Connectivity in deep water sharks and implications for bycatch

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Elasmobranchs as bycatch in fisheries

- Unwanted bycatch, commercially valuable non-target catch, or targeted
- Shark finning is a major cause of shark population decline – high demand

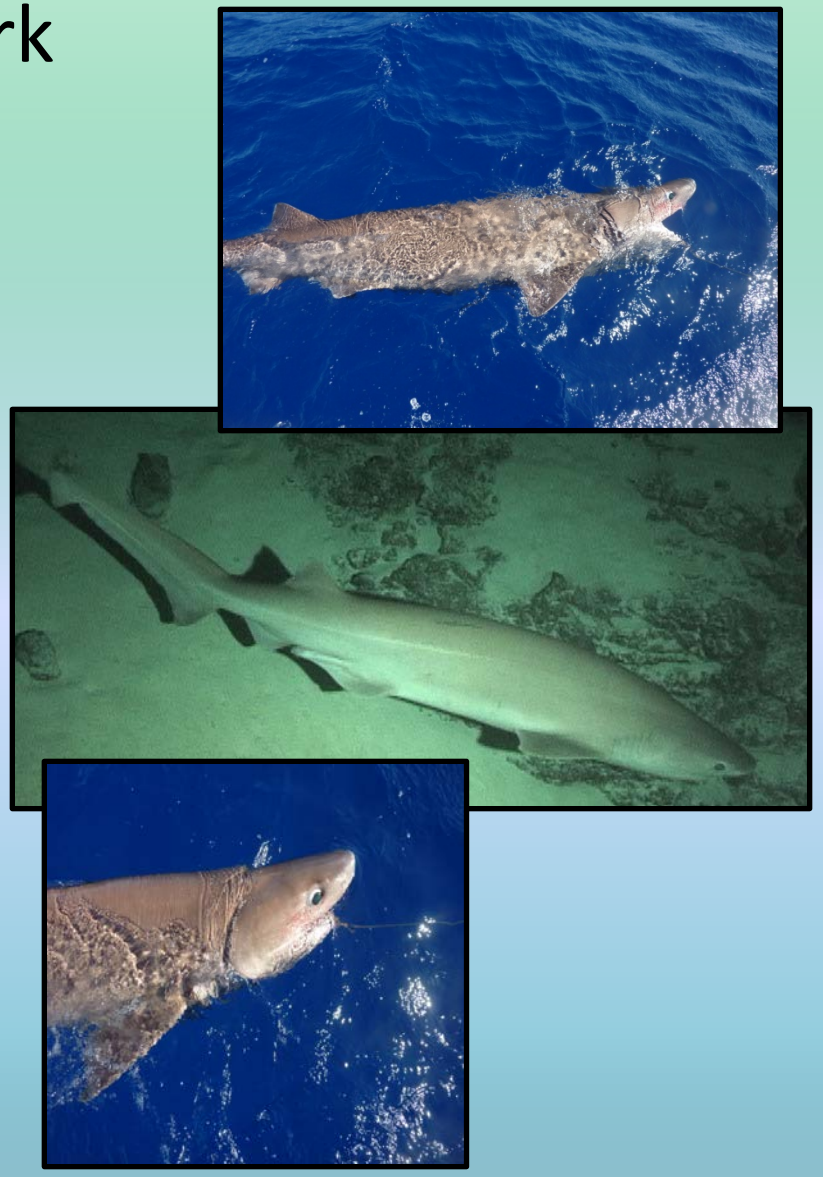
- Deep-sea sharks
  - Increasingly captured (sport, commercially valuable bycatch)
  - "Replacement" species as shallower populations are depleted
  - High impact expected
    - Long population doubling times
    - Many species have low fecundity
    - K-selected

Fig. 2.2—Deep-Sea shark fishery landing

Lewison et al. 2004, Akhilesh et al., 2011

The bluntnose sixgill shark (*Hexanchus griseus*)

- Extremely widely distributed species (i.e. Compagno, 1984; Ebert 1986)
- Common on continental shelves, island slopes, seamounts (Compagno, 1984)
- Reported up to 4.8 meters (females mature ~4m, males ~3m) (Bigelow and Schroeder, 1948)
- Thought to be sluggish and have a small home range individually
- Nothing known of population structure or migrations, if any



Why study sixgill sharks?

Conservation

- Anthropogenic impacts in fishing bycatch, climate change
  - Cross Seamount, N. America, Mexico, Mediterranean, Venezuela, Ireland, India, New Zealand… probably many more
  - Commercially used and sold in India, W. North America…
- Impacts at species and ecosystem level unknown! –suspected to be unsustainable
- Management requires more knowledge of basic biology + ecology

