential for substantial deeper water populations of some species, behavioral issues affecting visual survey data.
Rabbitfish (Siganidae)	Major component of catch at some locations, but are rarely encountered during CRED visual surveys
Misc. Reef-fish	Not clear which species are within this group.
Misc. Shallow Bottomfish	Which species? <i>Aprion virescens</i> ? We have some (but limited) data on that species
Misc. Bottomfish	Beyond REA range
Other Finfish	Not clear which species these are, or what scope for management of such a loosely defined group. Unlikely that CRED data would be relevant for non-reef species,
Bumphead Parrotfish	Limited data (v rare, somewhat clumped distributions). Towed diver survey data likely to be preferable to REA data.
Napoleon Wrasse	Limited data – rare enough. Towed diver survey data likely to be preferable to REA data
Reef Sharks	Potential for significant behavioral issues (mobbing in some locations, avoidance in others). Deeper populations also an issue. Towed diver data likely to be far preferable.
Crustaceans, Molluscs, Other invertebrates	Little relevant CRED data
Algae	CRED data may not be that useful – as is lacking information from shallow – presumably targeted –habitats)

Note: Species complexes highlighted in green are those where CRED visual survey data are likely to have most utility. Complexes in orange are those where CRED data is most likely to be useful as relative measures of density rather than absolute values.

Reef Fish Biomass By Size Class - Guam & CNMI



Photos: Jill Zamzow

