Testing the Waters: An Interdisciplinary Assessment of Current and Historical Shark Nursery Habitat in Hilo Bay, Hawaiʻi

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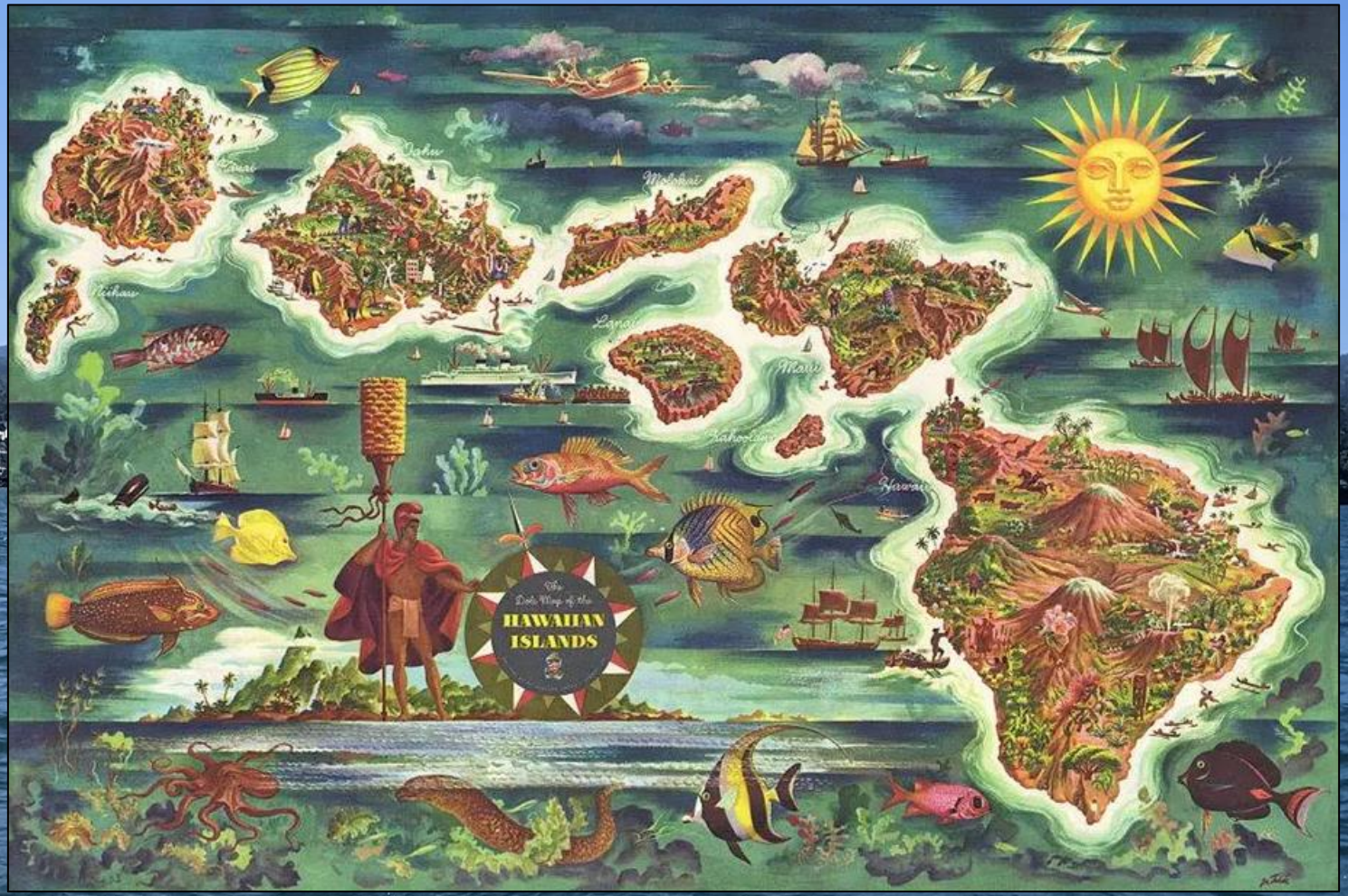
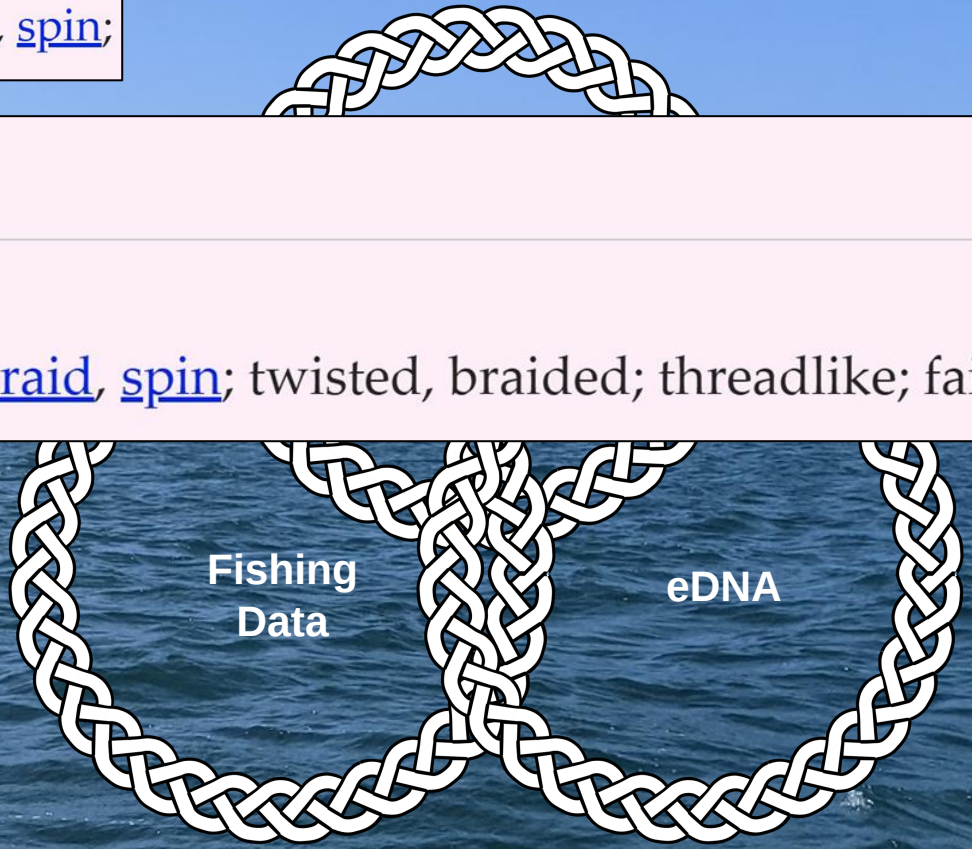

Oahu
Molokai
Lanai
Kahoolawe
Hawaii
HAWAIIAN
ISLANDS

hilo

1. *nvt.,* To twist, braid, spin;

hilo

1. *nvt.,* To twist, braid, spin; twisted, braided; threadlike; faint streak of light.



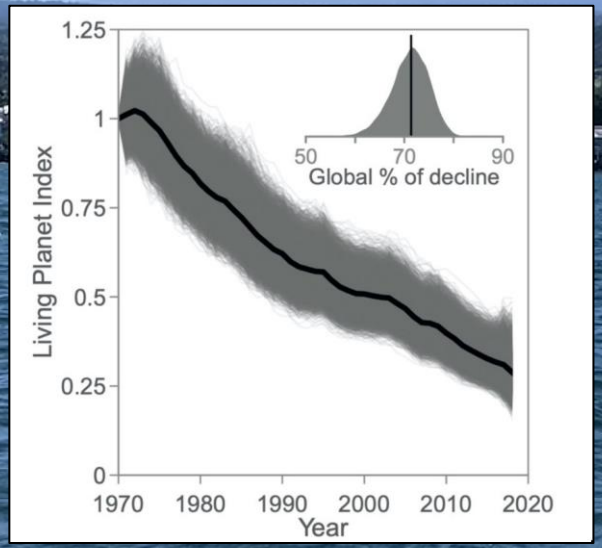
Sharks revered as ‘aumakua in Hawaiian culture,

Manō kupua, & hunted for sport or ancient food sources

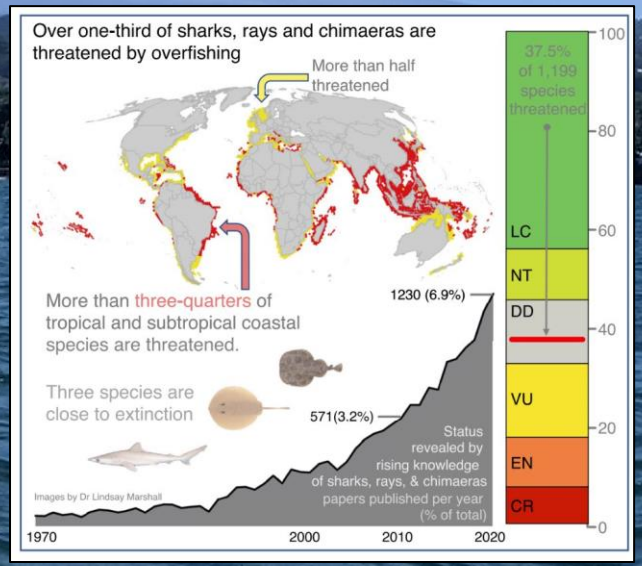
(Beckwith, 1917; Puniwai, 2020)

pinterest.com

Global elasmobranch abundance has declined ~71% in the last 50 years (Pacoureau et al., 2021)



Over ⅓ of species driven to extinction due to overexploitation (Dulvy et al., 2021)

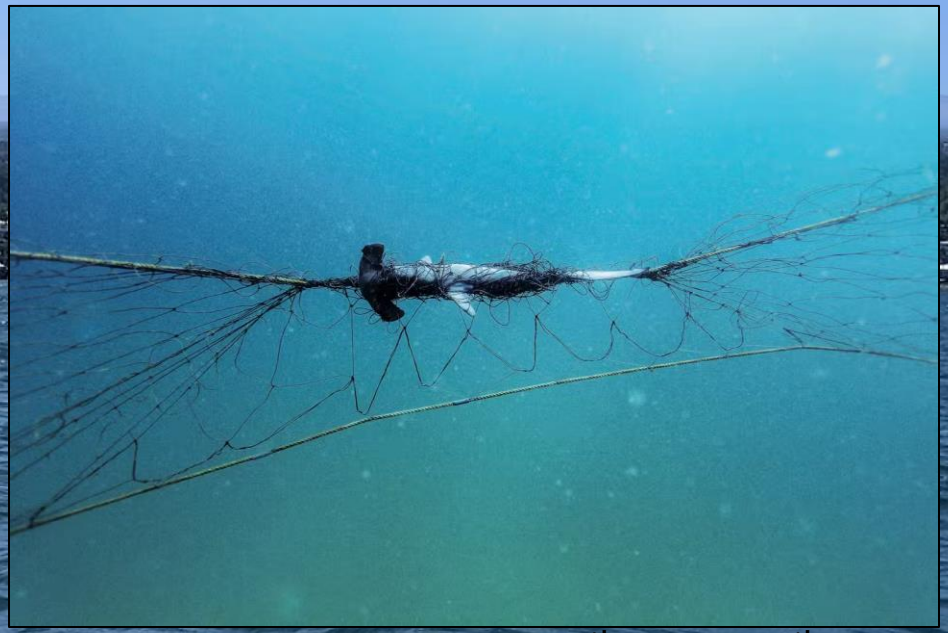


We know that the overfishing of adults causes population declines…

npr.org

cnn.com

…but we don’t know much about how exploitation during early life history affects populations