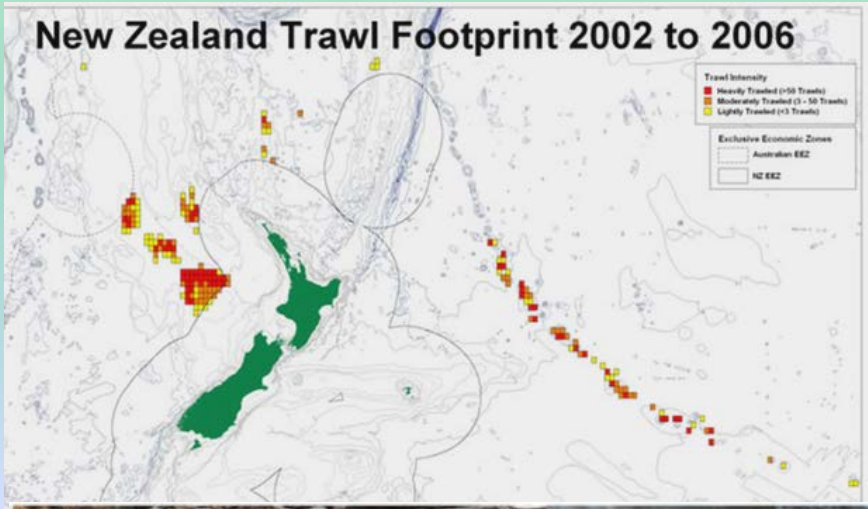
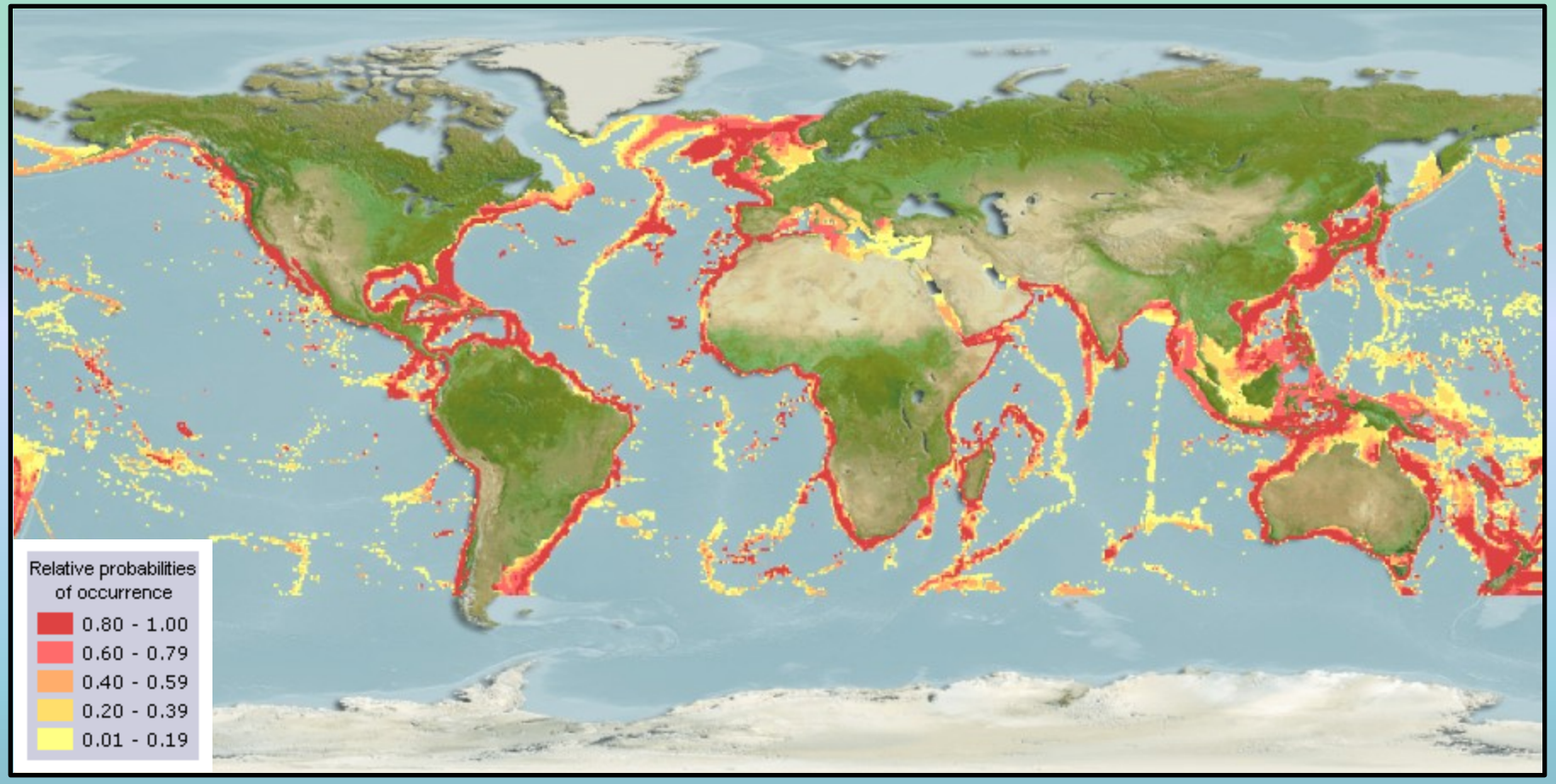


Fig. 4.2—Drying deep-sea shark fins for export

Near-global distribution of the sixgill shark

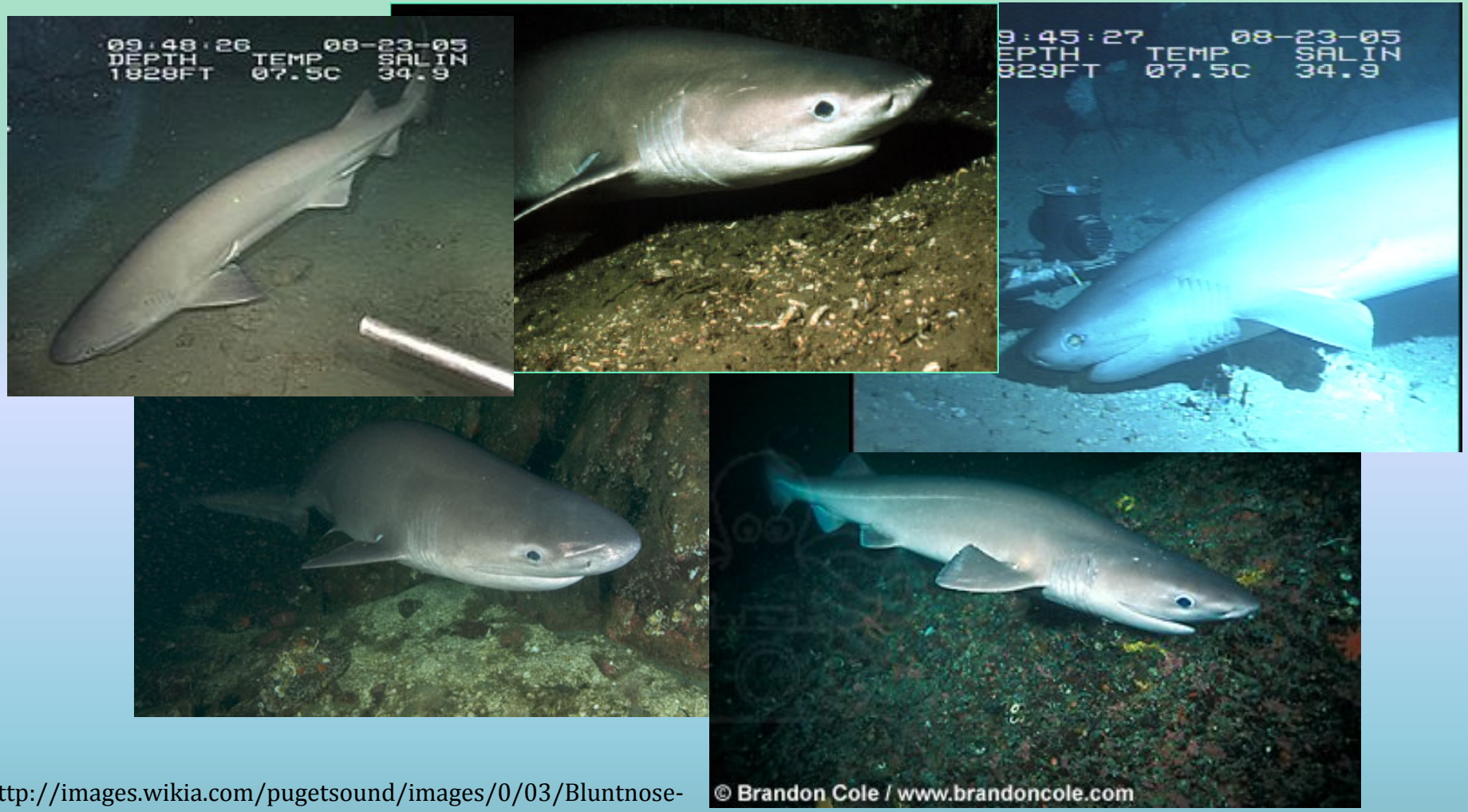
Expected distribution based on observations and
Fishbase designated suitable habitat



FishBase, www.fishbase.org

http://www.ngu.no/geodynamics/gplates/bathy-450dpi.jpg

Sixgill sharks… on the bottom!



