Using sensory cues to reduce sea turtle and shark interactions with fishing gear

John Wang, Shara Fisler, Yonat Swimmer,
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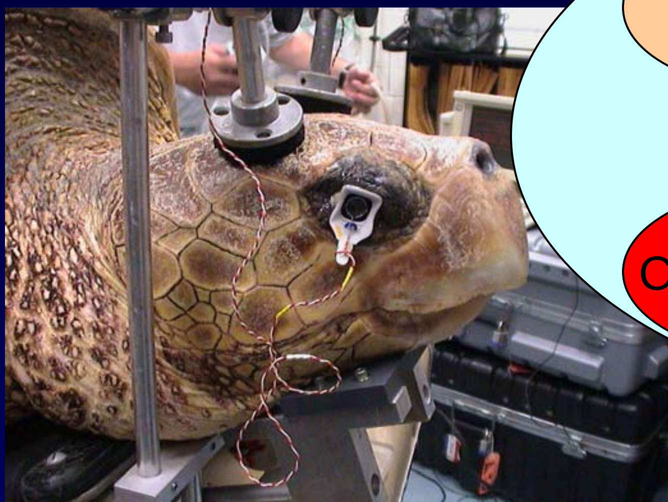
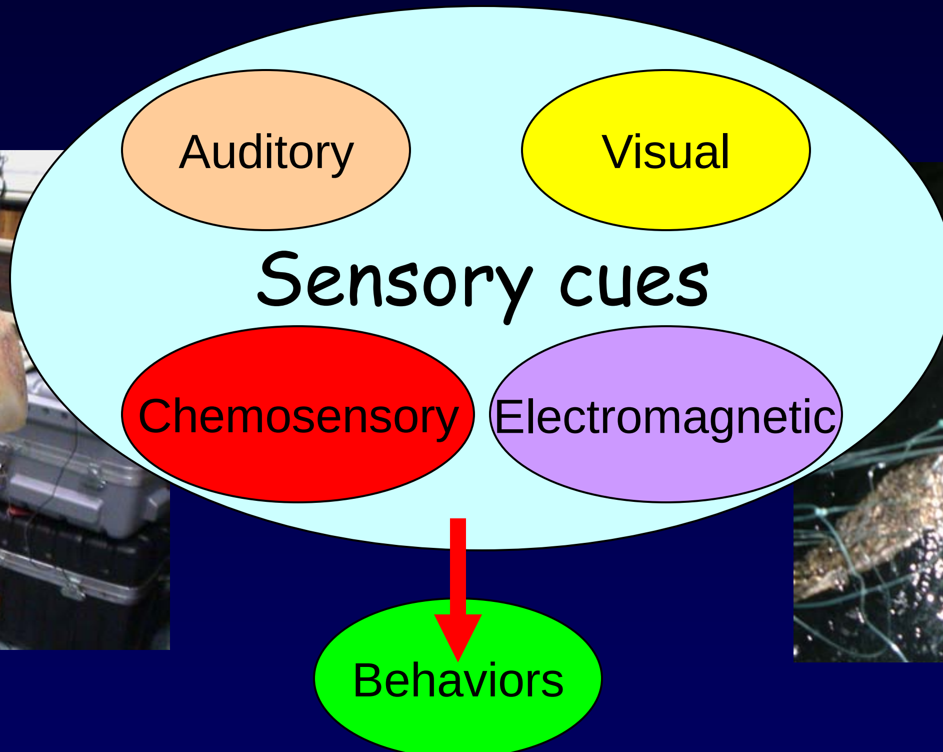
Heide Dewar, Russ Vettar, James Wraith

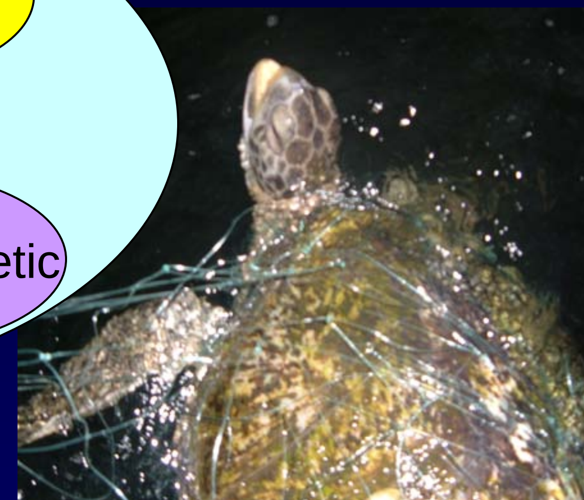
1. Developing visual deterrents to reduce sea turtle bycatch in coastal gillnets

2. Use of electropositive metals to reduce shark feeding behaviour and shark capture rates

Understanding sensory cues and behaviors that lead to interactions with fishing gear







Sound, chemical, and light detection in sea turtles and pelagic fishes: sensory-based approaches to bycatch reduction in longline fisheries

Endanger Species Res, 2008

Amanda Southwood[1,*], Kerstin Fritsches[2], Richard Brill[3], Yonat Swimmer[4]

Novel Tools to Reduce Seabird Bycatch in Coastal Gillnet Fisheries

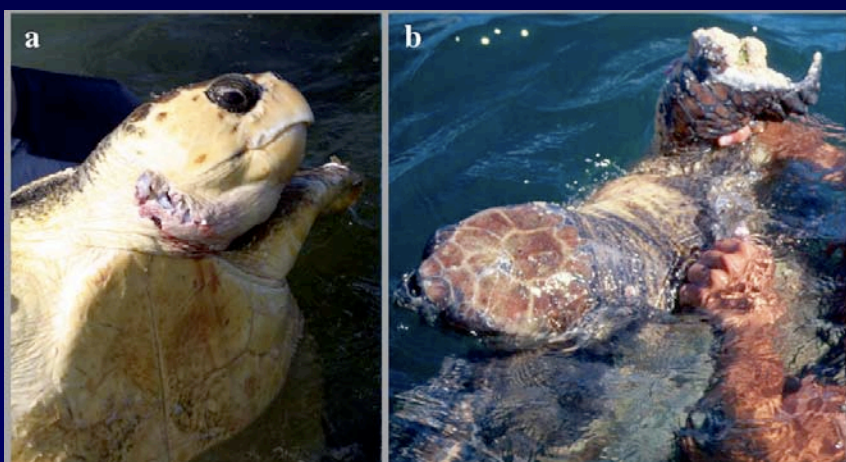
Conservation Biology, 1999

EDWARD F. MELVIN*, JULIA K. PARRISH†, AND LOVEDAY L. CONQUEST‡

- Drift gillnet salmon fisheries in Puget Sound
- Diving birds (Common Murre) are bycatch
- Utilized visual alerts
  - highly visible netting
  - upper portion of net
- Bycatch reduced by 45%

Using predator shapes as scarecrows: Sharks are the primary predator of sea turtles

High rates of shark encounters -– change in foraging behavior



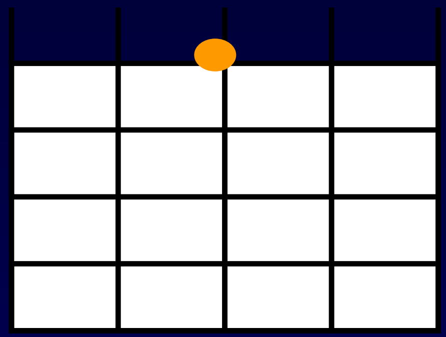
From Heithaus et al, 2008

Escape responses - Innate response

Video: B. Higgins, NOAA-Galveston

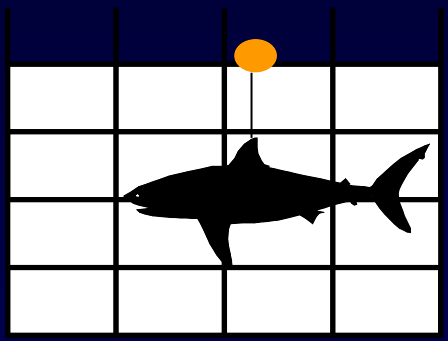
Visual alerts that could act as sea turtle deterrents in gill net fisheries

1. Predator shapes → trigger flight responses



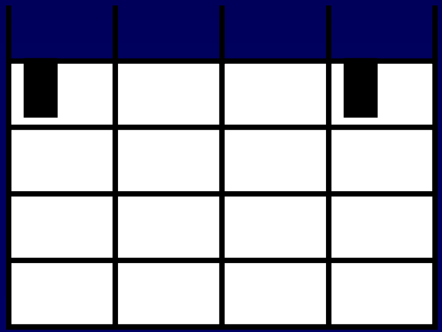
Control Net
Sharks absent

VS



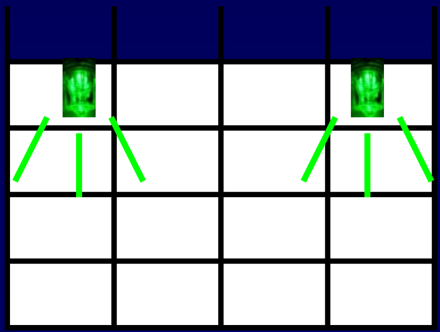
Sharks present

2. Net Illumination → visual alert



Control Net
Inactive LEDs

VS



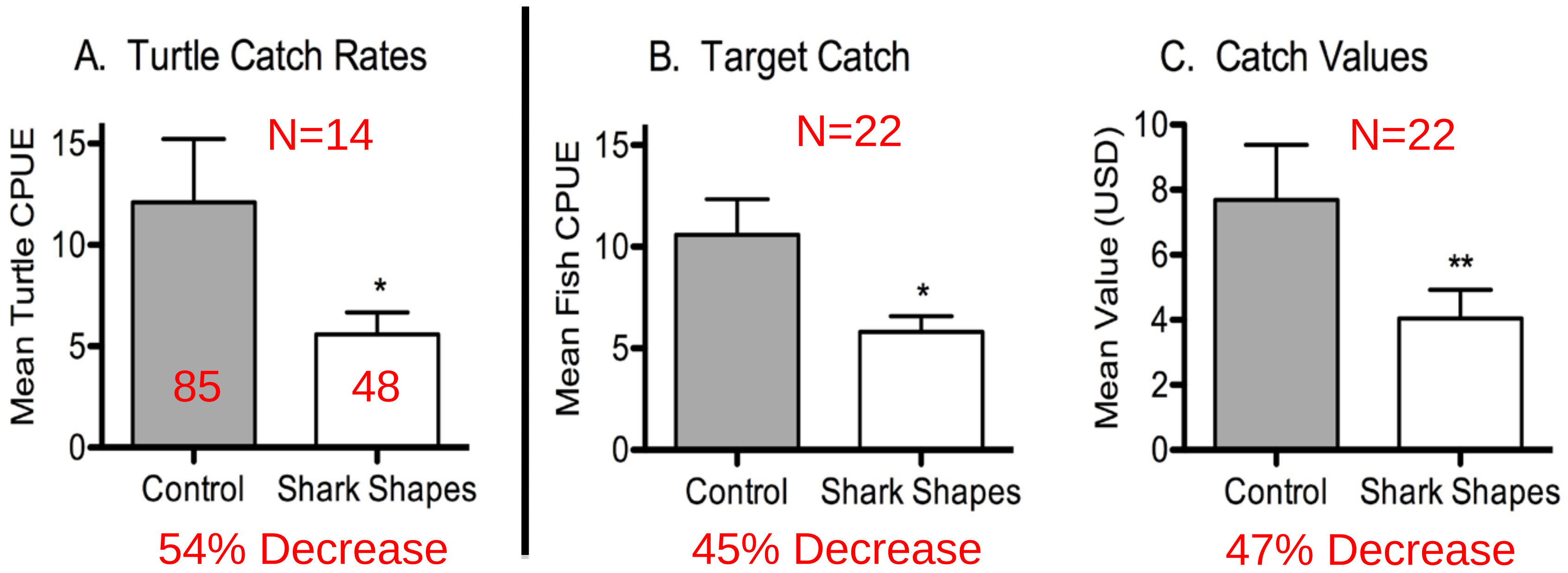
Activated LEDs

Research Sites along the coast of Baja California

- **Punta Abreojos** - Fishing Cooperative manages a green turtle (*Chelonia mydas*) monitoring program with highest catch rates in Baja

- **Bahia de los Angeles** – Fishing community that allows us to monitor and modify their commercial bottom gillnet fishery.