theconversation.com

Many sharks use coastal habitats as nurseries…

cbsnews.com

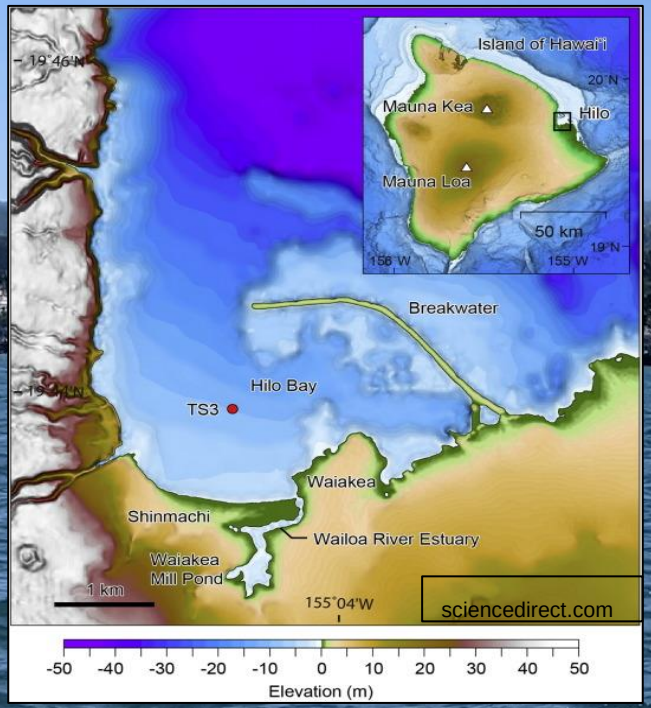
coastalanglermag.com

...putting them in close proximity to increased human impacts

Research Objectives

- Assess the current relative abundance of two natal shark populations in Hilo Bay
  - Local Ecological Knowledge (LEK)
  - Fishing Data (i.e. catch per unit effort)
  - Environmental DNA (eDNA)
- Establish historical/ecological baseline for Hilo Bay
  - Document and analyze LEK data to elucidate changes in relative fish and shark presence in the last ~75 years

Study Area



Species of Interest

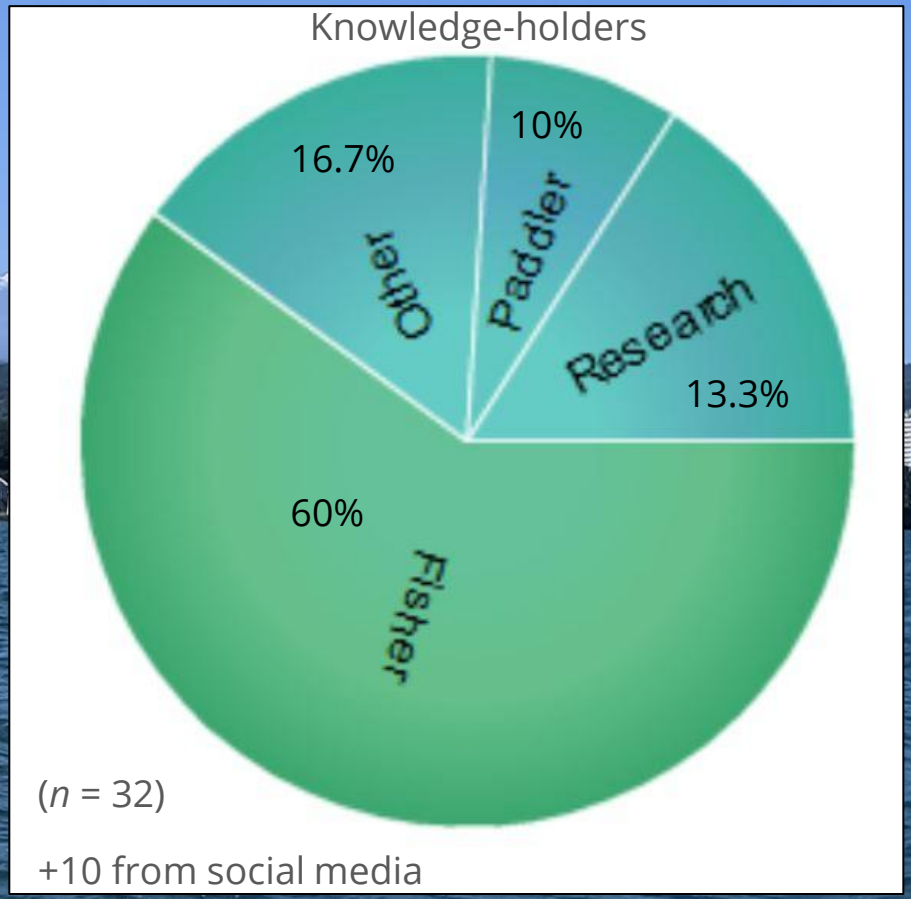
- Scalloped Hammerhead shark (*Sphyrna lewini*)
- Blacktip shark (*Carcharhinus limbatus*)

YOY *S. lewini* - Manō kihikihi

Juv. *C. limbatus* ~ Manō pa'ele

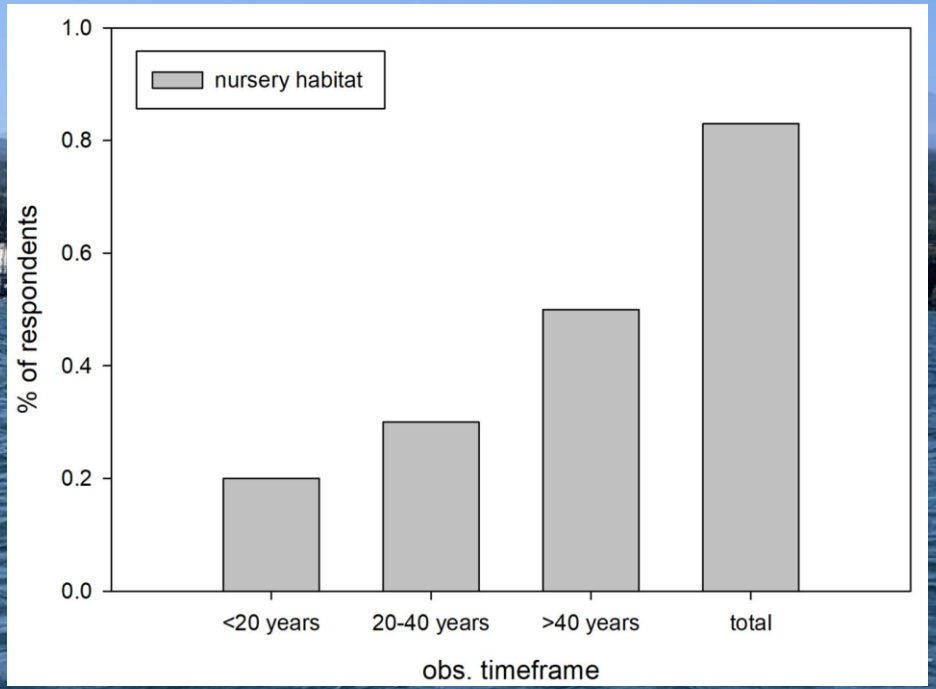
LEK Methods

- Semi-structured “talk story sessions” conducted throughout the community
- Transcribed, coded and analyzed in Dedoose Software

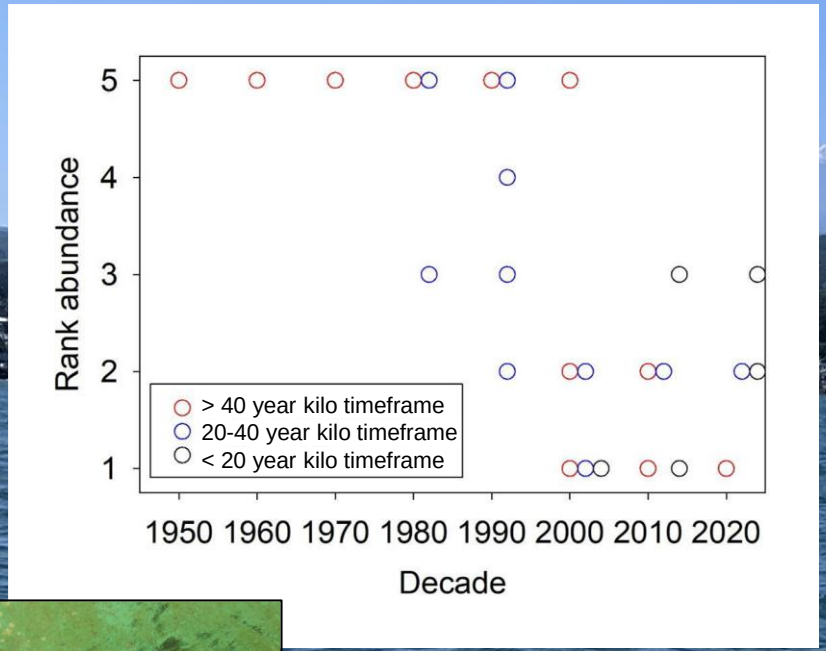


LEK Results

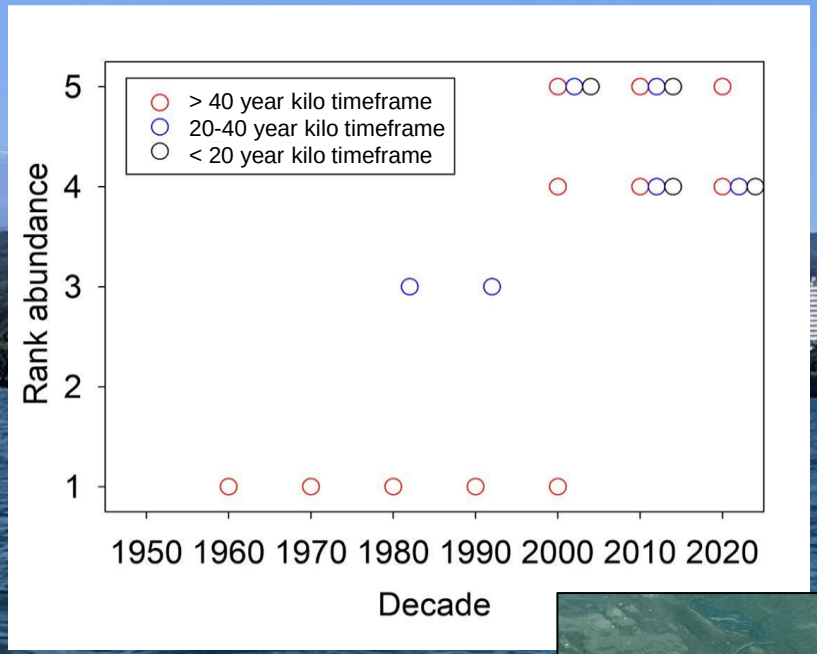
Over 80% of knowledge-holders observed shark nursery habitat