http://images.wikia.com/pugetsound/images/0/03/Bluntnose-sixgill-shark-01.jpg

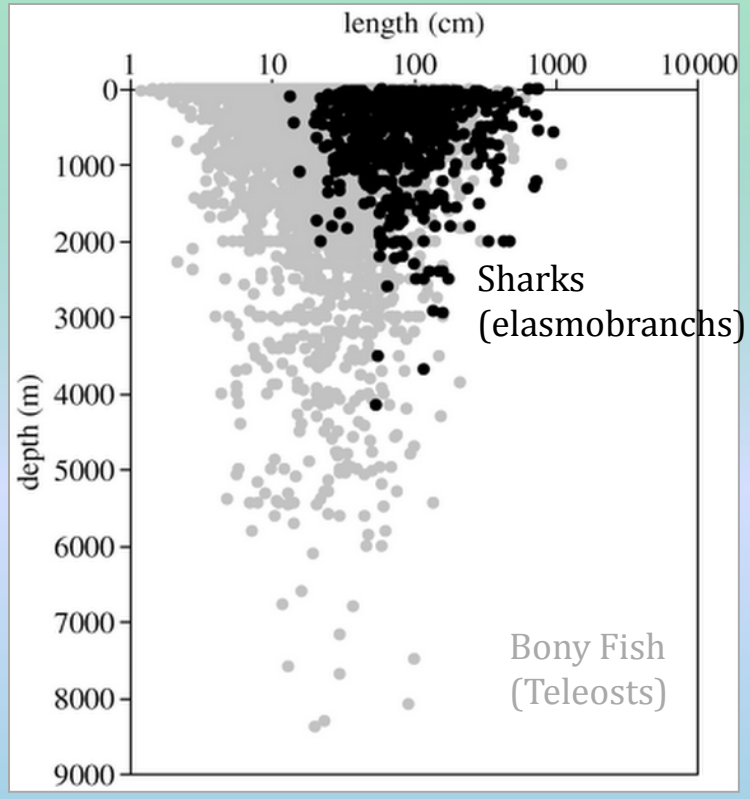
http://2.bp.blogspot.com/-ESl7KSxpBWE/TjKki5RbBbI/AAAAAAAAAjE/uKZNBOgRybo/s640/bluntnose-sixgill-shark-01.jpg

http://www.photolib.noaa.gov/bigs/expl0447.jpg

This study…

- Do sixgill sharks leave the benthos to traverse deep channels?
  - Alinuihaha, Kauai channels
  - Movement between Cross Seamount and archipelago
- Home range size

- Elasmobranchs are not found deeper than about 2500m
- Solely benthic sharks would have populations isolated by depth barriers



Priede et al. 2006

Hypothesis: Sixgill sharks will not cross open ocean or channels deeper than 2500m.

Methods: Capture and tagging

- Bottomset longline, 300-600m
- Instrument: pop-up satellite archival tag
  - Wildlife Computers, Seattle, WA
  - Depth, temperature, light
  - Detaches and reports data to satellite

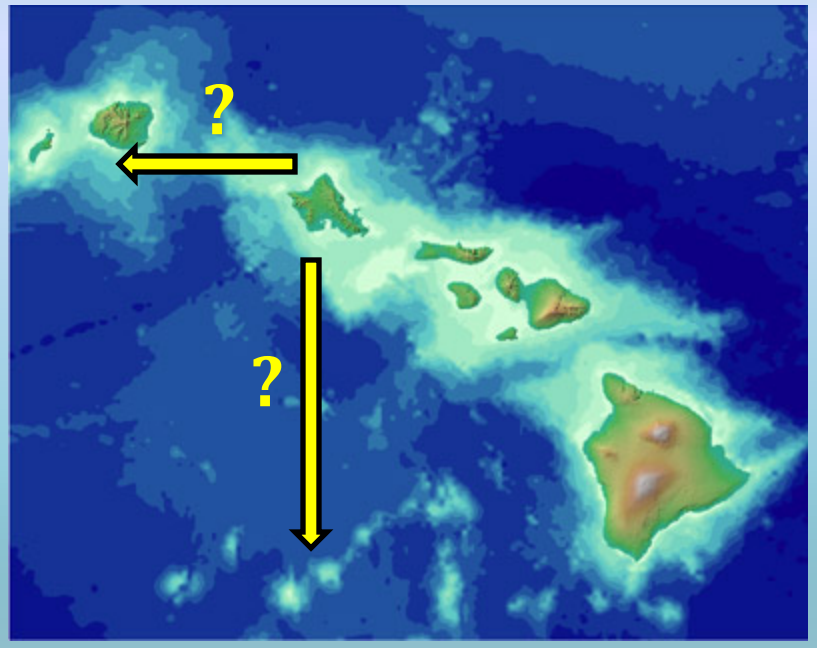
Methods: Data recovery

- Tag transmissions include GPS position
- Radio direction finder to recover tags that pop up within range
  - Detailed record
  - 3-5 second intervals
  - 1.5 million records
- Download data from satellite
  - 5 minute sampling interval

  - ~55,000 records

Methods: Data analysis

- Horizontal movements
  - Tagging and pop-up location
  - Light based geolocation not possible
  - Quality control: are pop-up locations accurate? Drift between release and first location?
- Vertical movements
  - Diel vertical migrations
  - Rate of movement / activity level at varied temperature and depth