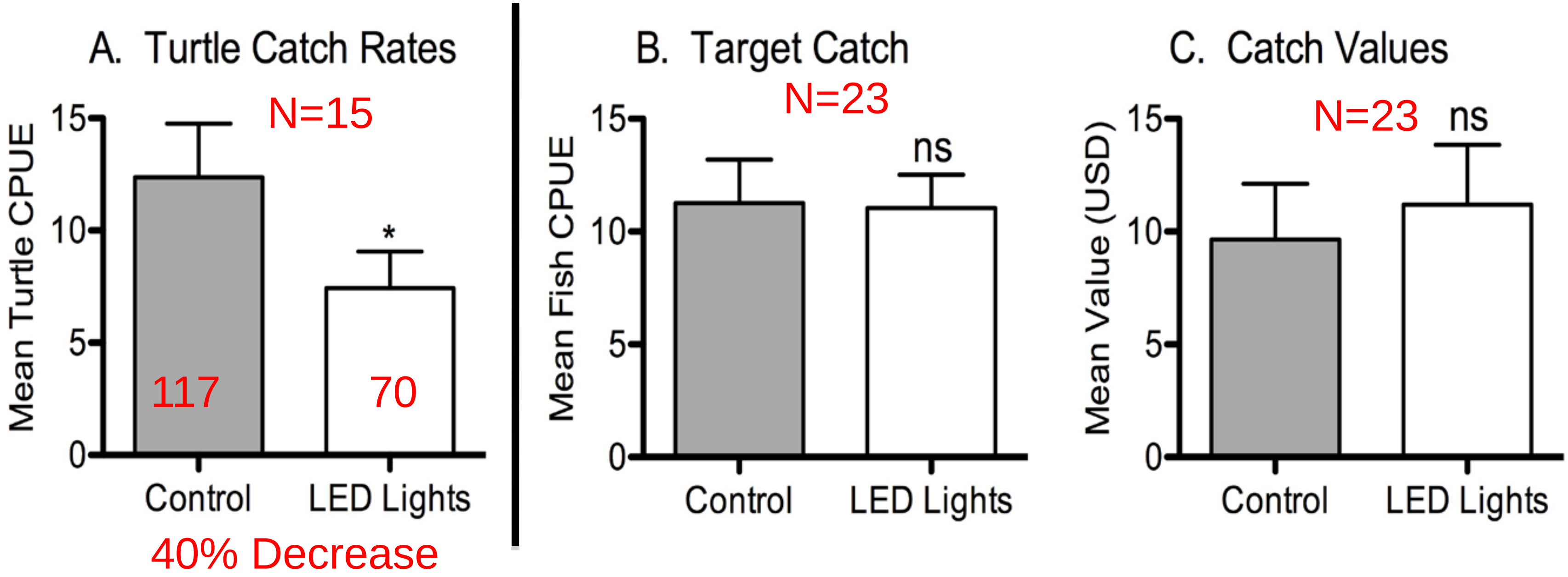
Predator Shapes: Shark shapes every 10m



Wilcoxon Matched-Pairs Signed-Rank test, significance: **P<0.01; *P<0.05

Wang et al, 2010

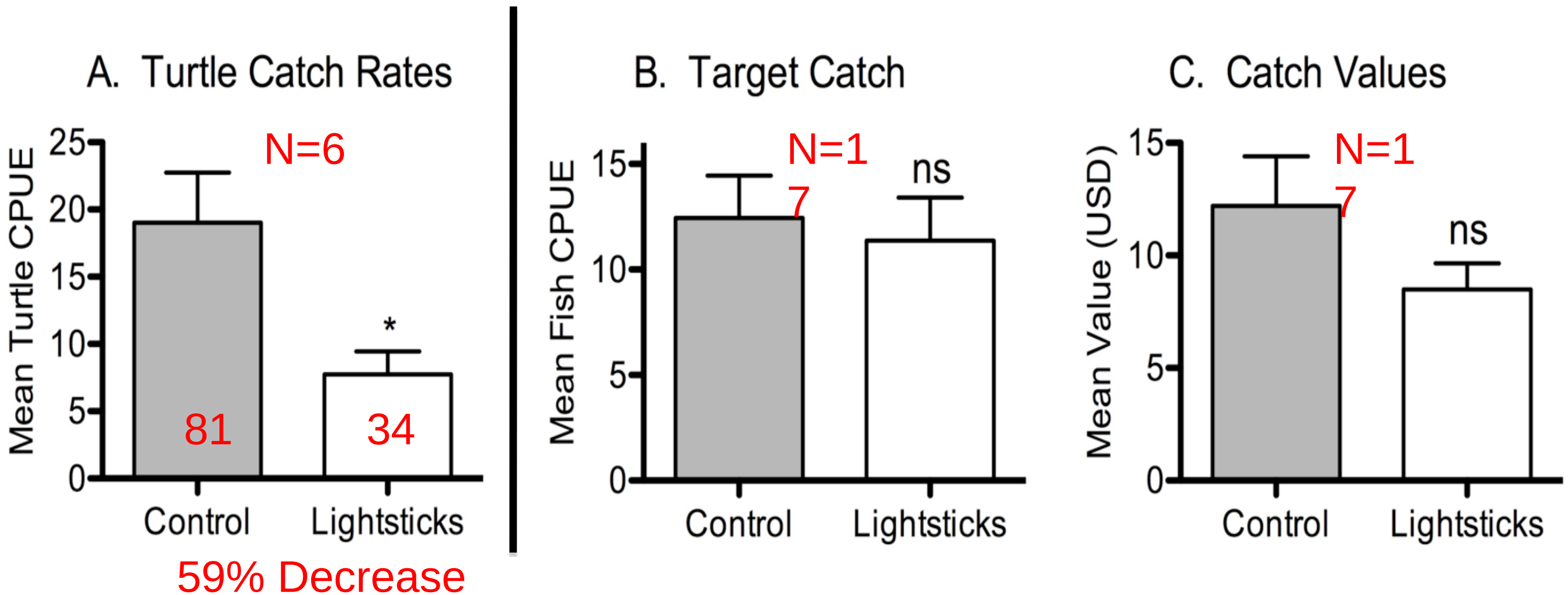
Net Illumination:
LED lights every 10m



Wilcoxon Matched-Pairs Signed-Rank test, significance: *P<0.05

Wang et al, 2010

Net Illumination: Chemical Lights every 5m



Wilcoxon Matched-Pairs Signed-Rank test, significance: **P<0.01; *P<0.05

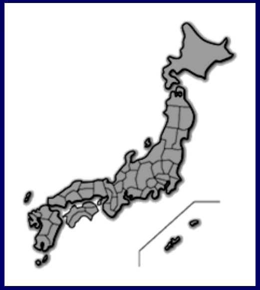
Wang et al, 2010

Potential Applications

- A variety of gill net fisheries (e.g. Baja, Peru, USA-NC)


- Reducing interactions with Coastal Power Plants intakes


- Other fishery settings – Japanese coastal poundnets




Japanese Coastal pound nets

Length： 325m
Width： 90m
Depth： 50m
Type: Mid layer

Closed

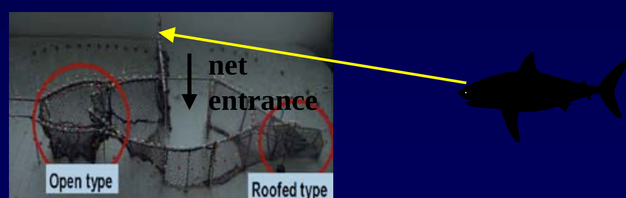
Turtle Catch in ONE SINGLE pound net

95% Mortality
62 Loggerhead sea turtles/year
92 Green sea turtles/year

Data from T. Ishihara, STAJ

1. Develop Poundnet Escape Device (PED)

2. Reduce turtles entering net
   - Shark shapes along the lead-net



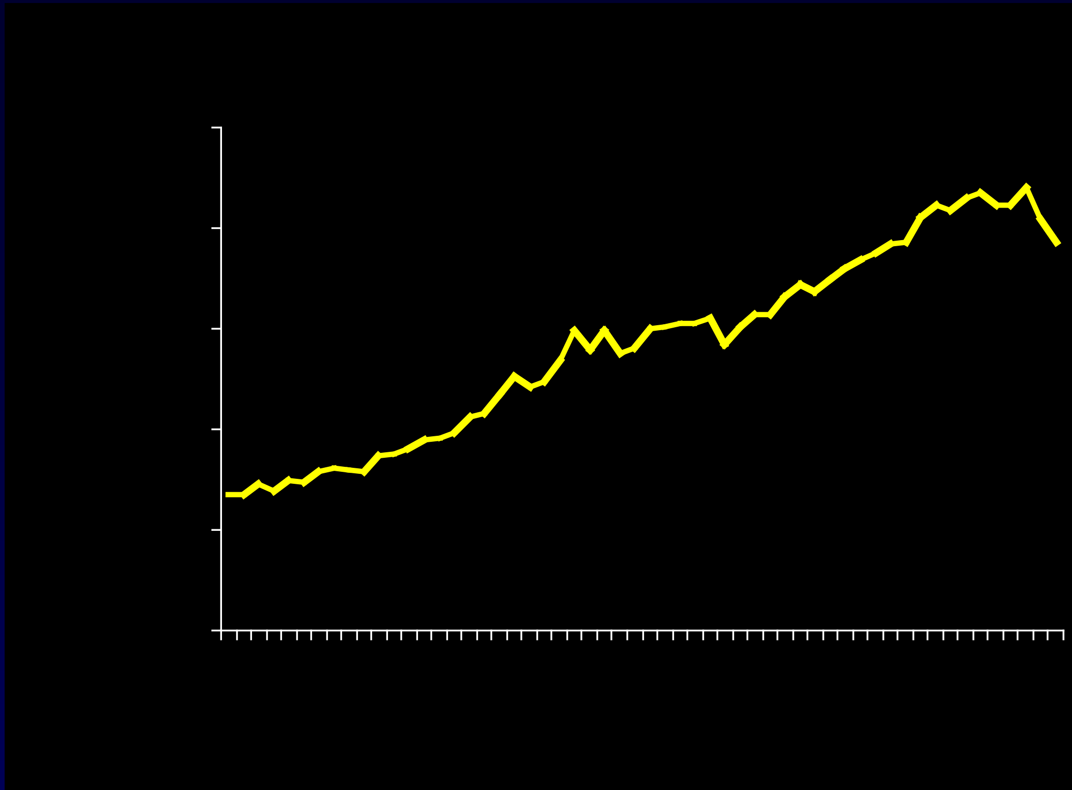
3. Use light cues to guide turtles to the PED (poundnet escape devices)
   - Less searching behavior
   - Faster escape time