LEK Results



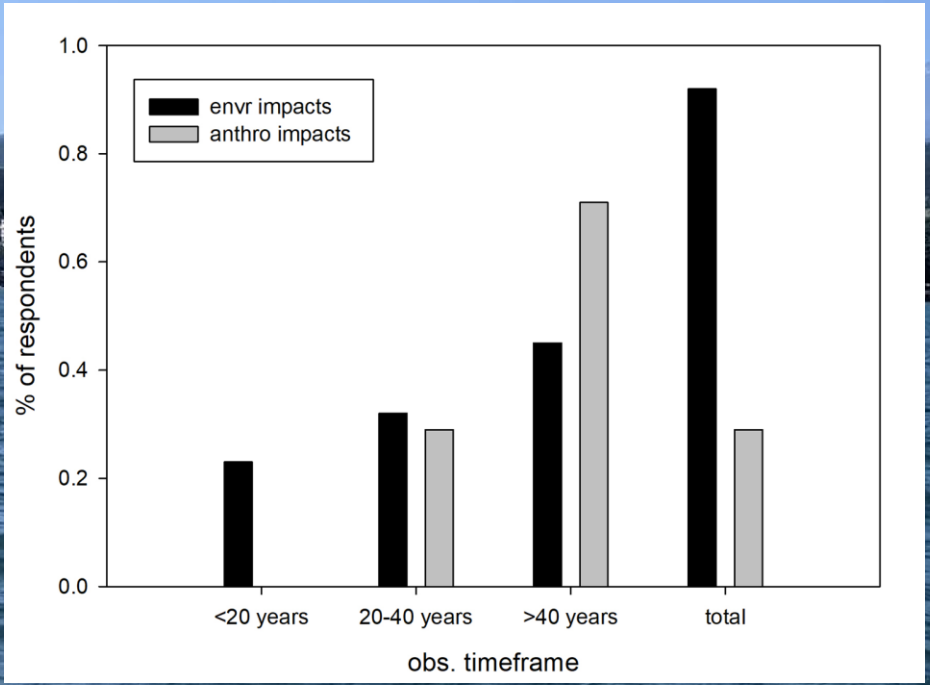
S. lewini

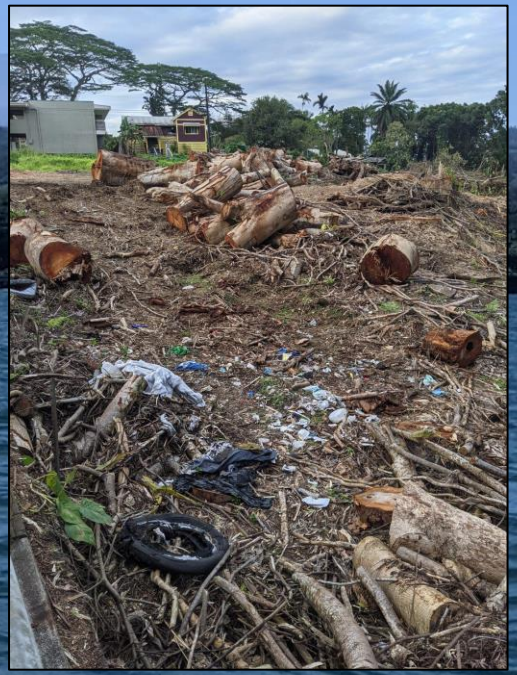


C. limbatus

LEK Results

Groups with longer kilo (obs.) timeframes mentioned more anthropogenic & environmental impacts

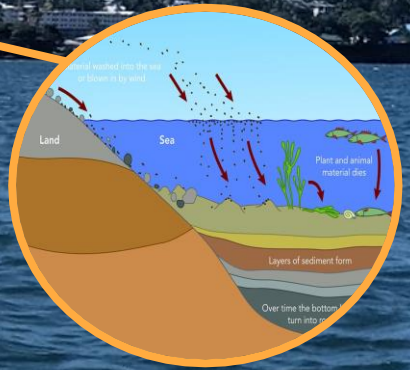




ANTHRO

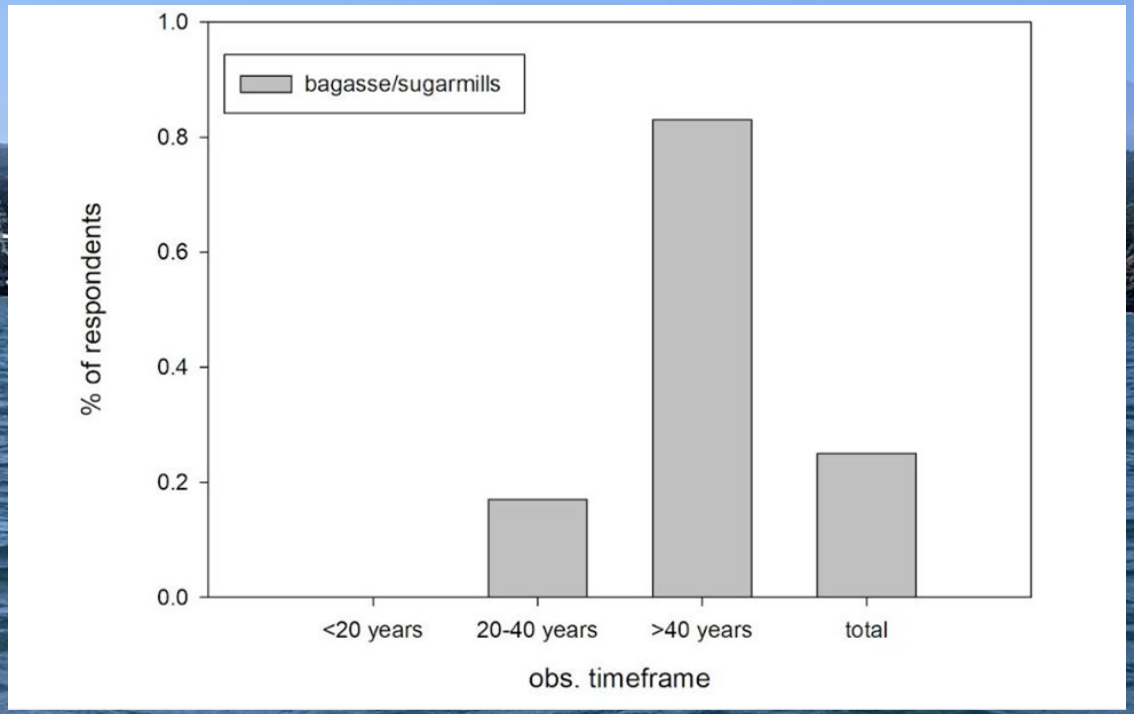
ENVIRO

DECLINE



LEK Results

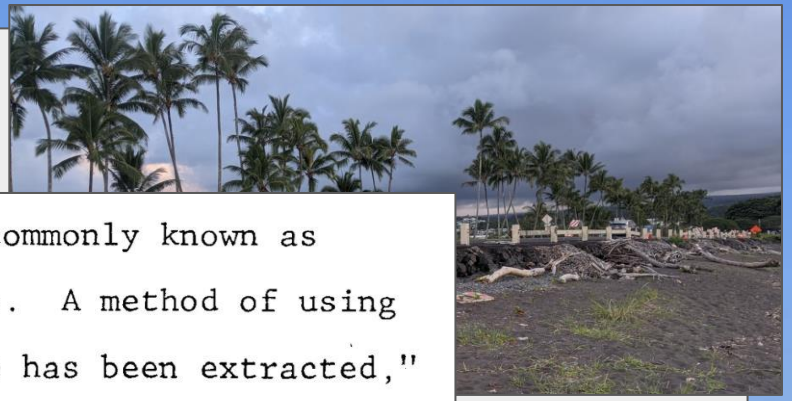
Groups with longer kilo (obs.) timeframes noted more impacts of sugar era



sugar-asia.com

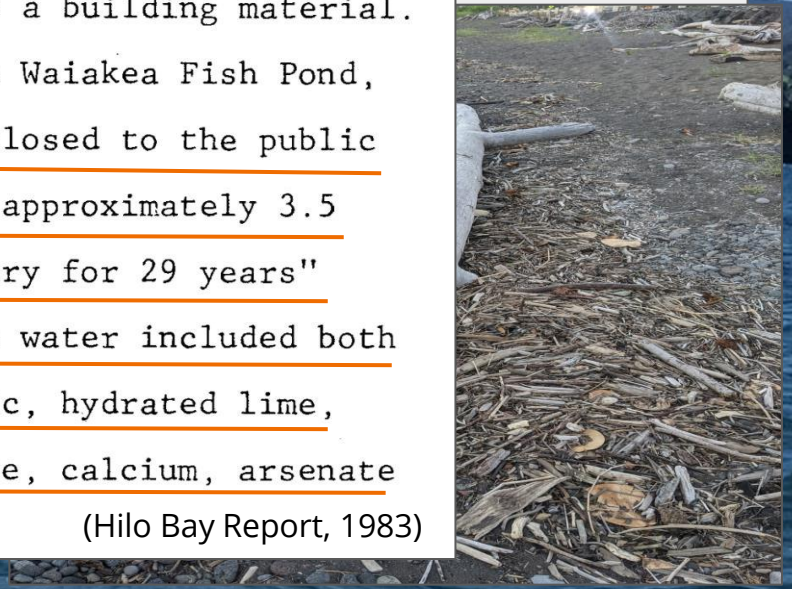
Bagasse from sugar plantations clearing out of the bay in past ~20 years

LEK Results



In 1923, Hawaiian Cellulose, Ltd., commonly known as the Canec Plant, was incorporated in Hilo. A method of using baggase, "trash from cane after the juice has been extracted," was devised for fabricating wall board as a building material. The plant opened in April, 1932 along the Waiakea Fish Pond, near the Waiakea Sugar Mill. As was disclosed to the public in 1973, the canec plant had "discharged approximately 3.5 mgd of waste water into the Waialoa estuary for 29 years" (Neighbor Island...1973:12).[5] This waste water included both toxic and lethal chemicals such as arsenic, hydrated lime, hydrosulfate, ethyl silicate, hydrosulfate, calcium, arsenate and arsenic acid.

(Hilo Bay Report, 1983)

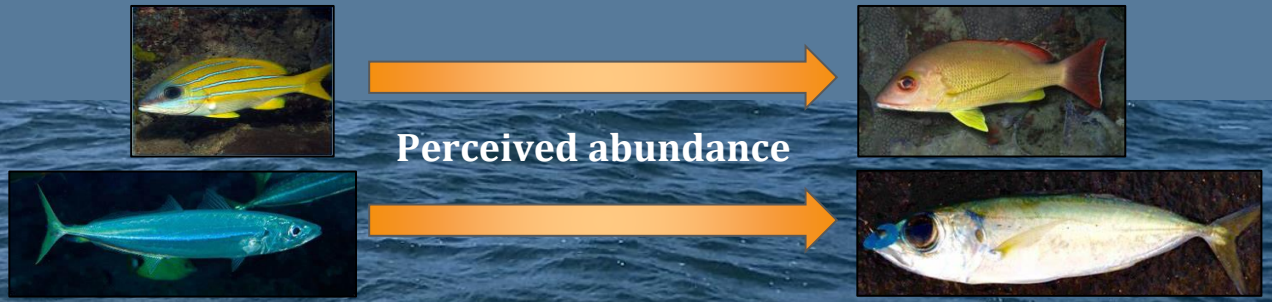


LEK Results Summarized

- Decline in juvenile scalloped hammerheads
- Increase in juvenile blacktips

Potential shift from imperiled specialist to abundant generalist species!