http://ccma.nos.noaa.gov/products/biogeography/mapping/dems/

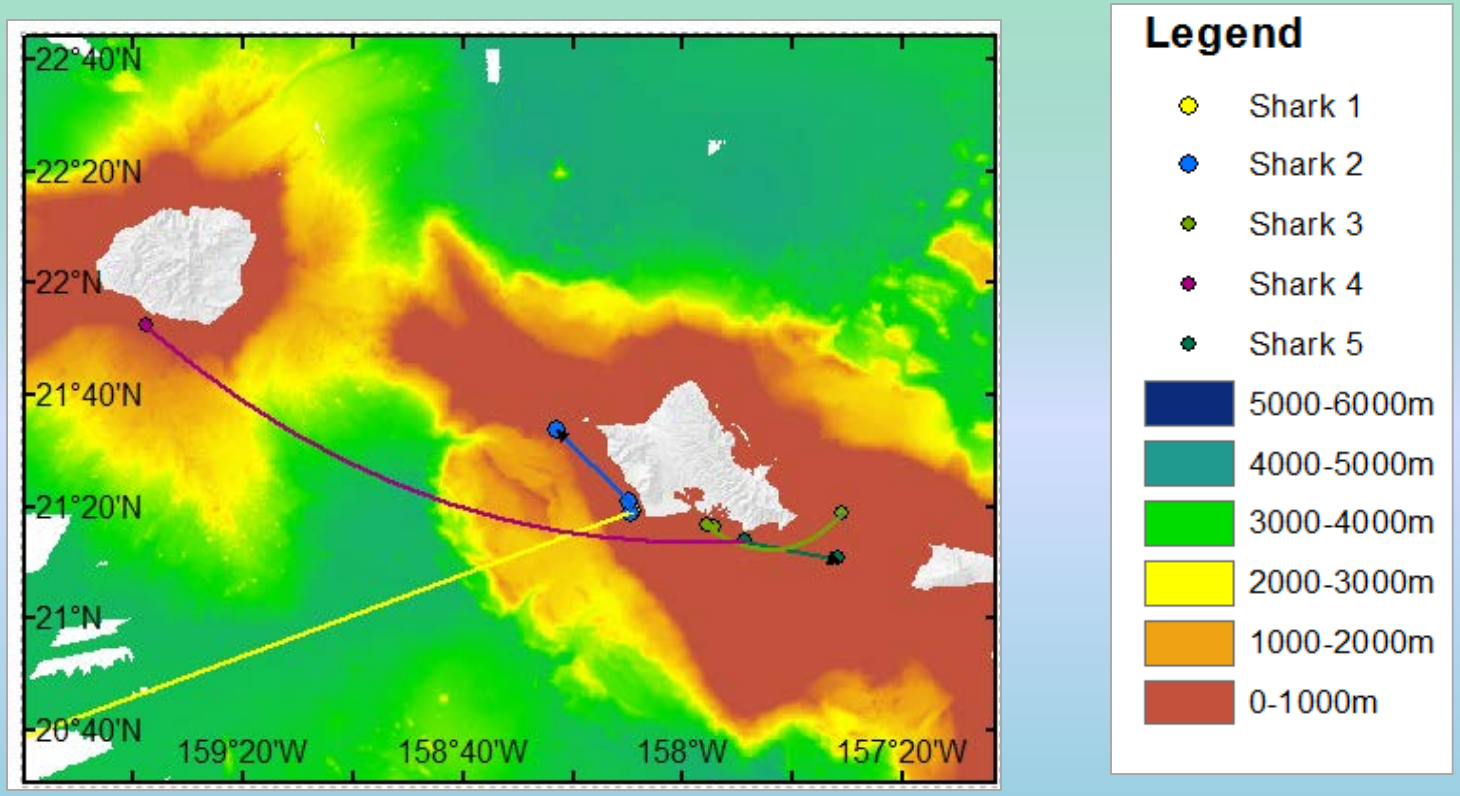
Results: Tagging and data recovery

- Tagged:
  - 2 mature males
  - 3 immature females
  - 1 immature male
- Recovered
  - 4 archival records (MiniPAT)
  - 1 transmitted record (MiniPAT)
  - 1 tag did not transmit (MK-10)

83.3% recovery!

Results: Horizontal movements

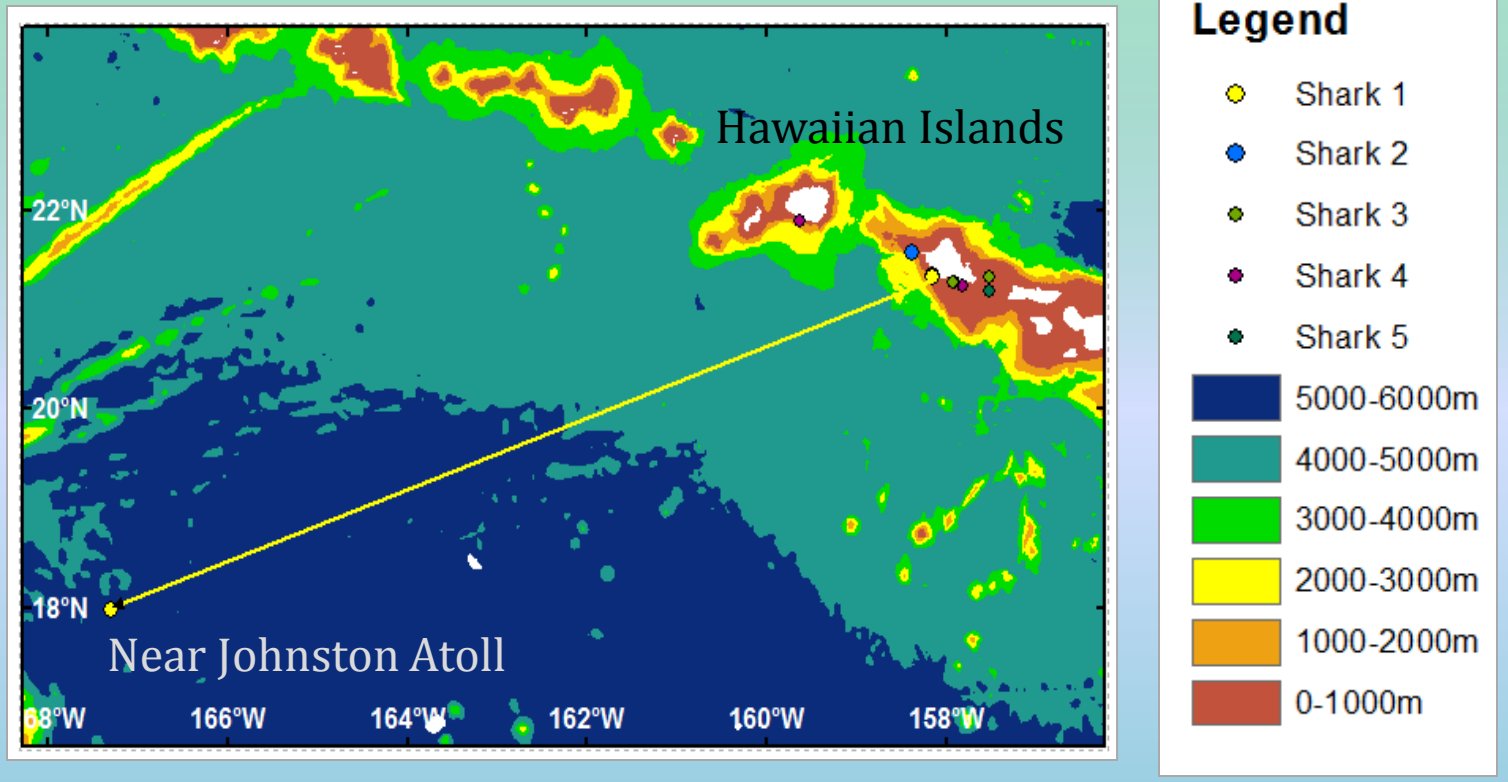
Hypothesis: Sixgill sharks do not cross channels or open ocean >2500m depth.



Sixgills were expected to stay near Oahu, but one crossed the deep Kauai channel (mature, male)

Results: Horizontal movements

~~H1: Sixgill sharks do not cross channels or open ocean >2500m depth.~~



…. And one (also a mature male) left the island chain and swam almost 1000km SW, towards Johnston Atoll!

Compare: Horizontal movements in Hawaii vs. Washington (Puget Sound)