Additional ongoing research

- Refining illumination technique to make it more cost effective
  - Construct nets with luminescent materials
    - » strontium aluminate ($SrAl_2O_4$)


- Testing effectiveness of net illumination on other bycatch spp
  - California Sea Lion


2. Use of electropositive metals to reduce shark feeding behaviour and shark capture rates



Data from FAO (Food and Agriculture Organization)

Elasmobranch Life History Strategies

- **Slow growth**
- **Late age at maturity**
- **Low fecundity**
- **High juvenile mortality**

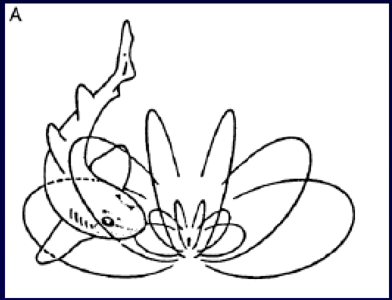
Ecology Letters, (2006) **9**: 1115–1126 doi: 10.1111/j.1461-0248.2006.00968.x

Global estimates of shark catches using trade records from commercial markets

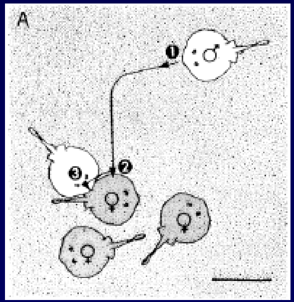
Clark et al, 2006

Electrosensory system in elasmobranchs

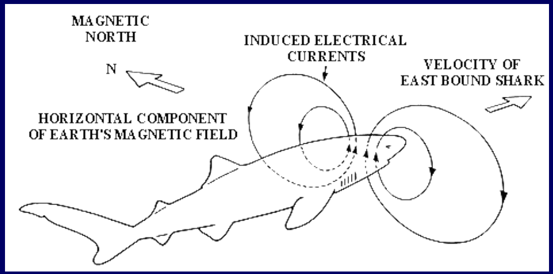
- Detects weak electric fields as low as 5nV/cm
- Functions in the detection of bioelectric fields produced by prey, potential predators and conspecifics during social interactions
- Navigation and Orientation



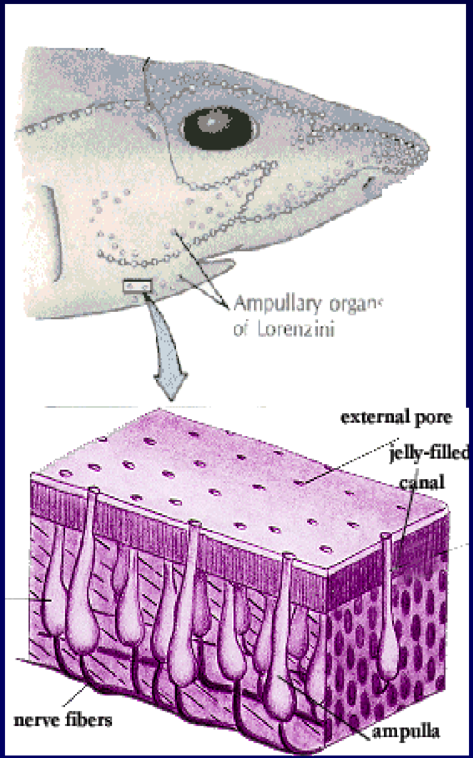
Kalimijn, 1982



Tricas et al., 1995



Montgomery & Walker, 2001



Ampullae of Lorenzini

Large electric fields can startle sharks : Specialized electronic equipment can be used to repel sharks.

Expensive – large – not useful for fisheries

Tonic immobility trials with Nurse Sharks

Scoring

0- No response
1- Minimal flinch, eye blink, fin twitch
2- Weak bend away from metal (up to 15’)
3- Strong bend away from metal (>15’)
4- Tonic immobility terminated / violent response

Figure from Eric Stroud, Shark Defense

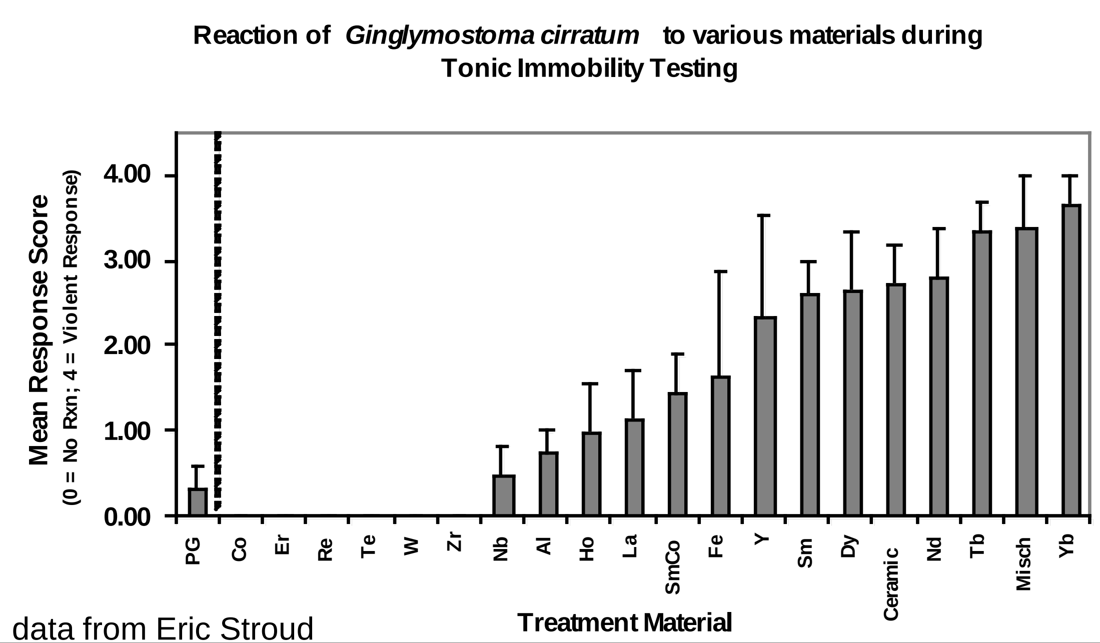
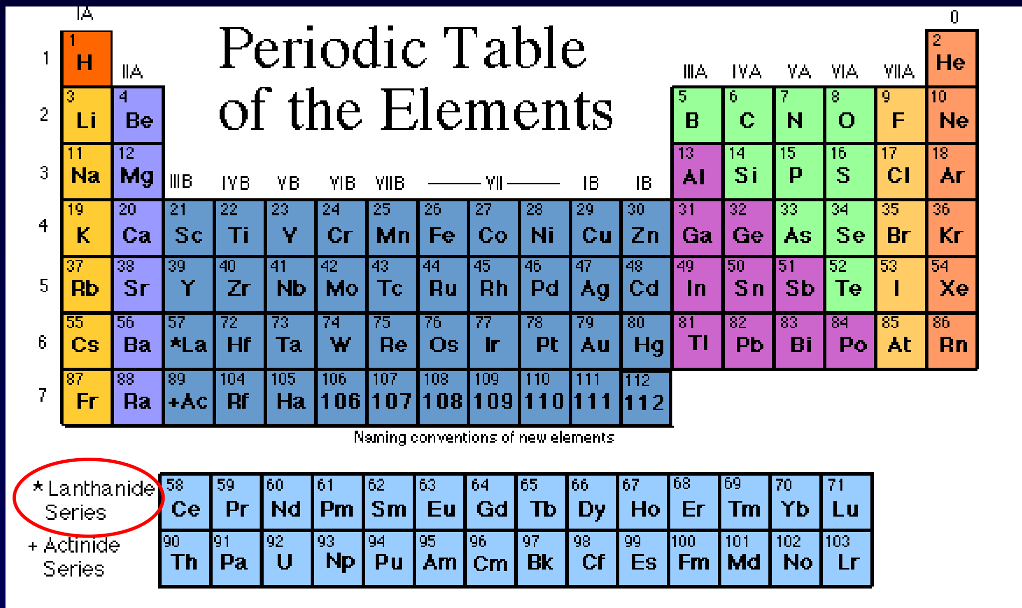


Figure 2. Reaction of immobilized juvenile nurse sharks, *Ginglymostoma cirratum*, when exposed to various test materials (chemical element symbols) during tonic immobility. PG = pyrolytic graphite, Co = cobalt, Er = erbium, Re = rhenium, Te = tellurium, W = tungsten, Zr = zirconium, Nb (sic) = niobium, Al = aluminum, Ho = holmium, La = lanthanum, SmCo = samarium cobalt, Fe = iron, Y = yttrium, Sm = samarium, Dy = dysprosium, Ceramic = barium-ferrite ceramic magnet, Nd = neodymium, Tb =terbium, Misch = cerium misch metal (lanthanide alloy), Yb = ytterbium

Lanthanide metals (highly E+)