- Hilo Bay observed to be shark nursery habitat since at least 1950's
- Ecological & anthropogenic drivers impacting fishery
- Sugarcane connections - bagasse creating prey environment? Pollution?
- Potential differences in pupping phenology compared to Kāne'ohe Bay
- Potential shifts in invasive and bait fish populations



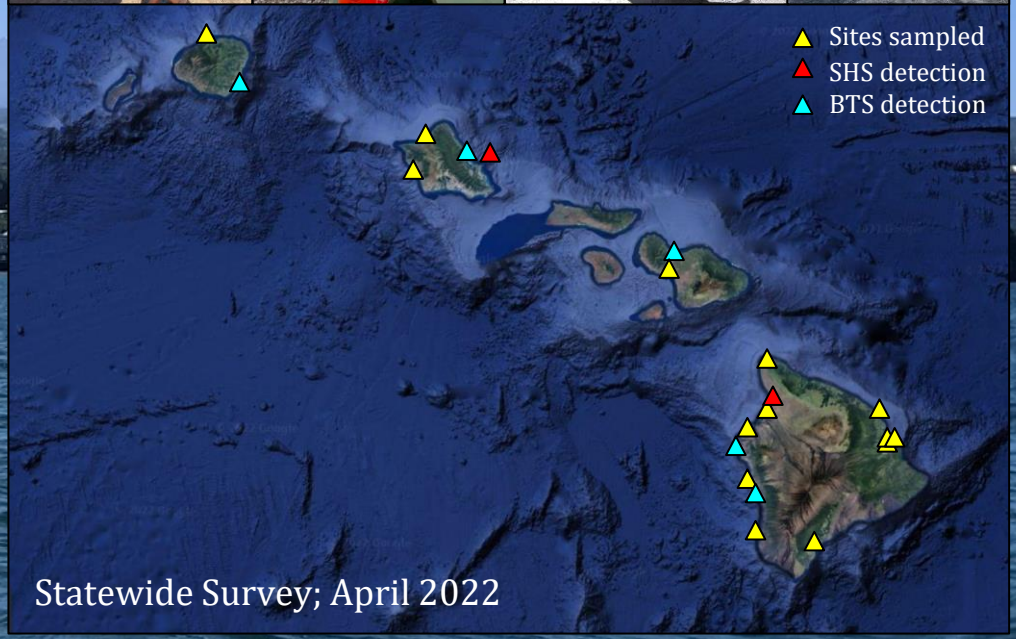
Why Environmental DNA?

- Monitoring sharks is difficult!
- Telemetry study not feasible (low juv. survivability)
- eDNA = Non-invasive methodology (water samples)
- Primers and assays developed for both species
  - Budd et al. 2021 & Postaire et al. 2020
- Collaboration & application potentials

eDNA Pilot Study

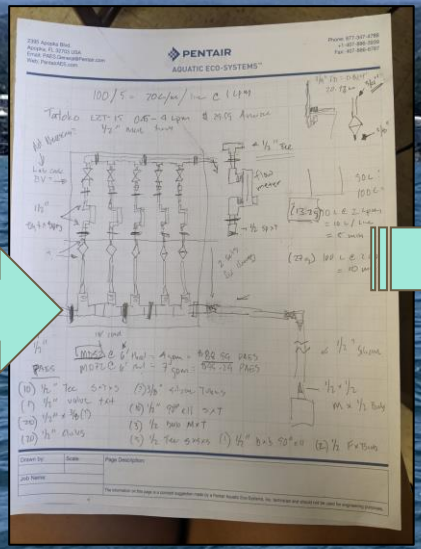
- April 2022 - statewide survey of 30 coastal embayments
- May - October 2022 - monthly sampling of Hilo bay; 6 sites

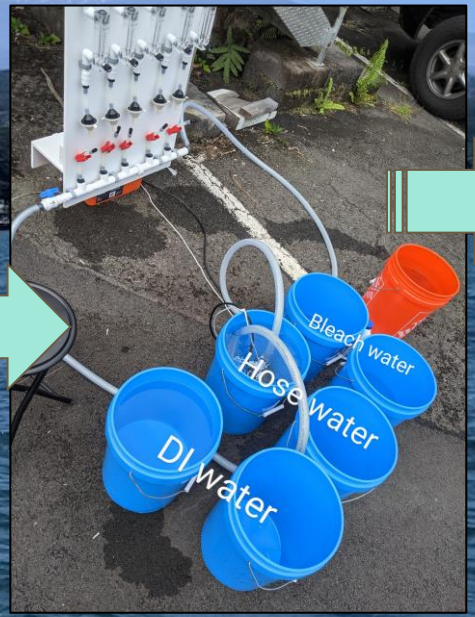
Lots & lots of optimizations!

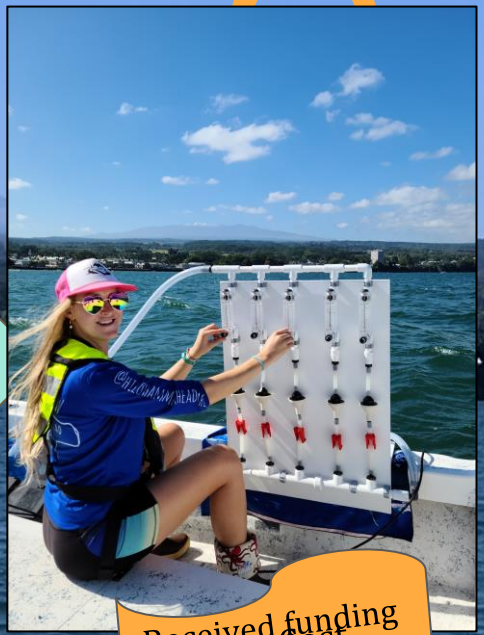


Seawater Filtration System Design

- October 2022 - April 2023
  - Concept, construction, trials, use







Received funding through Low-Tech Patents2Products High-Volume Fellowship

16-Month Paired Sampling Approach

- Fishing + eDNA survey
- April 2023 - August 2024: Biweekly sampling
  - Field control and eDNA filtration
  - Fish for one hour
  - Repeat at each of four sites
    - order randomized
  - Alternate AM and PM trips

eDNA Workflow

Field collection

eDNA Workflow

Field collection

DNA Extraction

Quantification

qPCR (mtDNA)

TaqMan 12s Primer+Probe

SYBR
NADH2

Bi-Directional Sanger Sequencing

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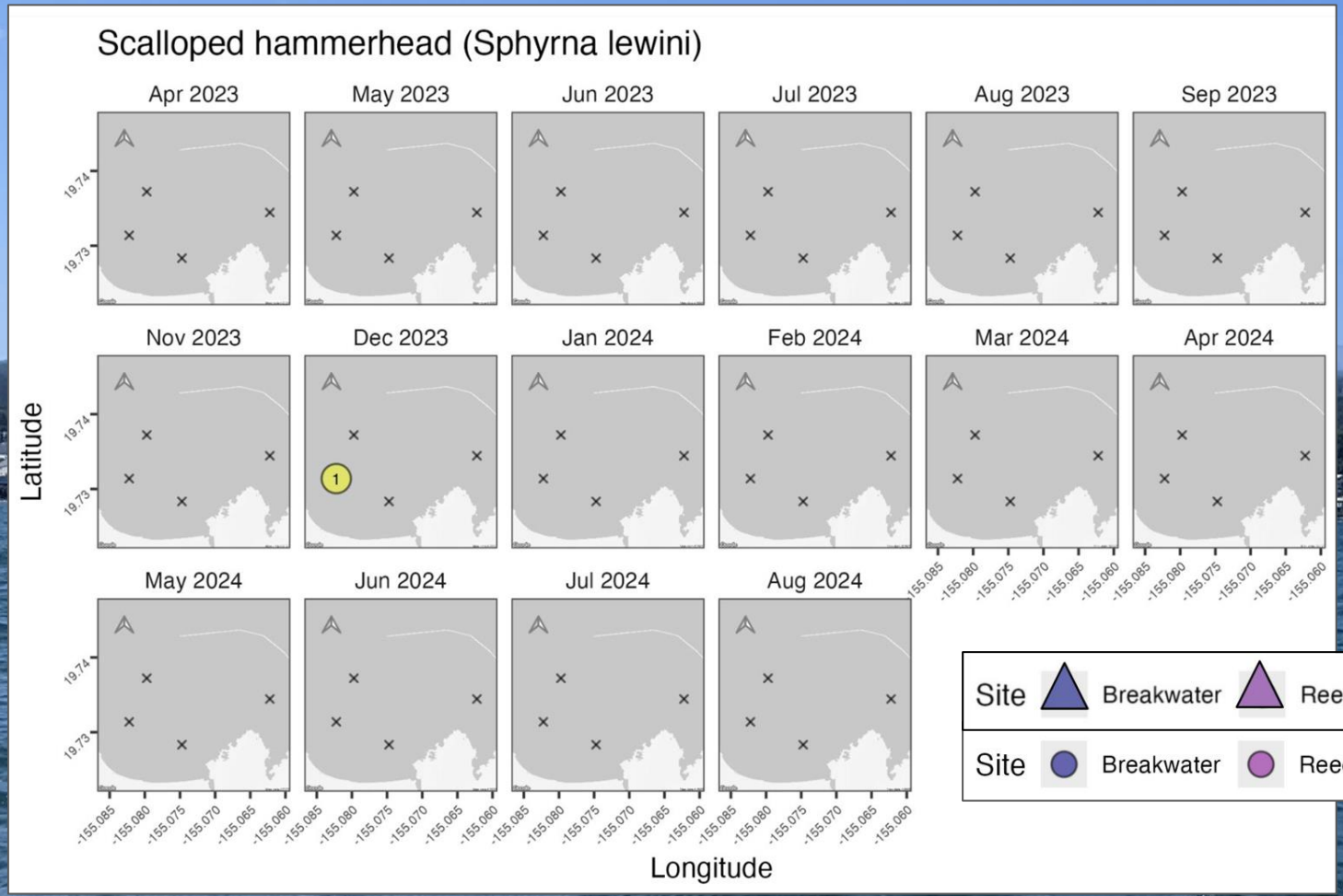
Genomics Core Laboratory