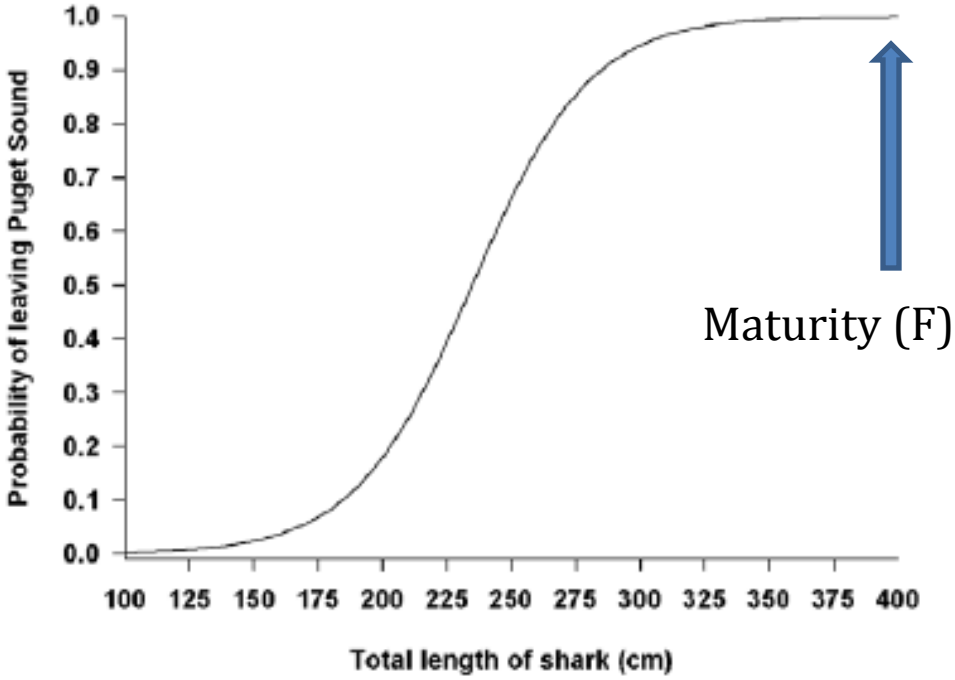
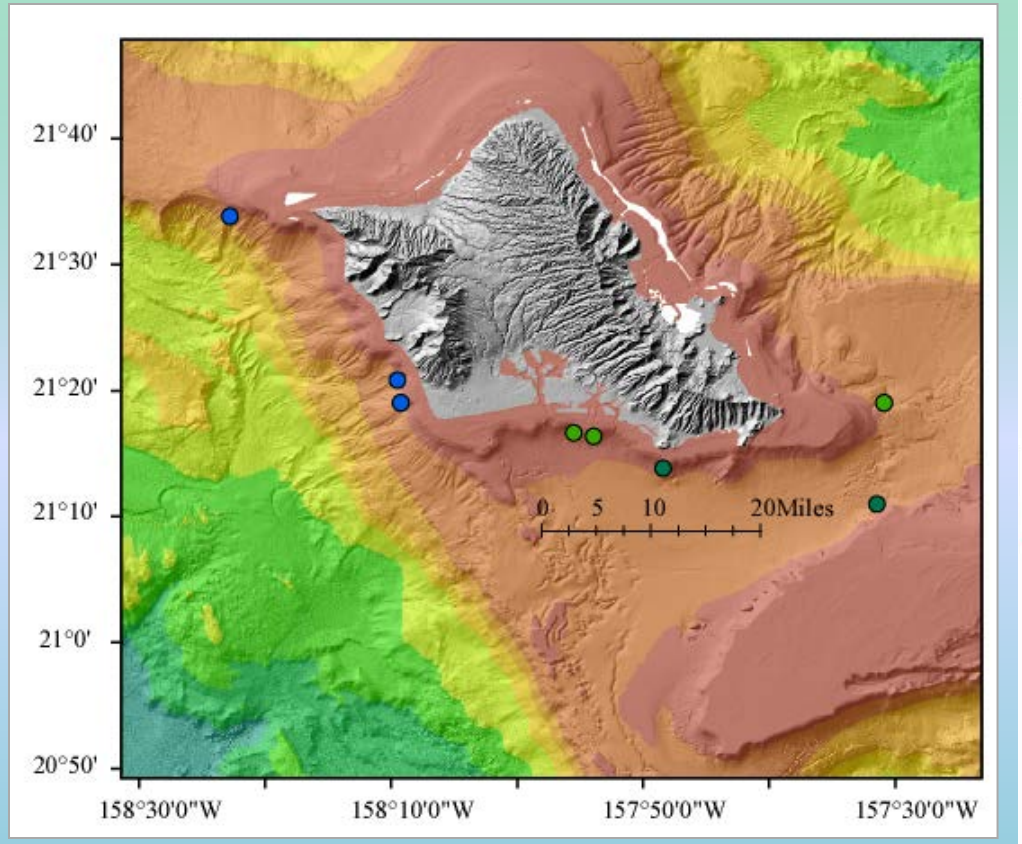


Figure 8. Probability of a female sixgill shark leaving Puget Sound, WA, USA as a function of the shark's total length.
doi:10.1371/journal.pone.0012549.g008

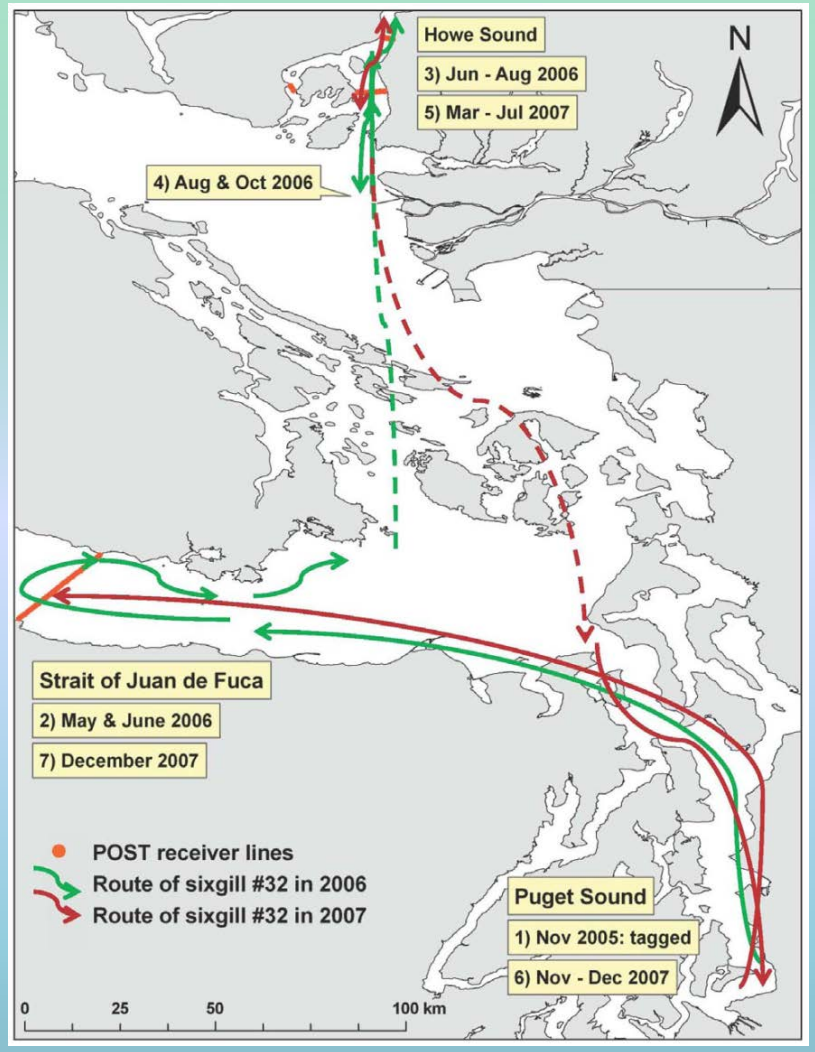
- Mature males left the Hawaii slope!
- Puget Sound, WA: Female sharks leave as they approach maturity