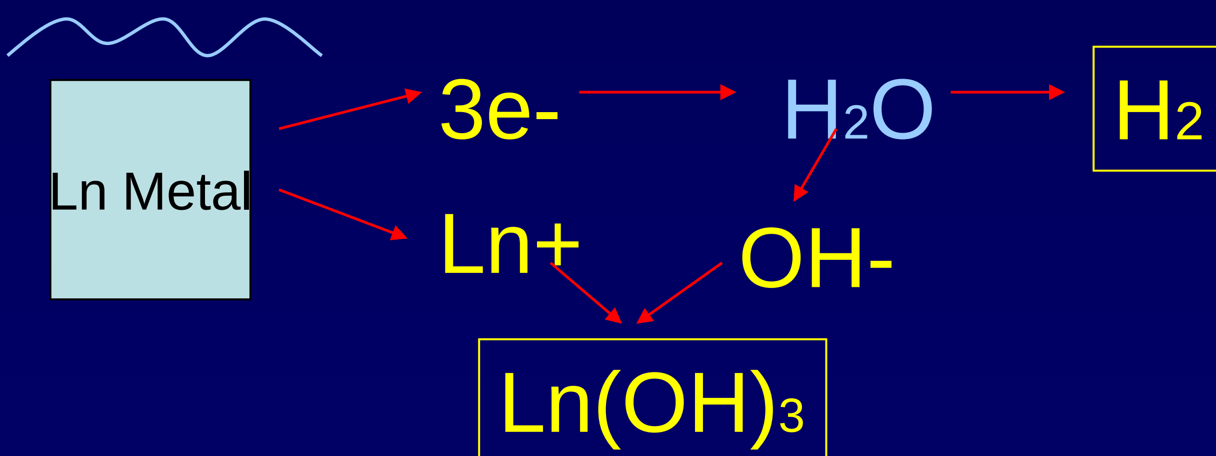


Medical applications:

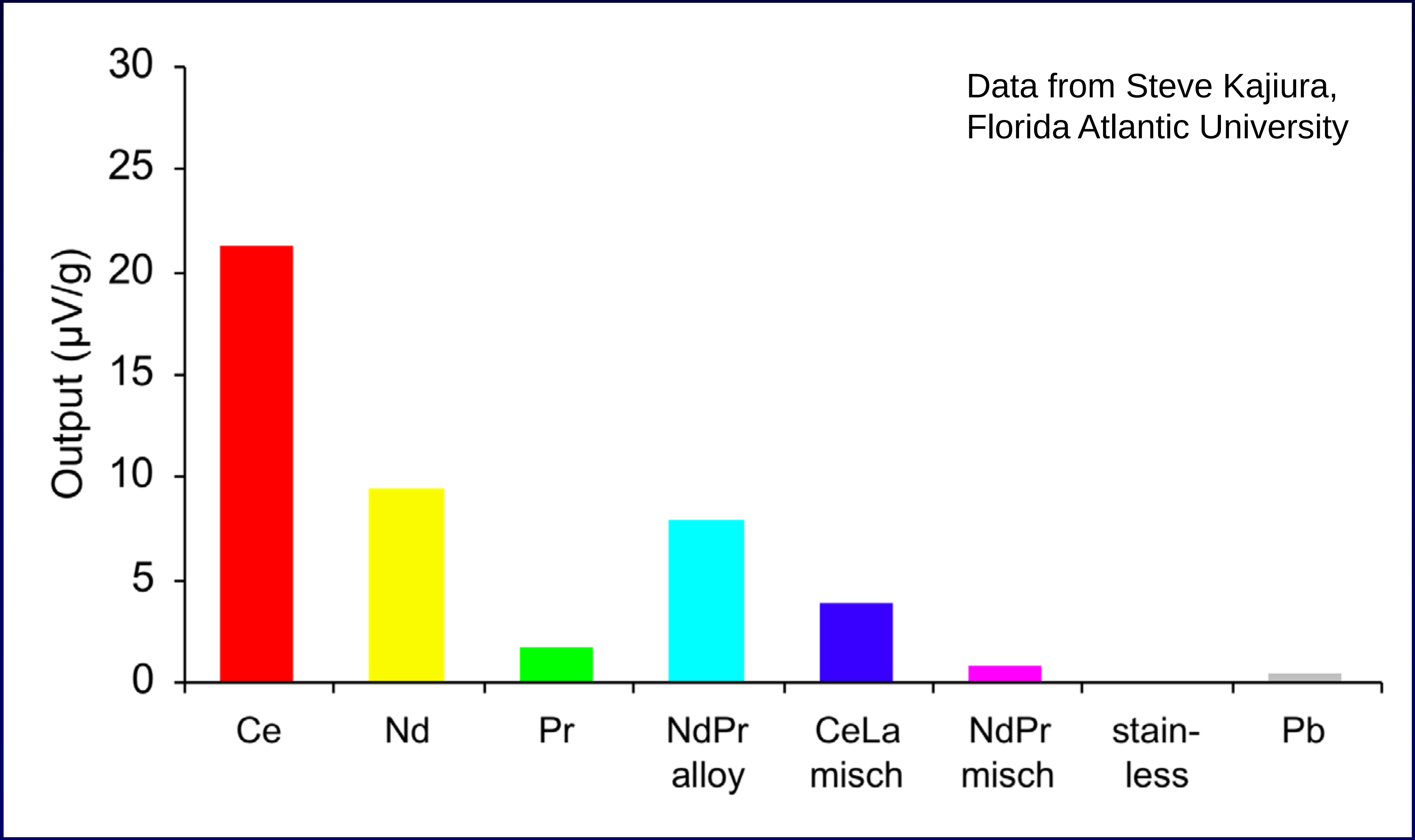
- Anti-microbial agents, used for burn wound treatments

Agricultural applications:

- Crop fertilizers
- Animal feed performance boosters (poultry, sheep, cattle, pork, fish)
- Low to negligible accumulation in tissue (Redling, 2006)



Electric Field Strength of Lanthanide metals (measured 5 cm from metals)



I. Paired bait presentation experiments

Bait was presented in a paired tests
One 5ft wood pole had bait next to a lead control
The other wood pole had bait next to a piece of Pr-Nd Alloy

Poles deployed simultaneously
Keeping the two poles about 2m apart

Standardized our bait using Opelu (*Decapterus macarellus*)

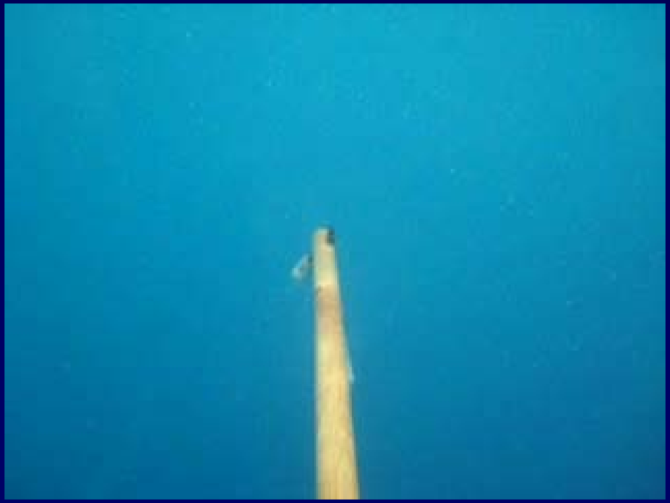
Neodymium -Praseodymium Alloy
(Nd: 76%, Pr: 23%)

5 cm X 2.5 cm X 0.64 cm
45 - 55 g

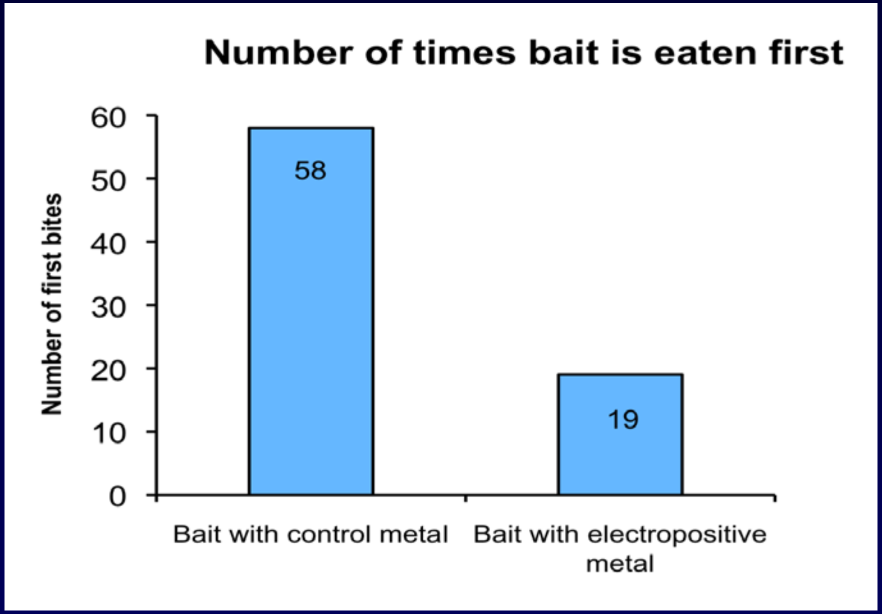
Once the shark bite - the bait was consumed

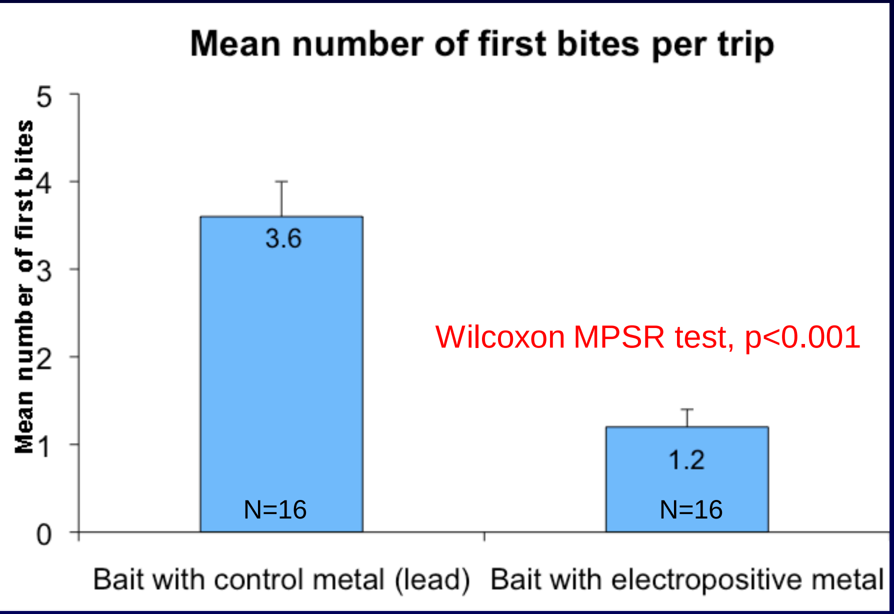
Control Metal (lead)