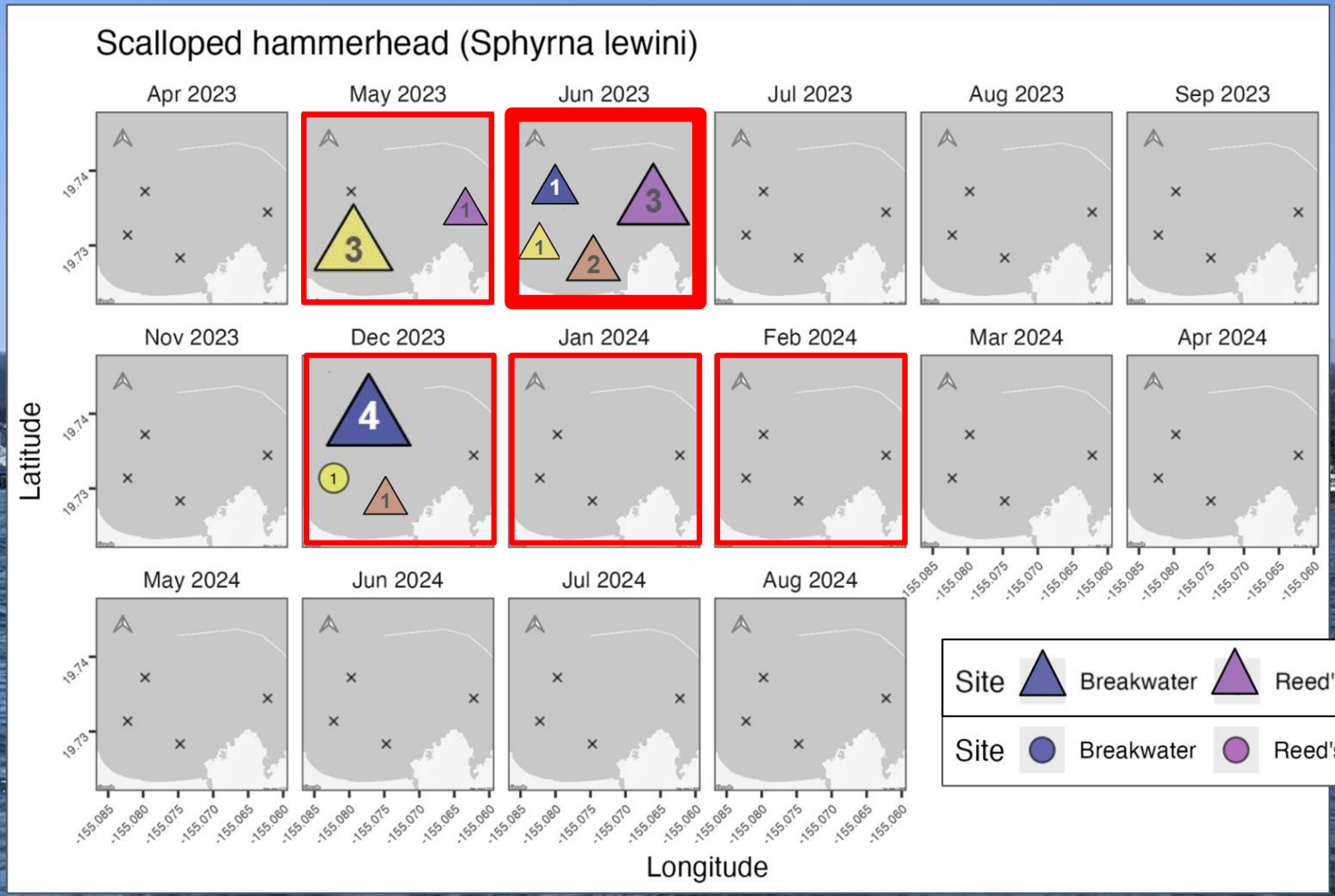
Collected to Date

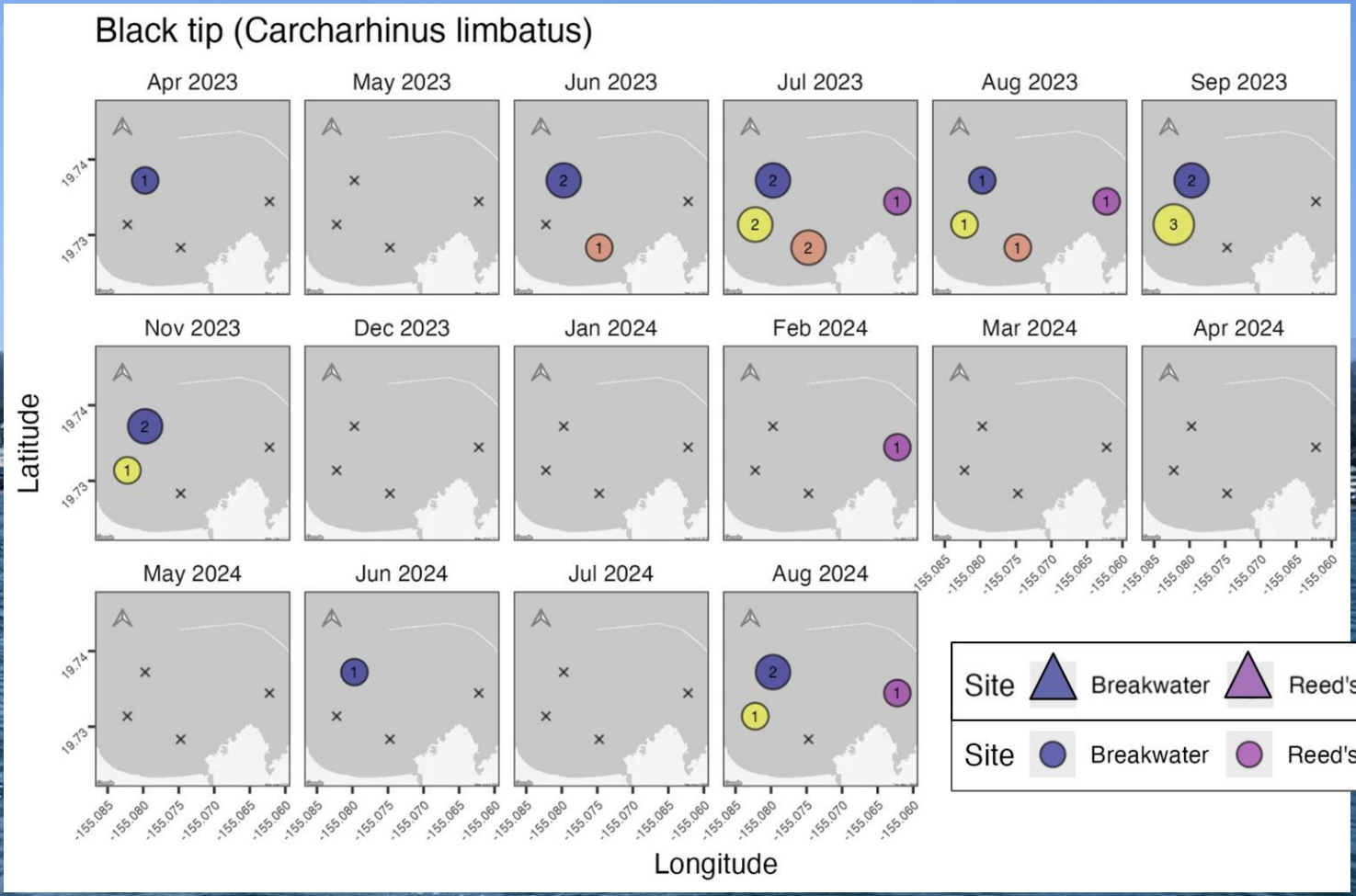
- 30 trips, 4 sites per trip
- ~ 7,200 L of seawater sampled (60 L per site)
- 720 filter papers (5 field reps + 1 field blank per site) since April 2023
- 400+ fishing hrs

Catch Only


Scalloped hammerhead (Sphyrna lewini)
Apr 2023
May 2023
Jun 2023
Jul 2023
Aug 2023
Sep 2023
Nov 2023
Dec 2023
Jan 2024
Feb 2024
Mar 2024
Apr 2024
May 2024
Jun 2024
Jul 2024
Aug 2024
Latitude
Longitude
19.74
19.73
-155.085
-155.080
-155.075
-155.070
-155.065
-155.060
1
Site
Breakwater
Reed's bay
Wailoa
Wailuku
Site
Breakwater
Reed's bay
Wailoa
Wailuku

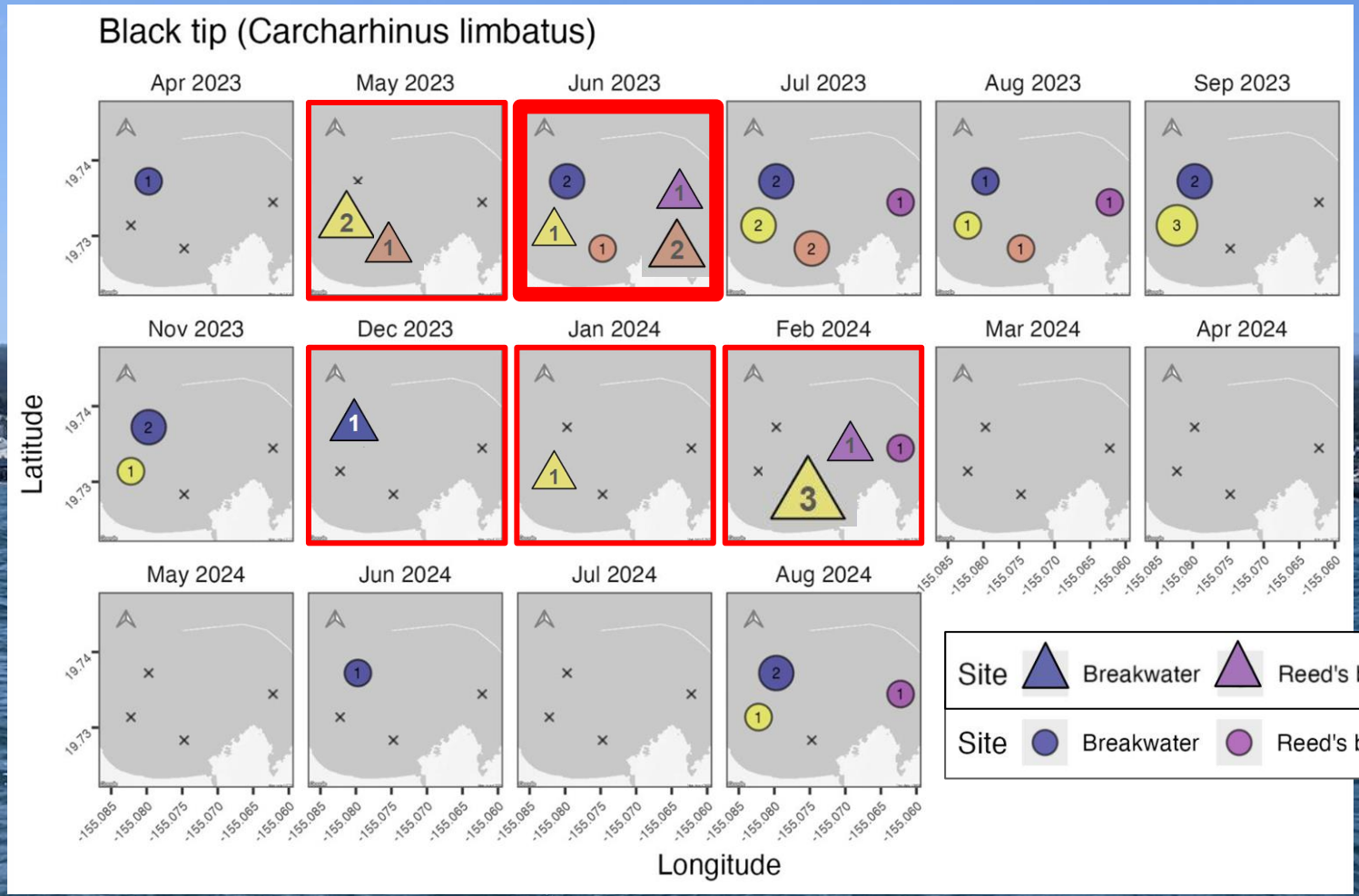
Catch + Detections




Black tip (Carcharhinus limbatus)
Apr 2023
May 2023
Jun 2023
Jul 2023
Aug 2023
Sep 2023
Nov 2023
Dec 2023
Jan 2024
Feb 2024
Mar 2024
Apr 2024
May 2024
Jun 2024
Jul 2024
Aug 2024
Latitude
Longitude
19.74
19.73
-155.085
-155.080
-155.075
-155.070
-155.065
-155.060
Site
Breakwater
Reed's bay
Wailoa
Wailuku
Site
Breakwater
Reed's bay
Wailoa
Wailuku

Catch Only

Catch + Detections



Assessing Predation Potential

In December 2023, we captured a juvenile Scalloped Hammerhead that we **believe to have suffered a predation attempt** from a Blacktip shark.