Andrews et al., 2010

Compare: Movements of immature sharks



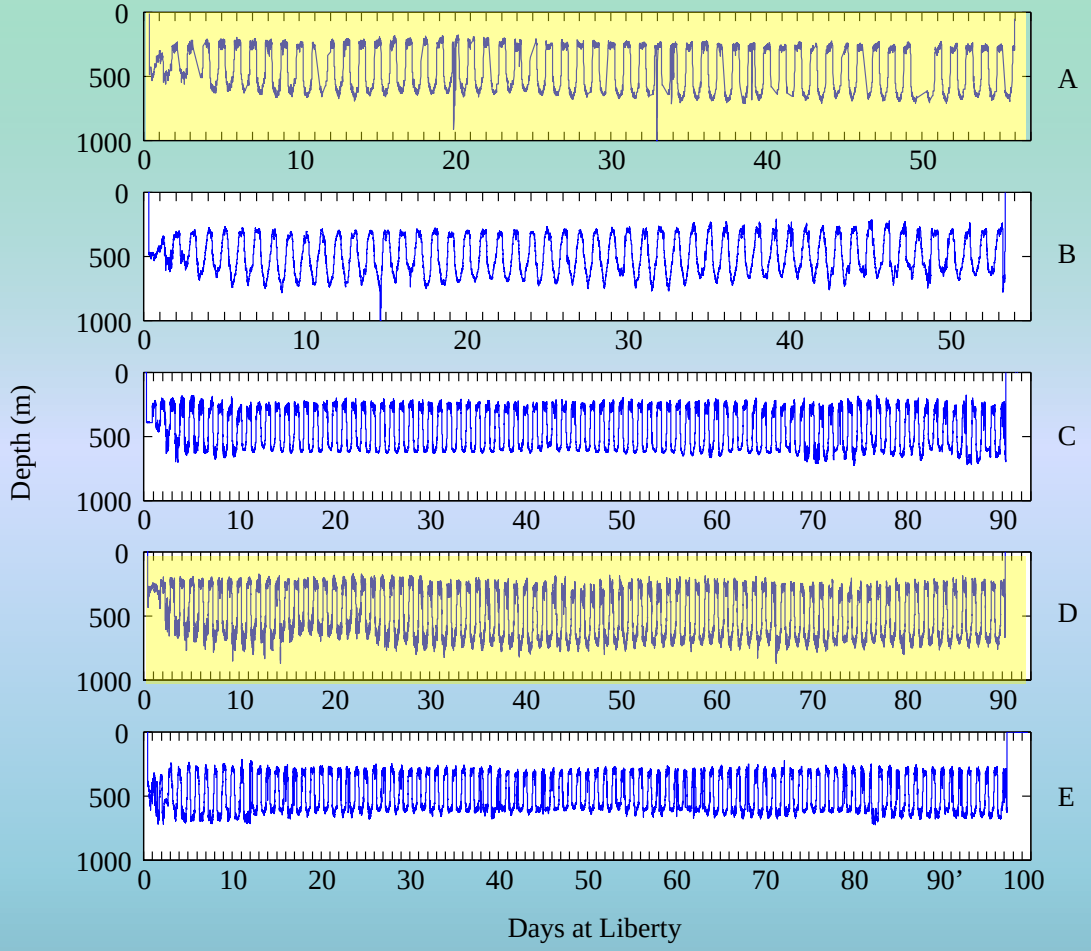
Hawaii Mapping Research Group, www.Soest.hawaii.edu/hmrg/cms



Andrews et al., 2010

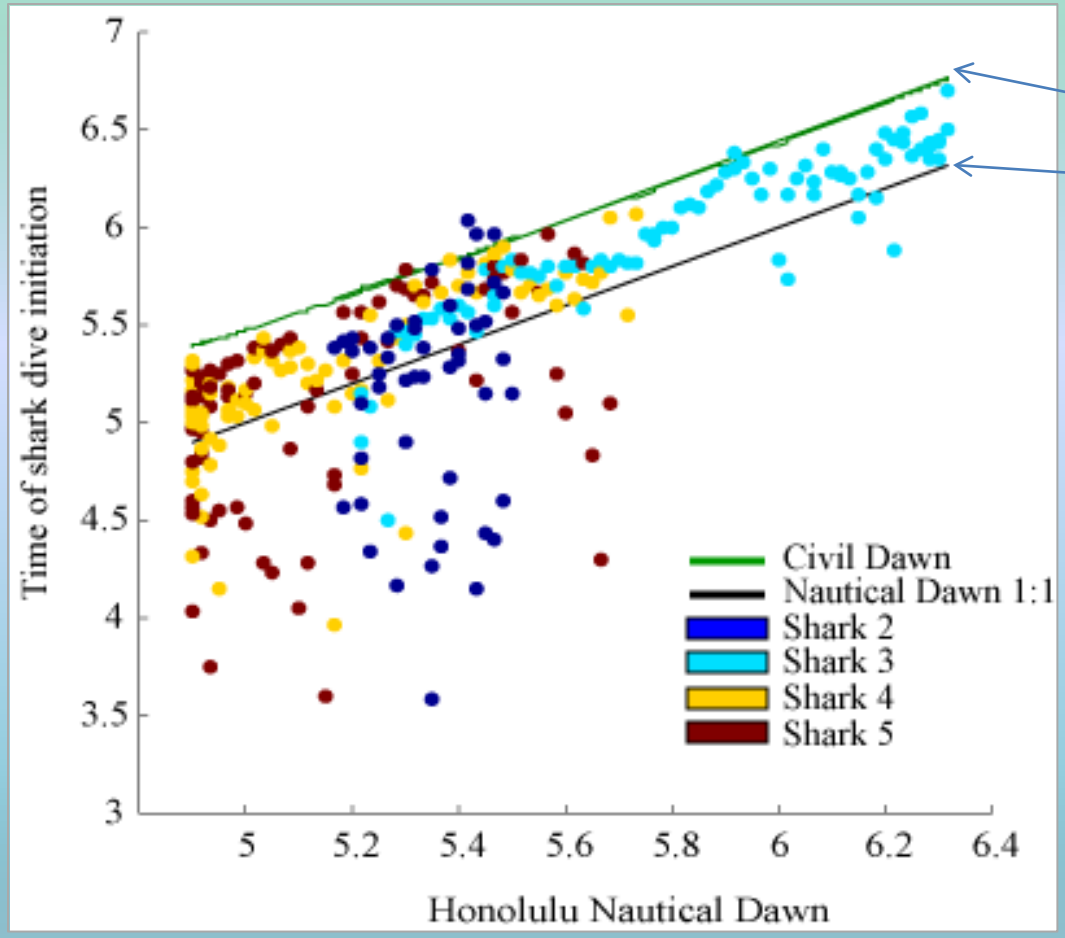
Did the sixgill sharks definitely move those long distances?