E+ metal alloy

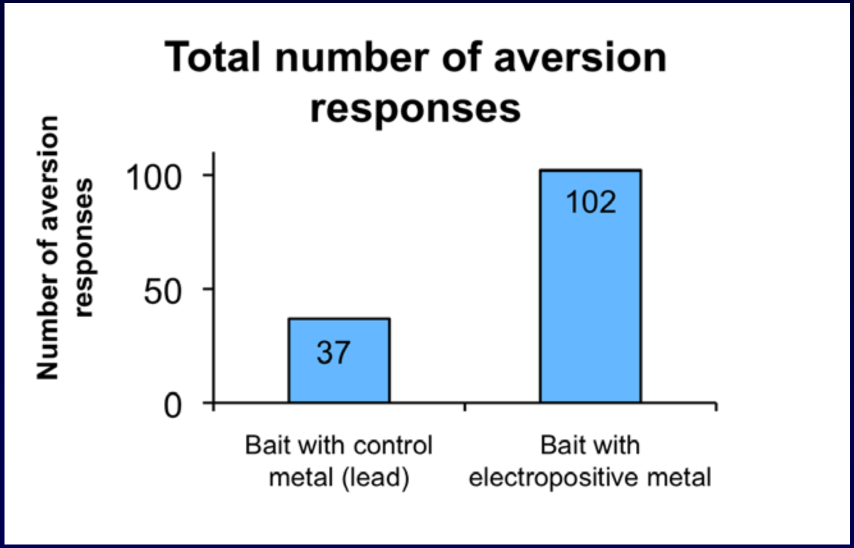


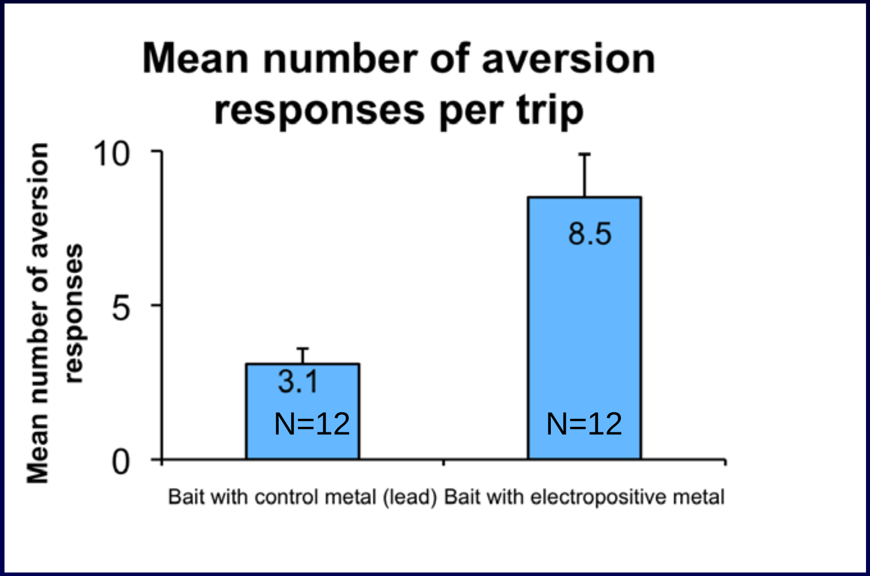
Does the E+ metal influence which bait treatment gets eaten first?





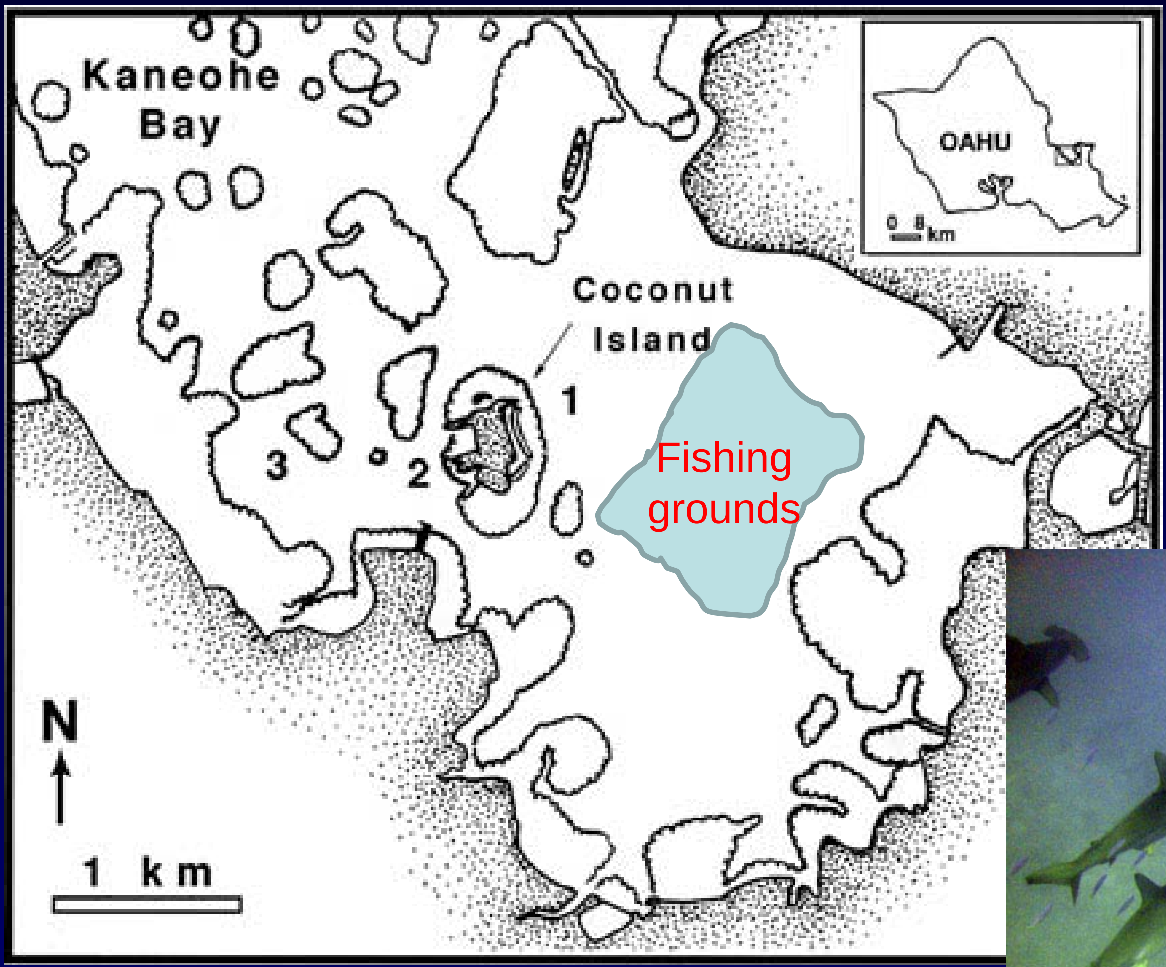
Does the E+ metal increase aversion responses?





Wilcoxon MPSR test, $p<0.01$

IIa. Fishing Experiments

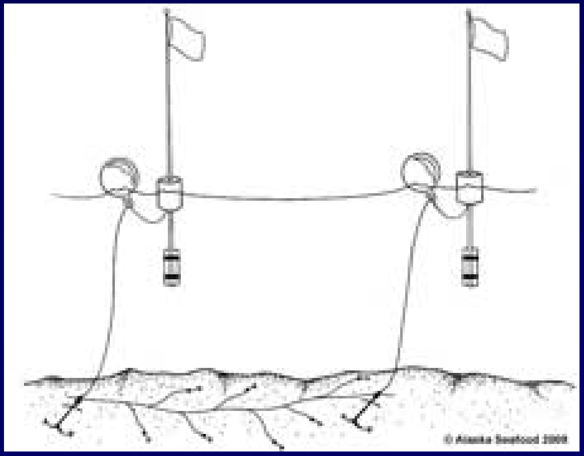


Kaneohe Bay, Oahu, Hi.

Longline experiments targeting scalloped hammerhead pups

Sphyrna lewini pup caught on a lead weight

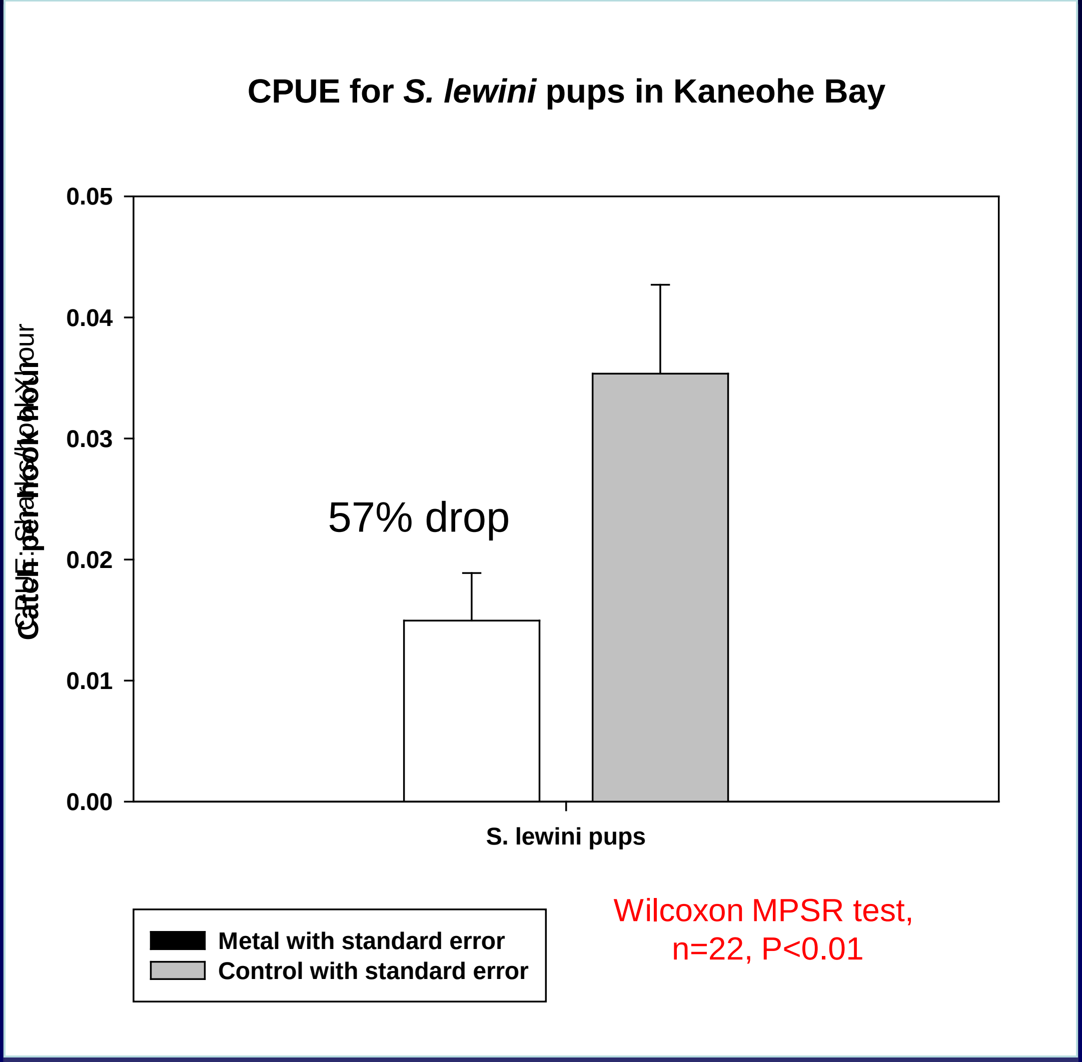
- Deployed 22 bottom longlines (500m)
- Paired design where tx types are alternated
- Soak time ~ 2 hours