We have since teamed up with the Bruno Lab at UNC Chapel Hill and are collecting cloacal swabs from captured blacktips to test for scalloped hammerhead DNA in the feces.

Ongoing Work

- Transitioned from MGAL to TAMU CC
- Lab work ongoing - **need for increased funding!**
- Cloacal DNA analyses pending
- Statewide metabarcoding collaboration with ToBo Lab @ HIMB
- Mentoring HS students - yield comparison/metabarcoding
- Contribution to IUCN ISRA proposals

References

- Beckwith, M.W., 1917. Hawaiian shark aumakua. *American Anthropologist*, *19*(4), pp.503-517.
- Puniwai, N., 2020. Pua ka wiliwili, nanahu ka manō: understanding sharks in Hawaiian culture. *Human Biology*, *92*(1), pp.11-17.
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- Reid, A.J., Eckert, L.E., Lane, J.F., Young, N., Hinch, S.G., Darimont, C.T., Cooke, S.J., Ban, N.C. and Marshall, A., 2021. "Two-Eyed Seeing": An Indigenous framework to transform fisheries research and management. *Fish and Fisheries*, *22*(2), pp.243-261.
- Bernard, N.D., & Orcutt, A.M., "STUDENT PROJECT PROPOSAL TO THE UNIVERSITY OF HAWAII MARINE OPTION PROGRAM DYNAMIC PROCESSES OF HILO BAY". 1983.
- Budd, A.M., Cooper, M.K., Le Port, A., Schils, T., Mills, M.S., Deinhart, M.E., Huerlimann, R. and Strugnell, J.M., 2021. First detection of critically endangered scalloped hammerhead sharks (Sphyrna lewini) in Guam, Micronesia, in five decades using environmental DNA. *Ecological Indicators*, *127*, p.107649.
- Postaire, B.D., Bakker, J., Gardiner, J., Wiley, T.R. and Chapman, D.D., 2020. Environmental DNA detection tracks established seasonal occurrence of blacktip sharks (Carcharhinus limbatus) in a semi-enclosed subtropical bay. *Scientific Reports*, *10*(1), p.11847.

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Mahalo nui loa!

TEXAS A&M UNIVERSITY CORPUS CHRISTI

Genomics Core Laboratory

University of Hawai'i at Mānoa
Marine Biology Graduate Program

UNIVERSITY of HAWAI'I MĀNOA
UNIVERSITY OF HAWAI'I AT MĀNOA
ASGPB

MGAL
Microbial Genomics and Analytical Laboratory

HAWAI'I COMMUNITY TAGGING PROGRAM

Kūlana Noiʻi

OFFICE OF INNOVATION & COMMERCIALIZATION
UNIVERSITY OF HAWAI'I SYSTEM

AAUW

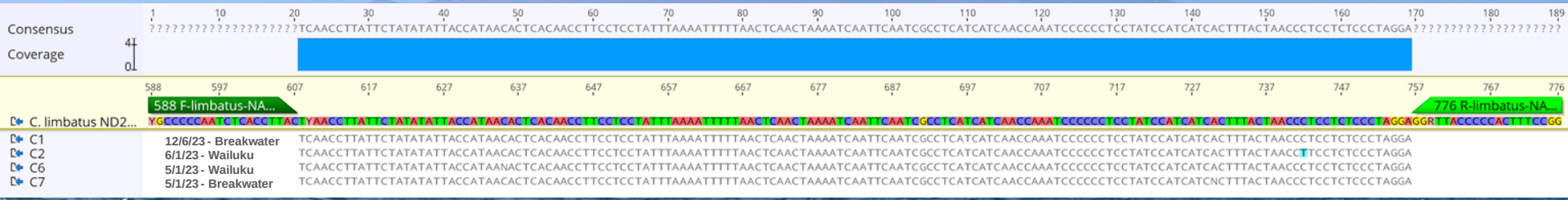
UNIVERSITY of HAWAI'I SYSTEM
USGS
science for a changing world

Pacific Islands Climate Adaptation Science Center

Local knowledge-holders!

& many fieldwork volunteers!

Sanger Sequencing for Positive Detection Confirmation



> 99% sequence similarity to the reference sequence for *C. limbatus* (Wailuku and Breakwater sites)

eDNA Pilot Study Results

- **Lab Optimizations:** tested numerous extraction kits, positive controls, assay designs, etc.
- **Field Optimizations:** tested various sampling regimes, filter pore sizes, water quantities and depths, etc.
    - Learned that sampling 2 L at a time wasn't sufficient

April 2022: statewide survey of 30 coastal embayments

Now being metabarcoded by ToBo Lab @ HIMB

2022 Pilot Sampling	Scalloped Hammerhead	Blacktip
# of positive amplifications	8	9
# of locations	2	7

Project Overview

Document and assess past and present changes in Hilo Bay juvenile shark populations through the combination of interdisciplinary techniques-

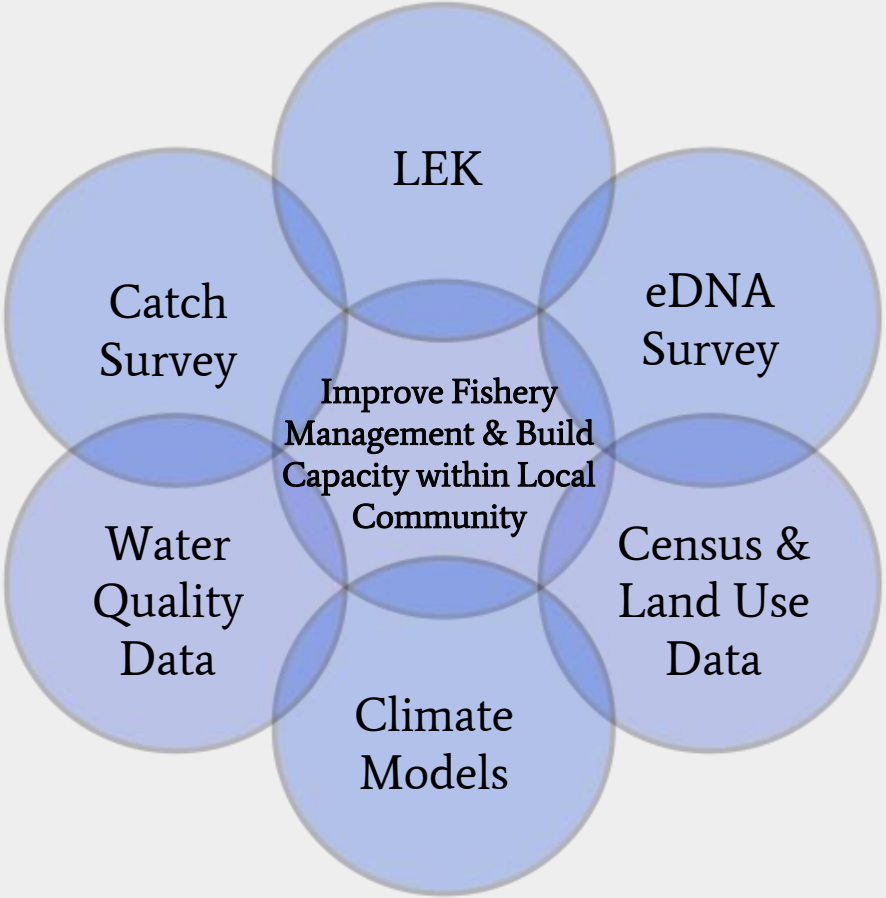
Here we collect and analyze local ecological knowledge from community members, conduct a novel eDNA survey of Hilo Bay, and gather catch-per-unit-effort data to infer historical and modern trends in the use of an embayment nursery habitat by two coastal-pelagic shark species.

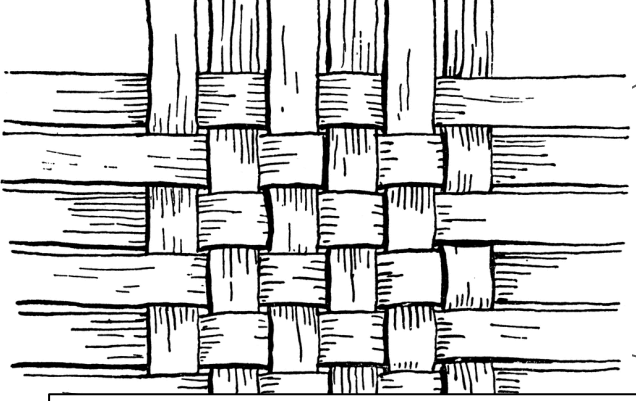
Introduction PAINT THE PICTURE

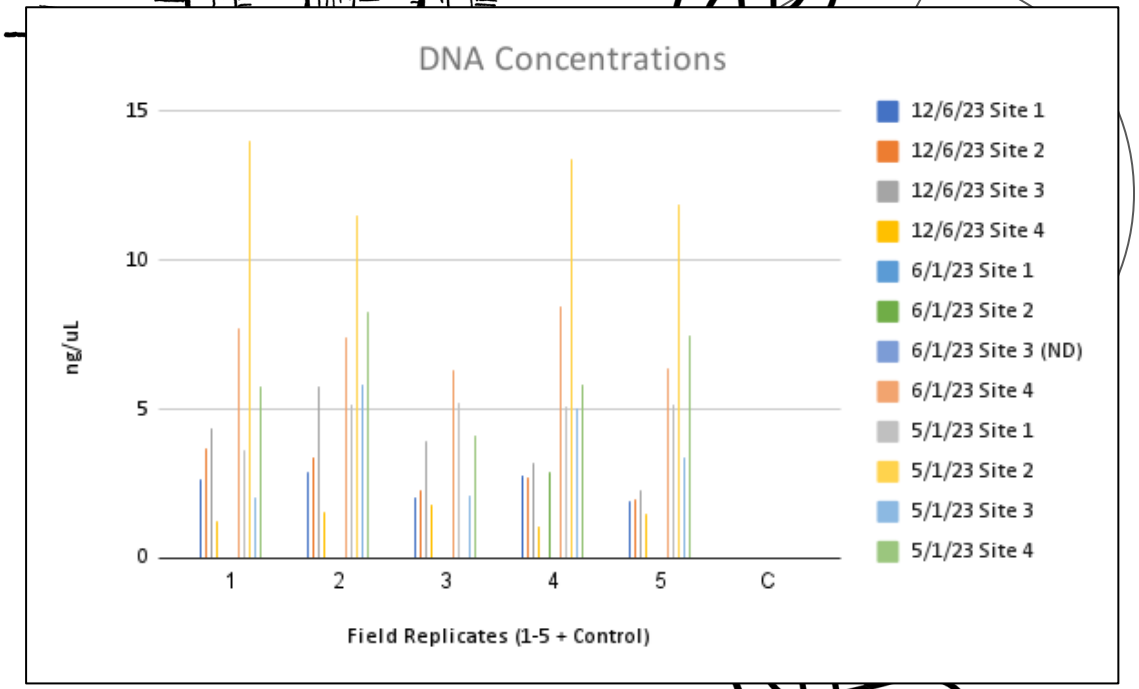
Talk about how shark nursery is difficult to study