- No behavior change between sharks which crossed open ocean and ones that had pop-up locations on Oahu.
- Good Argos location qualities (at least 1)



Results: Dive initiation in Hawaii

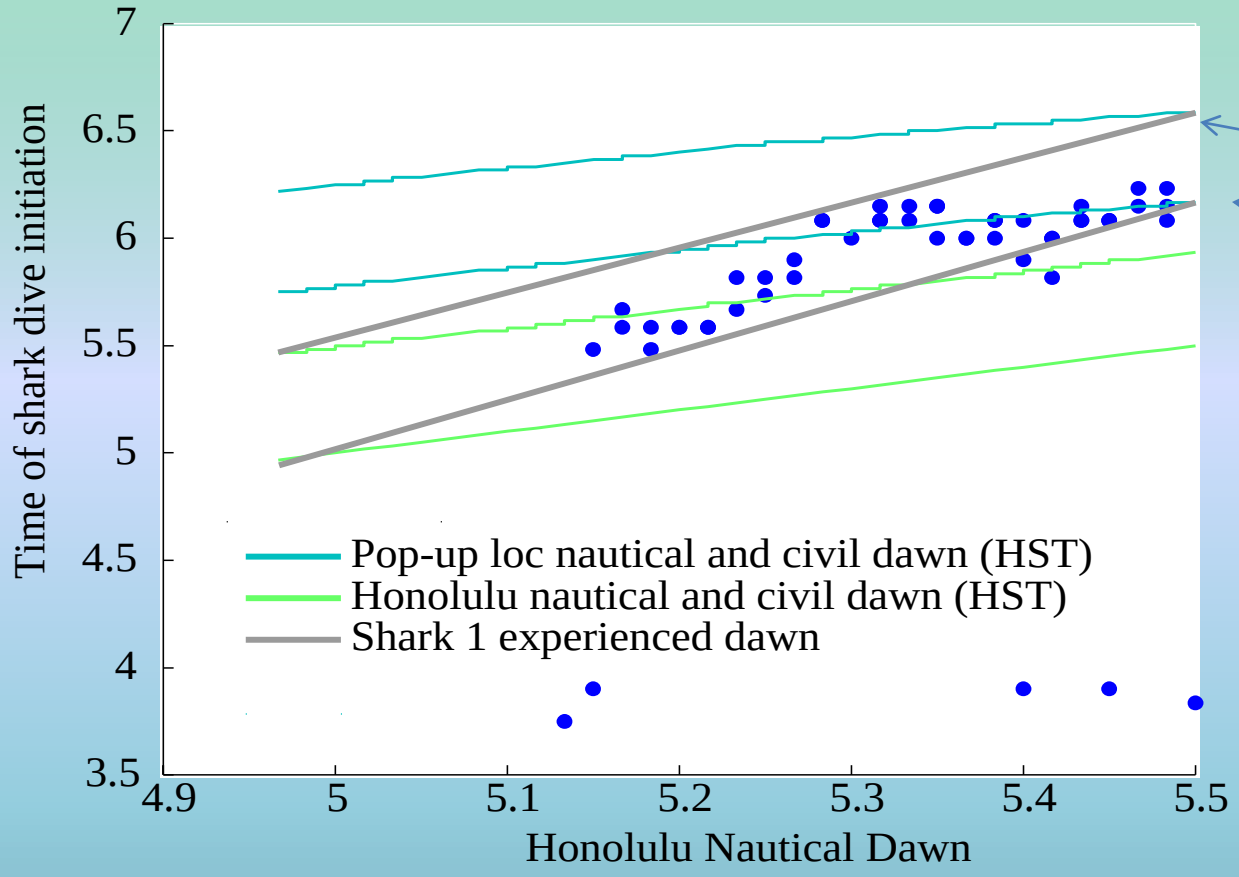
Sixgill sharks move to maintain a constant light level



Mostly before civil dawn and after nautical dawn

U.S. Naval Observatory, www.usno.navy.mil

Results: Dive initiation during a longitudinal shift (Shark 1)



Mostly before civil dawn and after nautical dawn

Project: Use dive initiation times to create a potential track from Hawaii to Johnston Atoll (longitude)

Summary: Sixgill shark movements and fishery interactions

- Sixgill sharks can cross deep channels and swim long distances in the pelagic + along shelf
  - May frequent a few locations
  - Connectivity between geographically distant habitats
  - Local fisheries have potential to impact more sharks, more ecosystems

- Fishery interactions
  - Sport, non-target but valuable for oil, meat
  - Directed fisheries being explored in British Columbia, India (Akhilesh et al., 2011)
    - 2000-2002: Deep sea elasmobranchs were <2% of catch in India's shark fishery
    - 2006-2007: Over 50%, but overall catch is lower - depletion

Implications for management

- Depending on level of individual movement between locations and gene flow….
  - Fishing could wipe out a seamount population, or it could be repopulated.
  - Genetics studies are needed to determine gene flow between distant habitats
  - More tagging studies can help to better understand individual movements + habitat use

Carey and Clark, 1995

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...+ more!!!