Catch rates of *Sphyrna lewini*

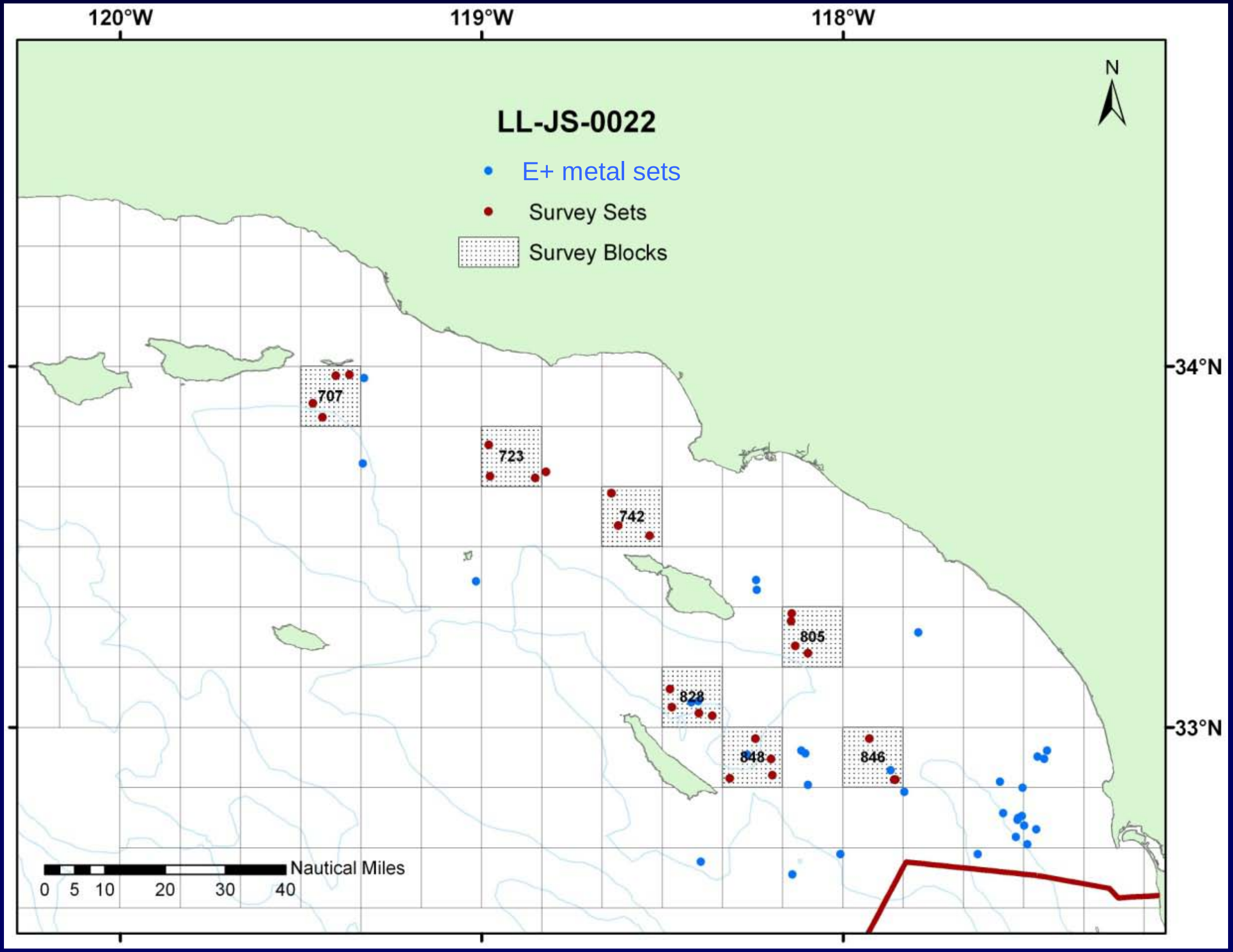
- Total 60 sharks caught
- 22 sets

  18 caught on E+ metal lines
  42 caught on control lines



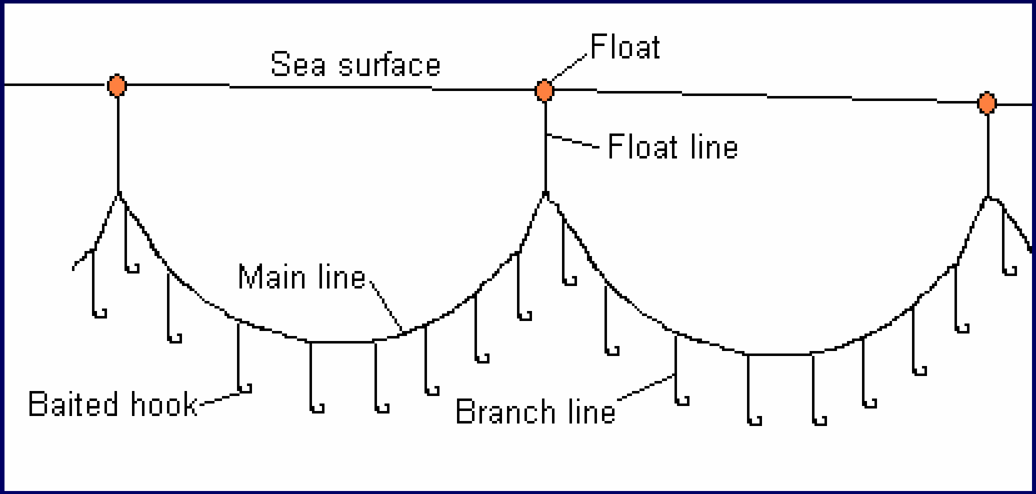
IIb. Fishing Experiments Pelagic Longline Sets - SCB

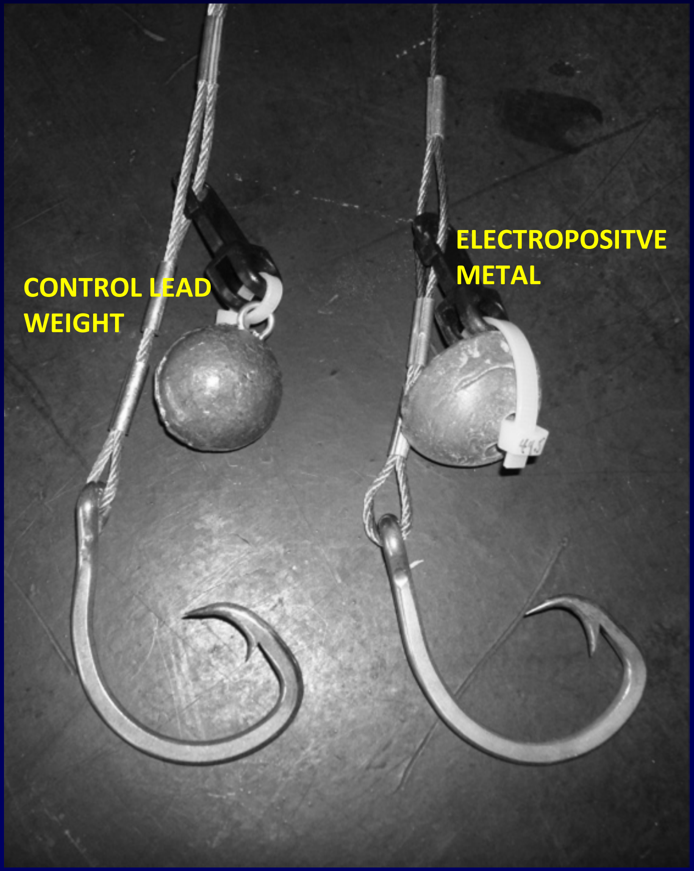
- 27 sets deployed in the Southern California Bight during the 2009 SWFSC Juvenile Shark Population cruise



Gear Configuration

- 27 - two mile sets
- 200 hooks/set alternating tx types
- Soak time ~4 hours





Pelagic longline catch stats

Species	Total Caught on Metal	Total Caught on Control	Total Caught
Mako Shark	57	60	117
Blue Shark	17	21	38
Common Thresher	0	1	1
Smooth Hammerhead Shark	1	0	1
Spiny Dogfish	1	0	1
Pelagic Stingray	8	5	13
Dorado	0	1	1
MolaMola	1	0	1
Totals	85	88	173

Catch per hook hour

<u>Size range & sex ratio</u>

Mako Sharks:

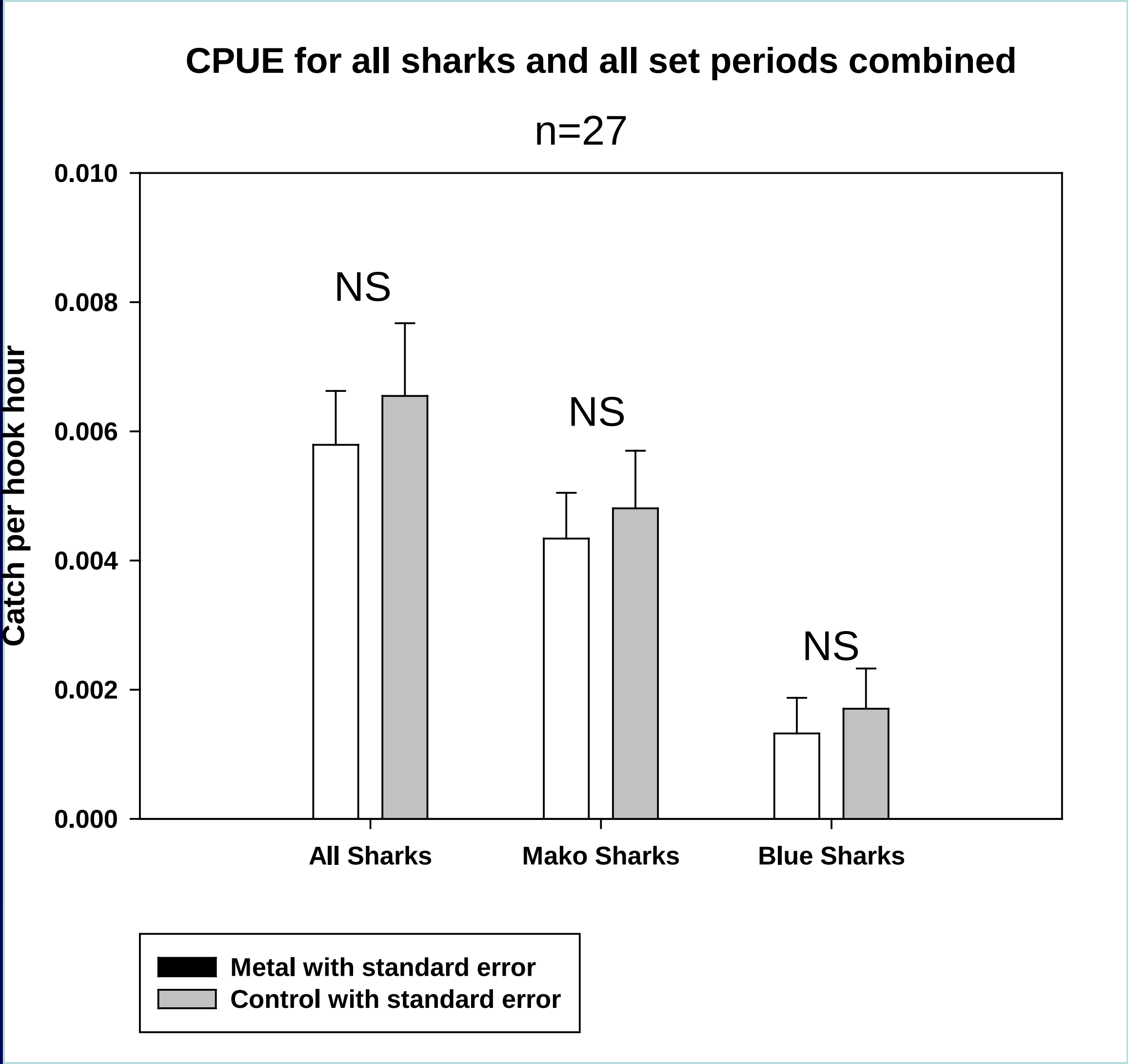
68-236 cm FL, 53:53 M:F

Median FL=106cm

Blue Sharks:

62-230 cm FL, 16:20 M:F

Median FL=90cm



Conclusions

- Inter-specific difference on the effects of Nd/Pr on shark catch.
- Inter-specific feeding behavior and ecology?
  - Coastal versus pelagic
- Differences in hierarchy of sensory cues used for feeding in that habitat type.
- Does neuro-anatomy reflect reliance on different sensory modalities?

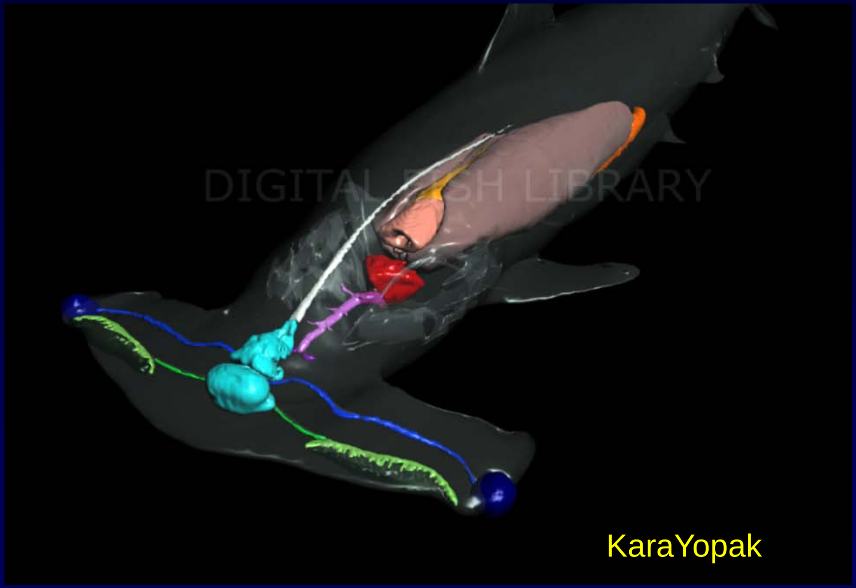
Interspecific differences in feeding ecology

- **Mako sharks** exhibit diel and vertical dive behavior with confirmed feeding events on a wide variety of fish & cephalopods (Sepulveda et al., 2004)

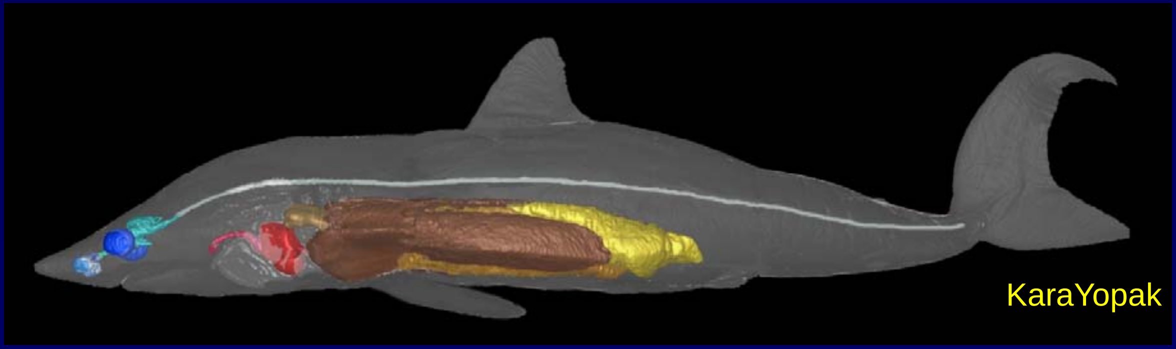
- **Blue sharks** do deep dives beneath the thermocline feed on deep water molluscs (Carey & Kohler, 1992)

•**Hammerhead** pups in a coastal embayment feed primarily at night on alpheid shrimp and gobies (Bush, 2001)

Does neuro-anatomy reflect prioritization of sensory cues used for feeding behavior?



- Mako sharks show a large optic tectum indicating a reliance on vision
- Blue sharks have a large olfactory bulb which occupies 67% of its total sensory area
- Sphyrnid sharks have a large octavolateralis (the region of the brain where electrosensory nerves innervate the brain)



Future Directions

- More data is needed on different species and size classes of those tested here.
- What is the interface between neuro-anatomy and neuro-ecology? Can we use this guide the development of bycatch strategies?

Acknowledgements – turtle research

<u>Funders</u>: NOAA-BREP, NOAA-PIFSC, NOAA – SWRO, NOAA-PIRO, University of Hawaii FDRP, Ocean Discovery Institute, PADI - Aware

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Fishers and communities of Bahía de los Angeles, Baja California

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<u>ODI Students and Staff:</u> E. Alva, A. Alvarez, U. Barraza, C. Castro, C. Corado, L. Cueva, K. C. Dam, A. C. Figueroa, Y. Mehari, D. Mercado N. Rangel, M. Rivera, A. Rodriguez, S. Sillas, S. Thang, T. Tran, and E. Trujillo.

Acknowledgements –shark research

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- Keith Bigelow NOAA-PIFSC
- Paul Rogers SARDI
- Jon Goin NOAA-SWFSC
- Lab group and friends: Jon Dale, Yannis Papastamatiou, Tom Tinhan, James Anderson, Austin Stankus, Kelvin Gorospe, Christine Ambrosino, Tracy Campbell

Other lab groups examining uses of lanthanides

- **Eric Stroud (Shark Defense LLC):** First group showing the potential for Lanthanides as a shark deterrent. Continue to identify chemicals and other metals that may be useful as deterrents.

- **Al Stoner (NMFS- Alaskan Fisheries Science Center) and Steve Kaimmer (IPHC):** Examining Ce mischmetal as a way to reduce dogfish (*Squalus acanthias)* bycatch in the halibut fisheries. Behavioral experiments indicate an aversion to Ce mischmetal, but fishing experiments show a very small decrease in catch rates.

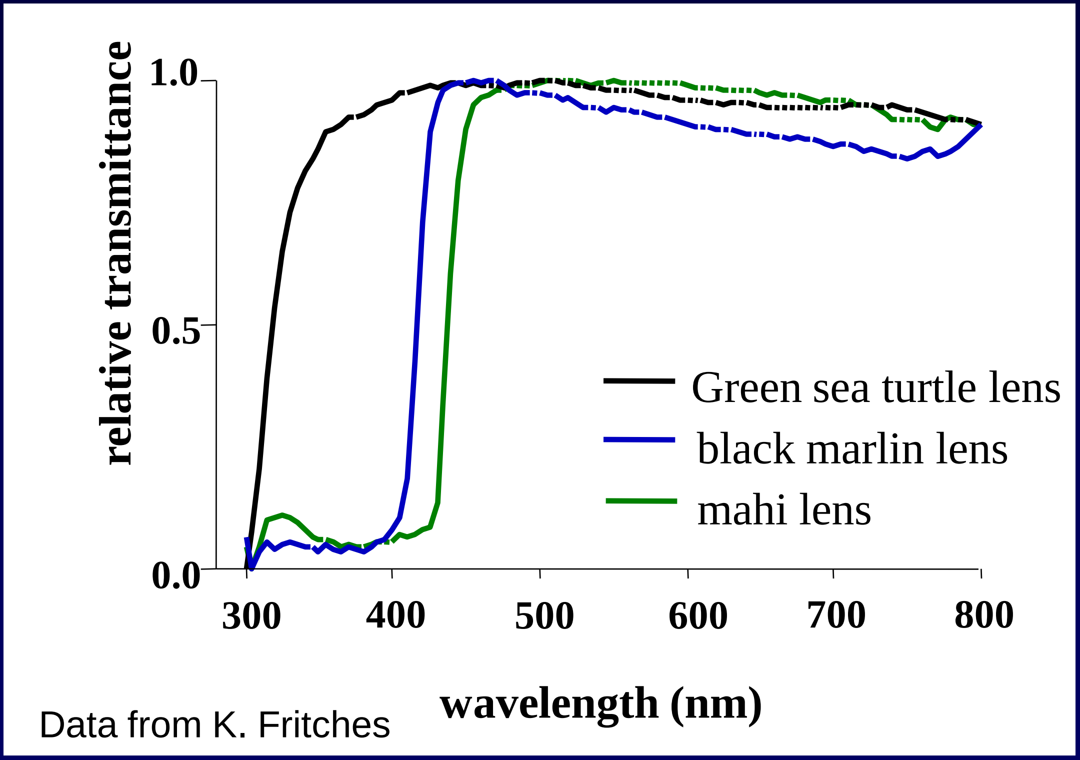
- **Shelley Tallack (Gulf of Maine Research Institute) and John Mandelman (New England Aquarium)** are also examining the use of Ce mischmetals to reduce spiny dogfish bycatch in the Gulf of Maine. Both laboratory and field experiments suggest that Ce mischmetal do not deter shark feeding nor change catch rates of sharks.