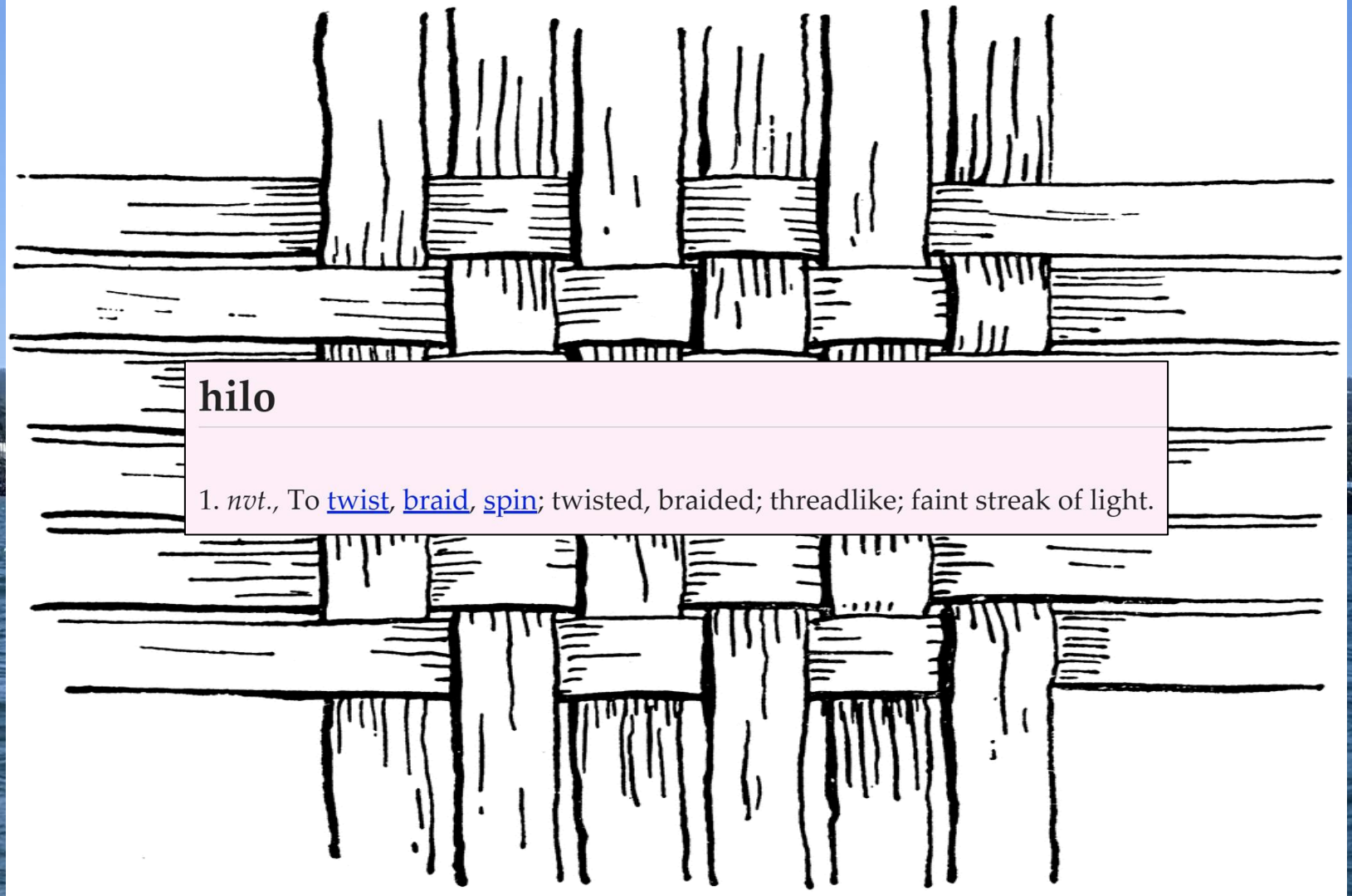
Take an area that has no existing historical record, and try to document the use of shark nursery habitat in HB. ill talk first about my LEK chapter bc that is the nearest to being finished, and then finish with the current efforts to fill out the storyline

Establishing historical baseline using LEK, and then going forward with eDNA as a tool for assessing presence, sharks facing pressures making them increasingly rare or difficult to sample effectively


LEK
Catch Survey
eDNA Survey
Improve Fishery Management & Build Capacity within Local Community
Water Quality Data
Census & Land Use Data
Climate Models




DNA Concentrations
15
10
5
0
ng/uL
1
2
3
4
5
C
Field Replicates (1-5 + Control)
12/6/23 Site 1
12/6/23 Site 2
12/6/23 Site 3
12/6/23 Site 4
6/1/23 Site 1
6/1/23 Site 2
6/1/23 Site 3 (ND)
6/1/23 Site 4
5/1/23 Site 1
5/1/23 Site 2
5/1/23 Site 3
5/1/23 Site 4



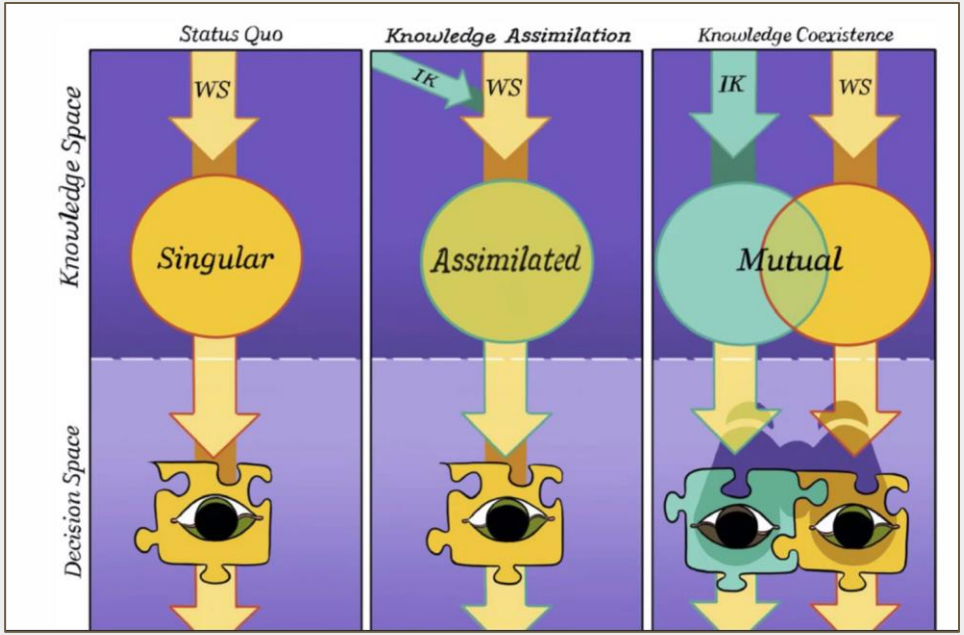
hilo

1. *nvt.,* To twist, braid, spin; twisted, braided; threadlike; faint streak of light.

Local Ecological Knowledge

“Two-eyed seeing” approach

- Knowledge co-production
  - **Research question originated by local fishing community**
  - Regular communication with knowledge-holders
  - Collecting data on community needs, perceived issues, solution suggestions, etc.



(Reid et al., 2020)

LEK Results

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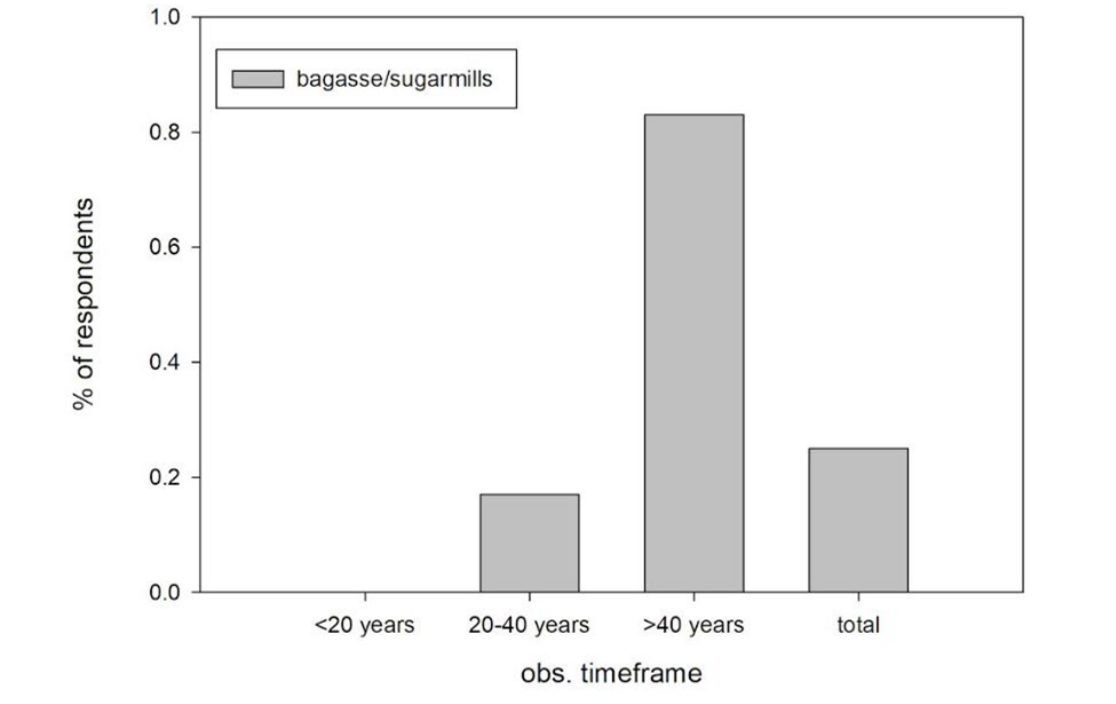