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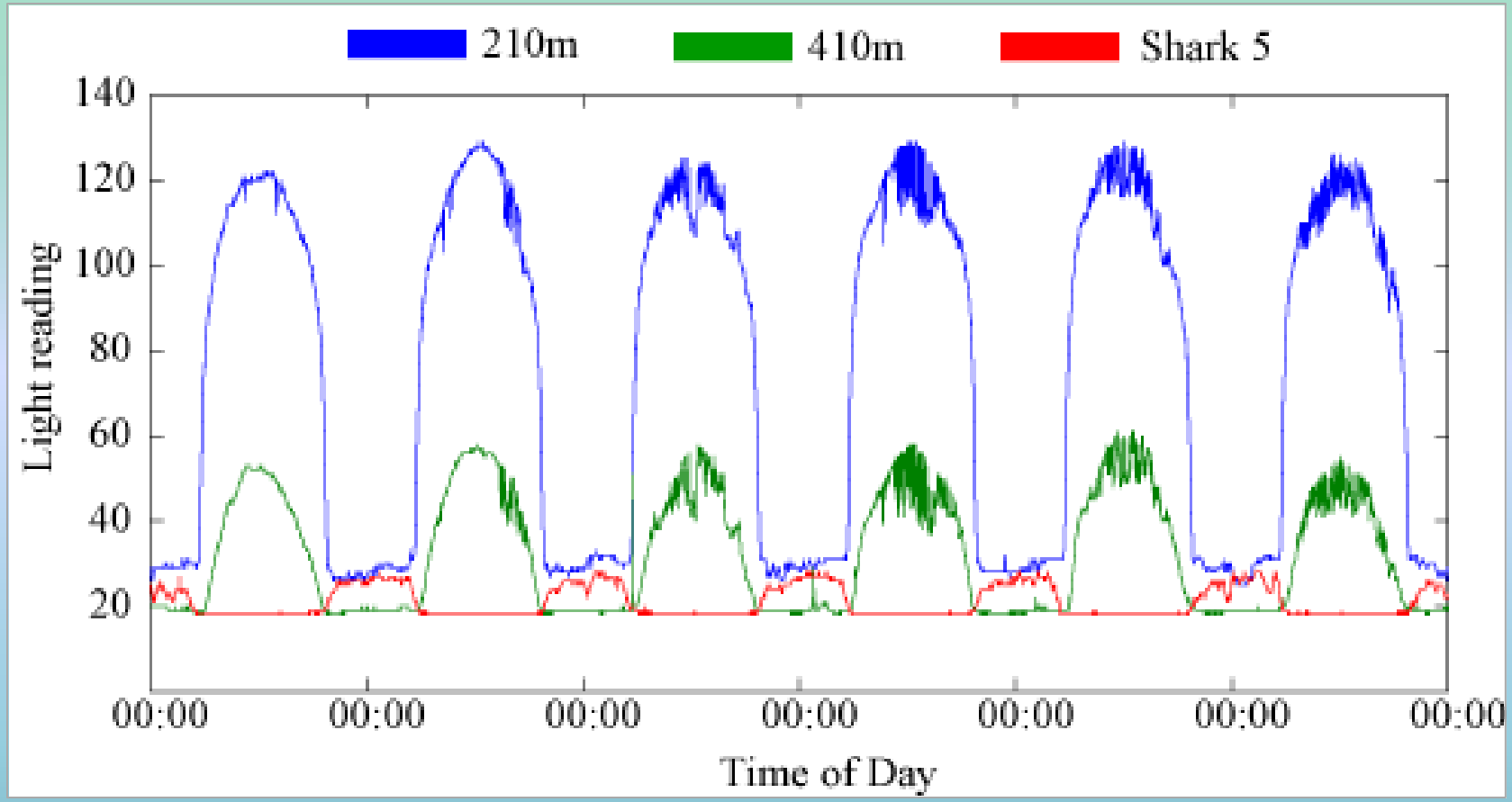
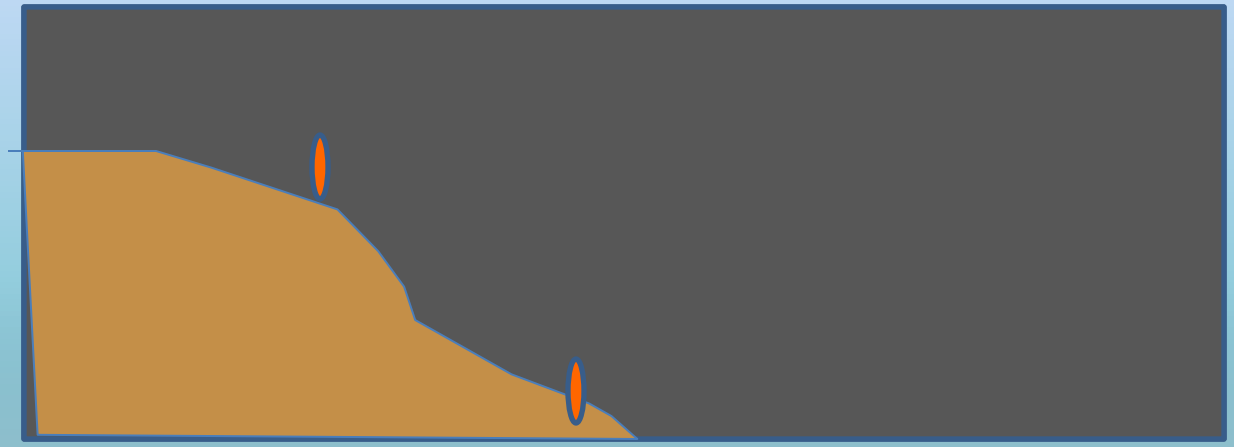
Thank you! Questions?

Photo : David Slater


210m
410m
Shark 5
140
120
100
80
60
40
20
Light reading
00:00
00:00
00:00
00:00
00:00
00:00
00:00
Time of Day

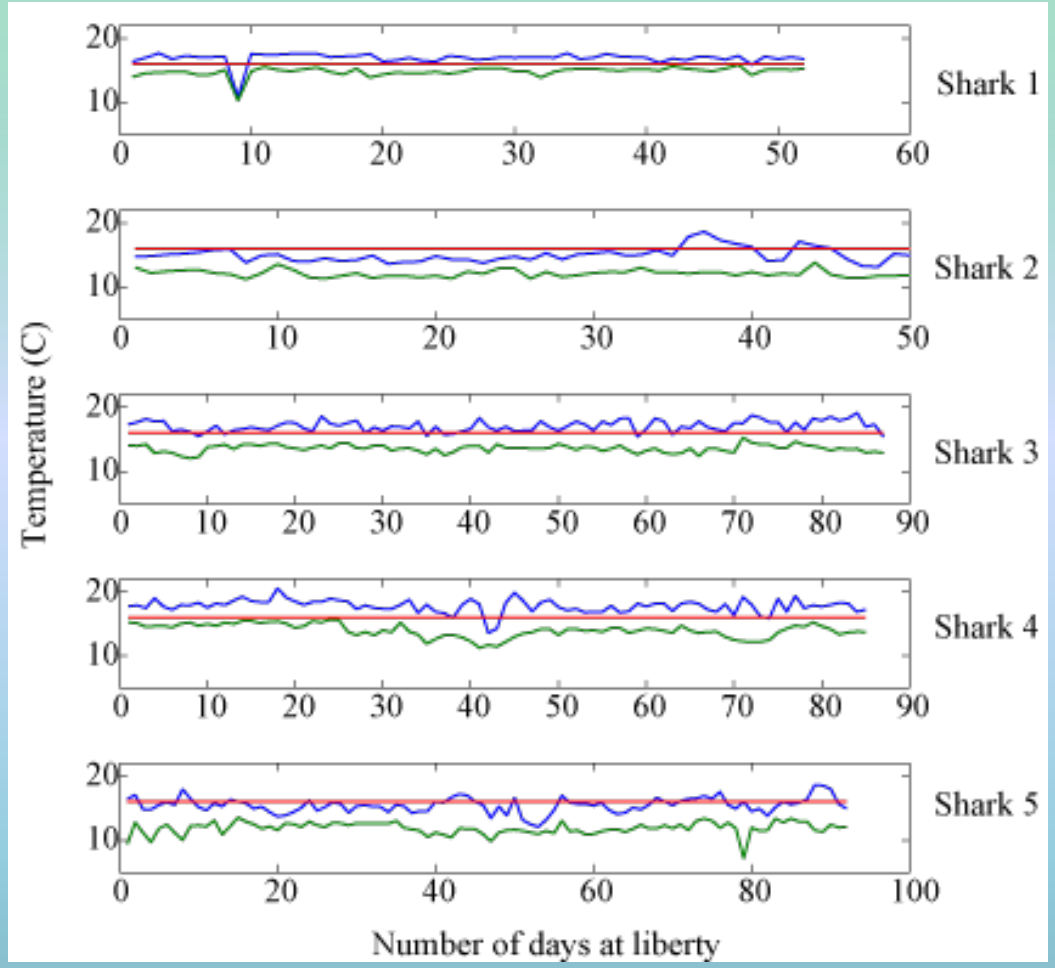
Methods: Data analysis

- Light
  - Deep deployments of MiniPAT tags at constant depth
    - Determine natural light variability at 210 and 410m
    - Compare to tagged shark records
  - Pinpoint initiation of daytime dive
  - Compare observations of sixgill shark light regimes in other habitats



Results: Warm excursions

Do oceanographic parameters define or influence sixgill shark depth habitat?



- All sharks swam above 16C
- Very common for 1, 3, 4.
- Highest observed temperatures: 17.X-19.05
- In Puget Sound, observed up to 16 C (surface waters in summer) (Dunbrack)

Results: Depth, temperature, and O2

- Diel vertical migrations
- Steep dawn dive; same angle!

- Spend day in OMZ: ~50% of total time
- Excursions to water warmer than 16°C
  - Up to two hours
  - Up to 19°C