- **Rich Brill (VIMS):** Examining the effects of Nd-Pr mischmetal on captive juvenile sandbar sharks using motion path analysis and field trials.

- **Steve Kajiura (FAU):** Physical measurements of the electric fields produced by various lanthanides as well as conducted behavioral experiments with bonnethead sharks

Exploit differences between turtle and fish vision

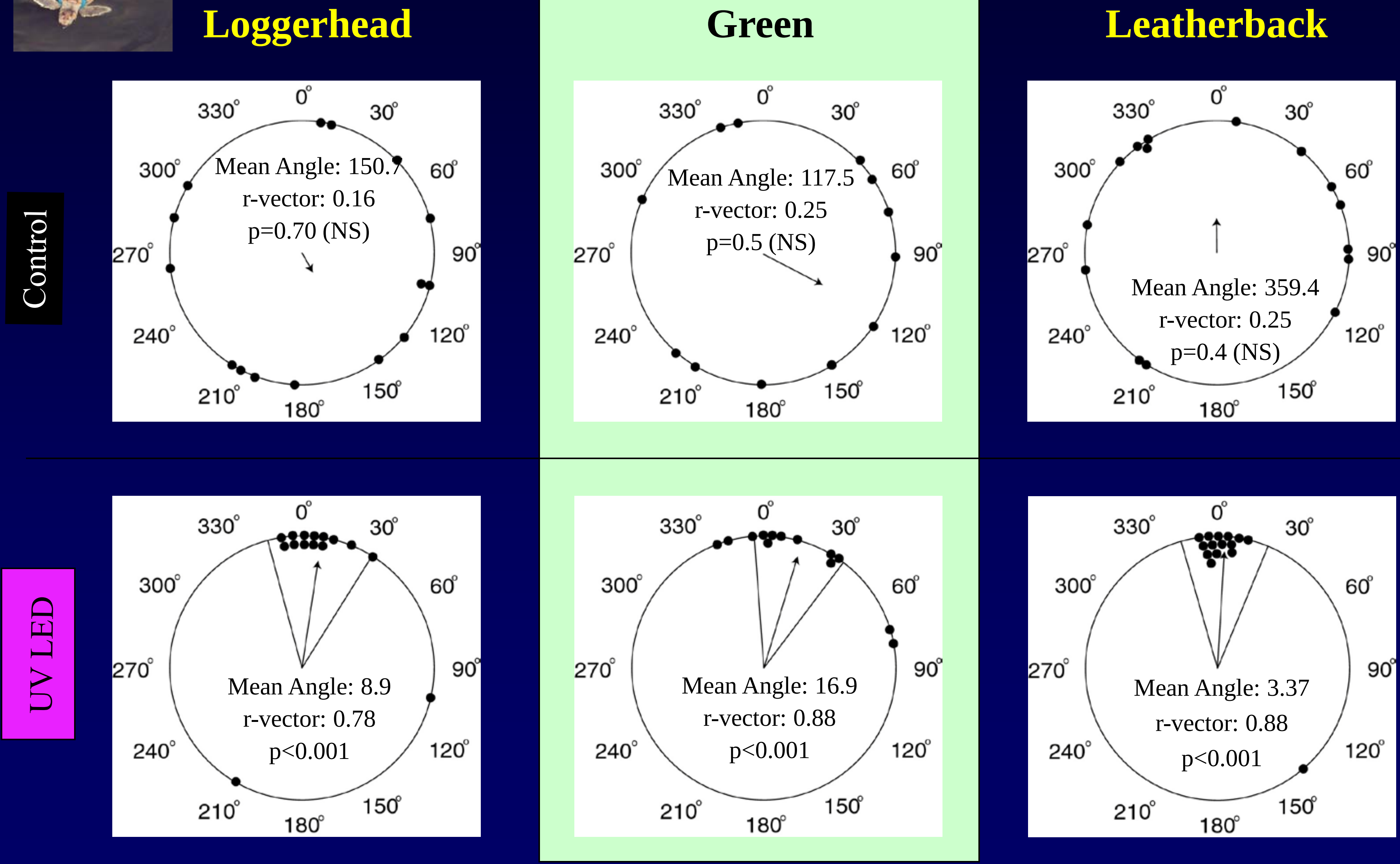
Sea turtle lens allow UV light to pass.
Some pelagic fish do not allow UV light to pass.



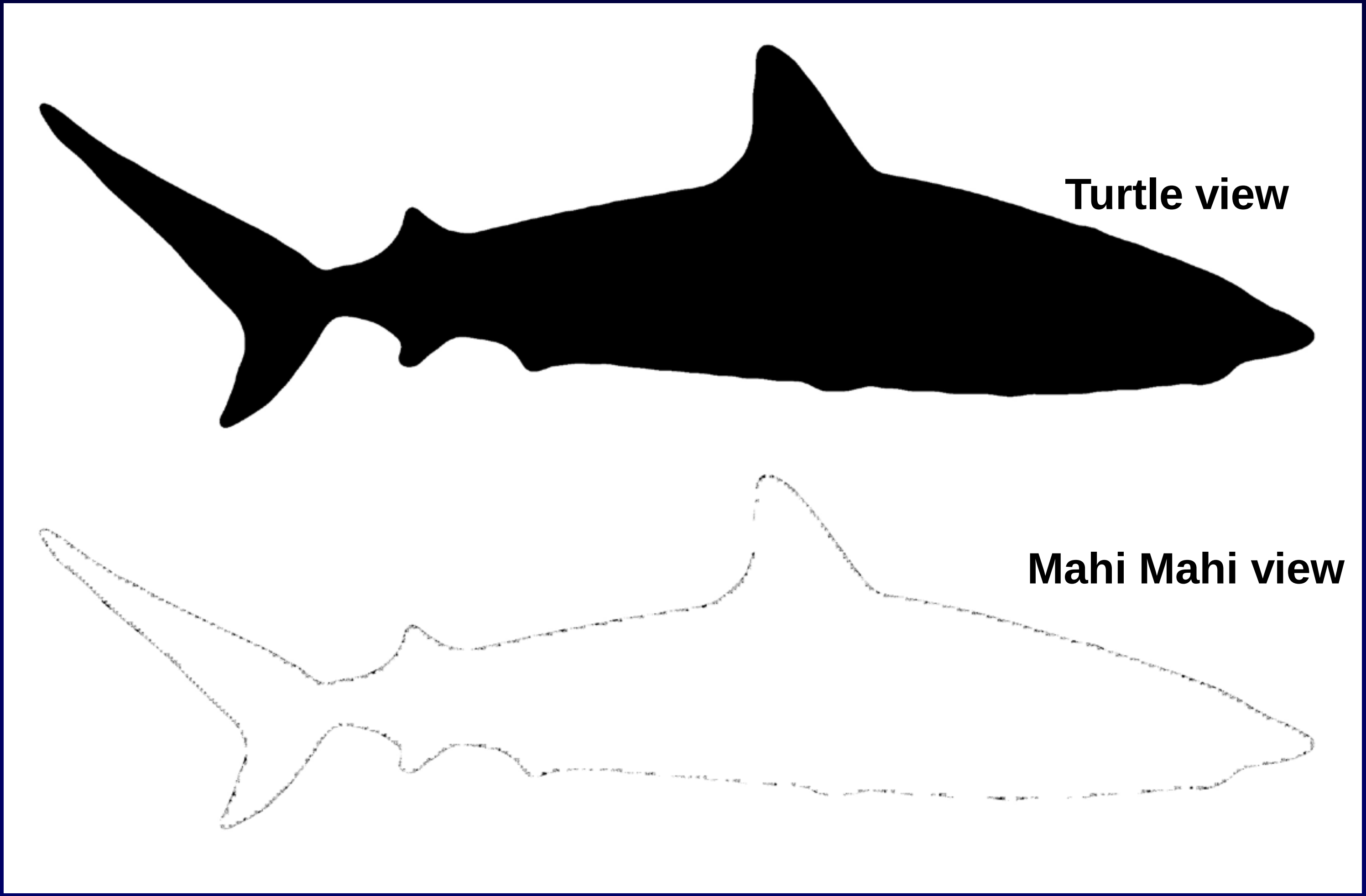
"Selective Communication Channel" for Sea Turtles?

Sea turtles orient to UV light

LED peak - 365 nm, Filter: Hoya U-340

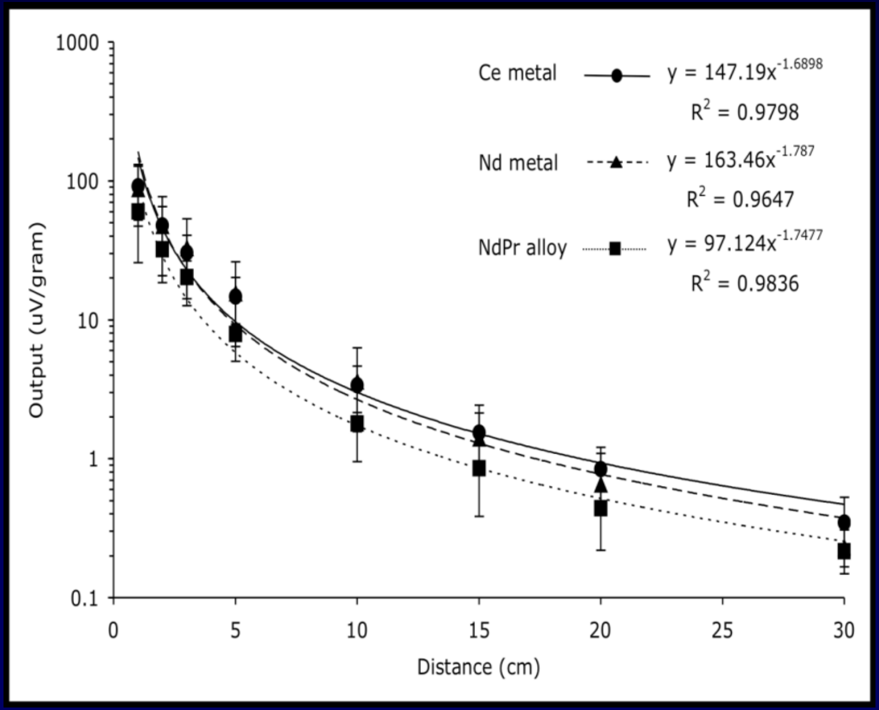


Shark silhouettes made of UV absorbent plastics (mylar, tedlar, plexi-glass, acetate sheets) should be visible to turtles but not fishes



Electrical output v. distance

All three metals demonstrate a similar correlation coefficient (x-1.7) which is intermediate between a monopole and dipole electric field.



S. Kajiura FAU

Novel electric field

Dipole electric field lines