sugar-asia.com

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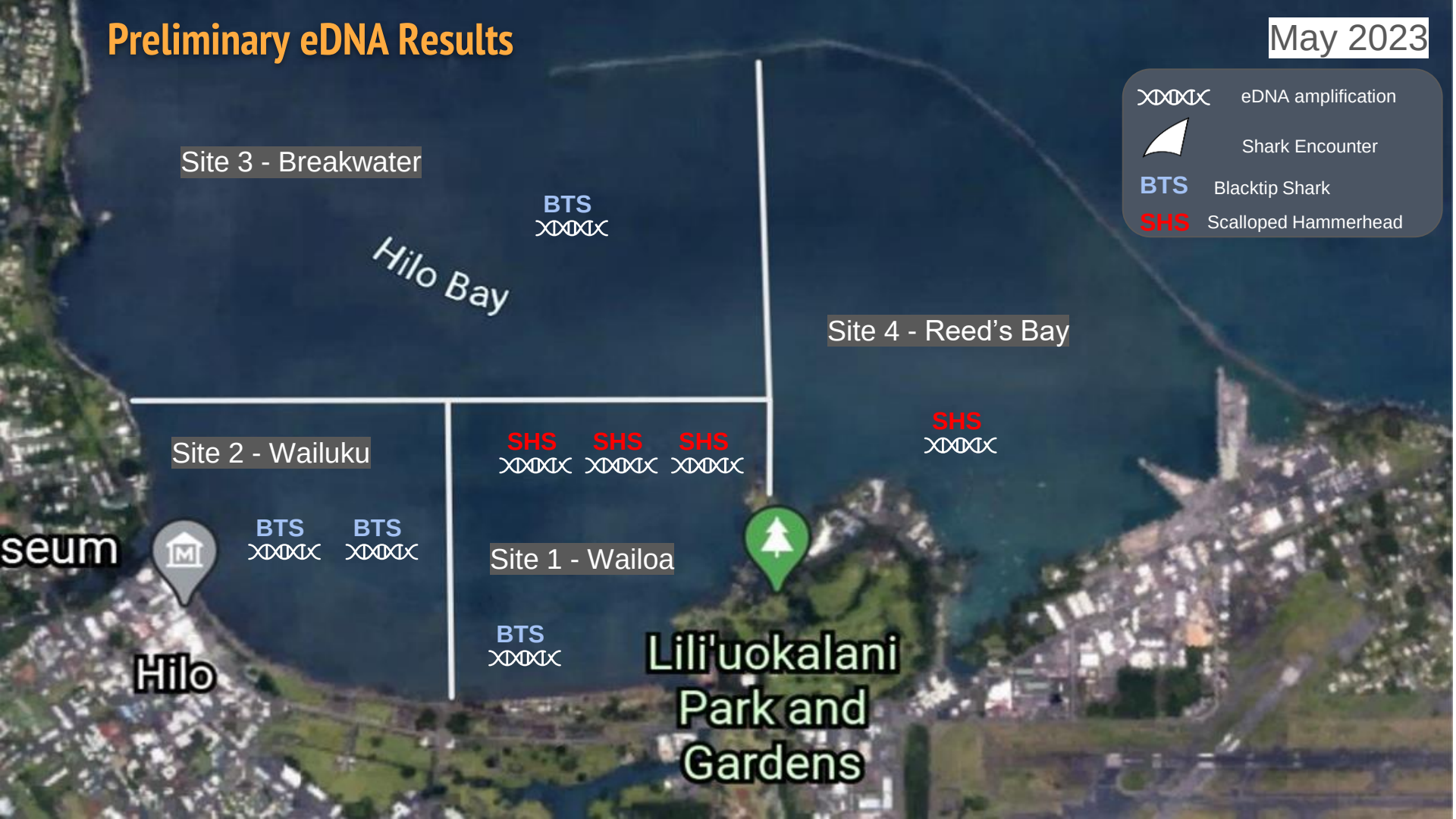
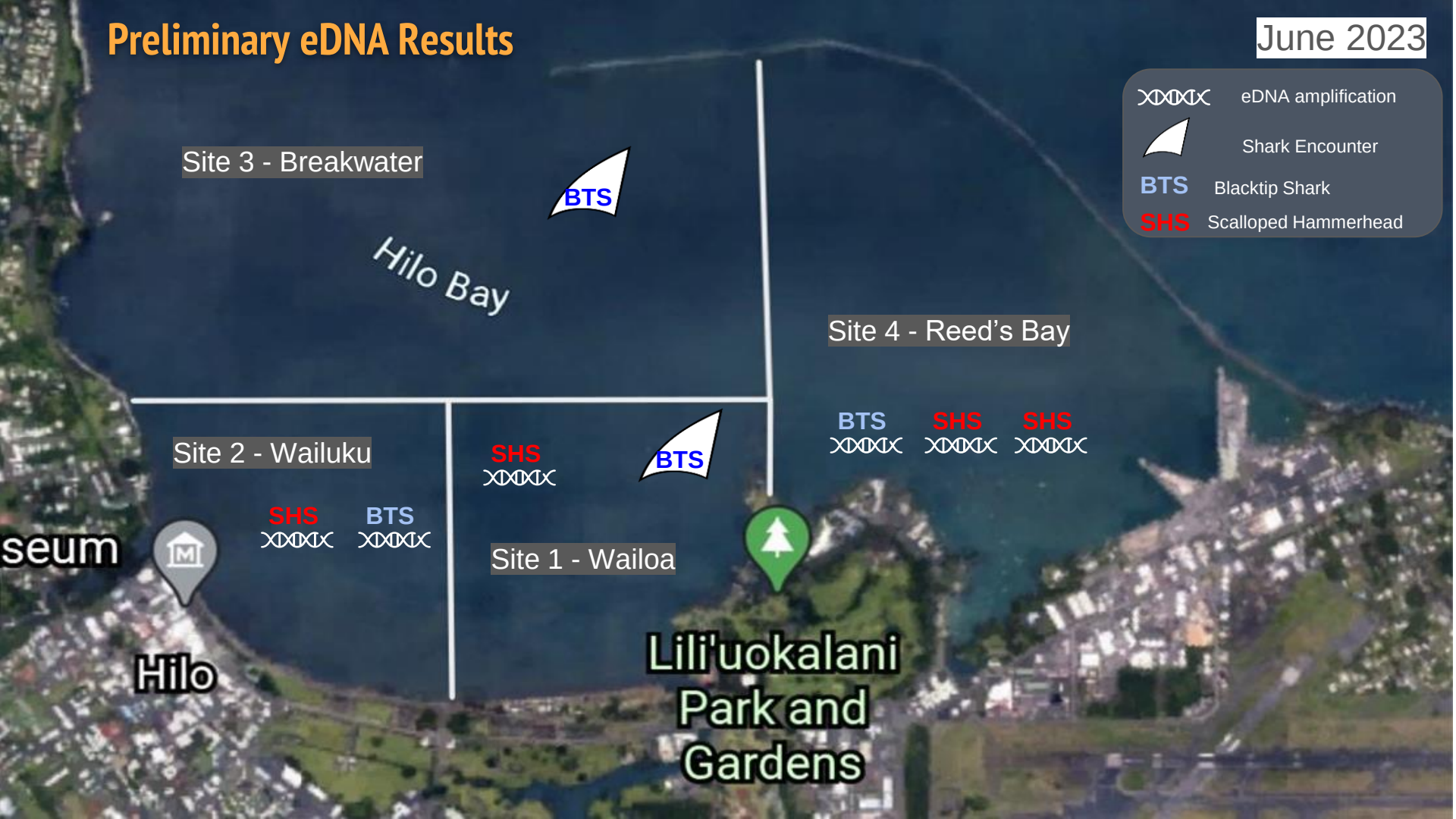
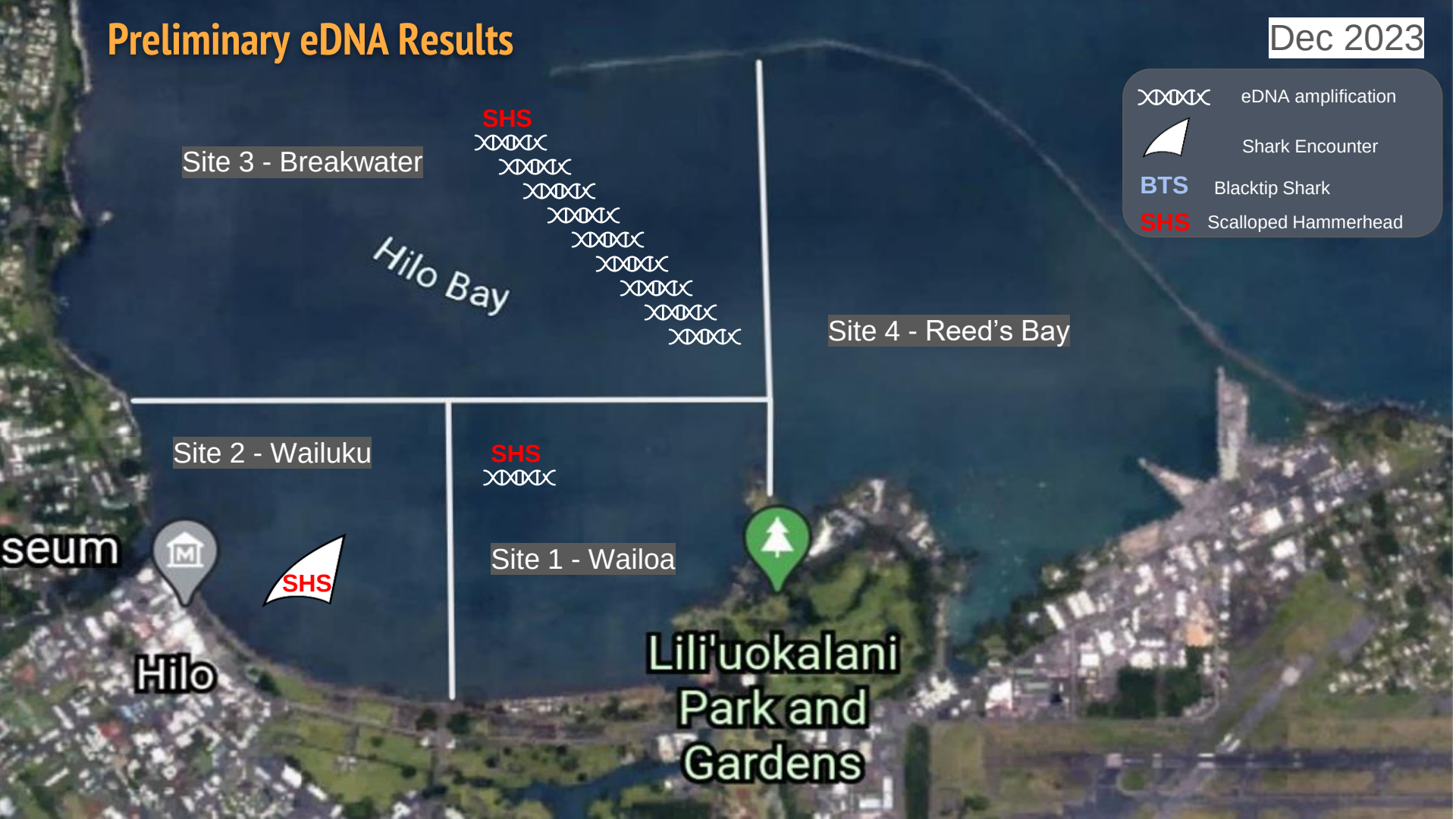

Preliminary eDNA Results
May 2023
eDNA amplification
Shark Encounter
BTS Blacktip Shark
SHS Scalloped Hammerhead
Site 3 - Breakwater
BTS
Hilo Bay
Site 4 - Reed's Bay
SHS
Site 2 - Wailuku
SHS SHS SHS
BTS BTS
seum
Site 1 - Wailoa
BTS
Hilo
Lili'uokalani Park and Gardens


Preliminary eDNA Results
June 2023
eDNA amplification
Shark Encounter
BTS Blacktip Shark
SHS Scalloped Hammerhead
Site 3 - Breakwater
BTS
Hilo Bay
Site 4 - Reed's Bay
BTS SHS SHS
Site 2 - Wailuku
SHS
BTS
SHS BTS
seum
Site 1 - Wailoa
Hilo
Lili'uokalani Park and Gardens


Preliminary eDNA Results
Dec 2023
eDNA amplification
Shark Encounter
BTS Blacktip Shark
SHS Scalloped Hammerhead
SHS
Site 3 - Breakwater
Hilo Bay
Site 4 - Reed's Bay
Site 2 - Wailuku
SHS
SHS
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