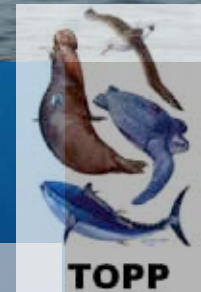
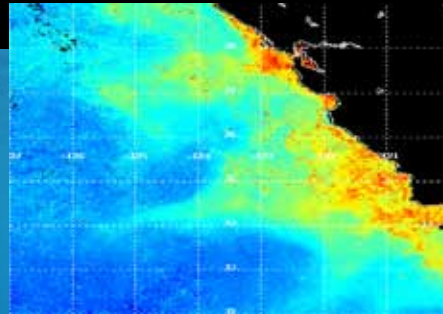


# Migration and Behavior of White Sharks in the North Eastern Pacific

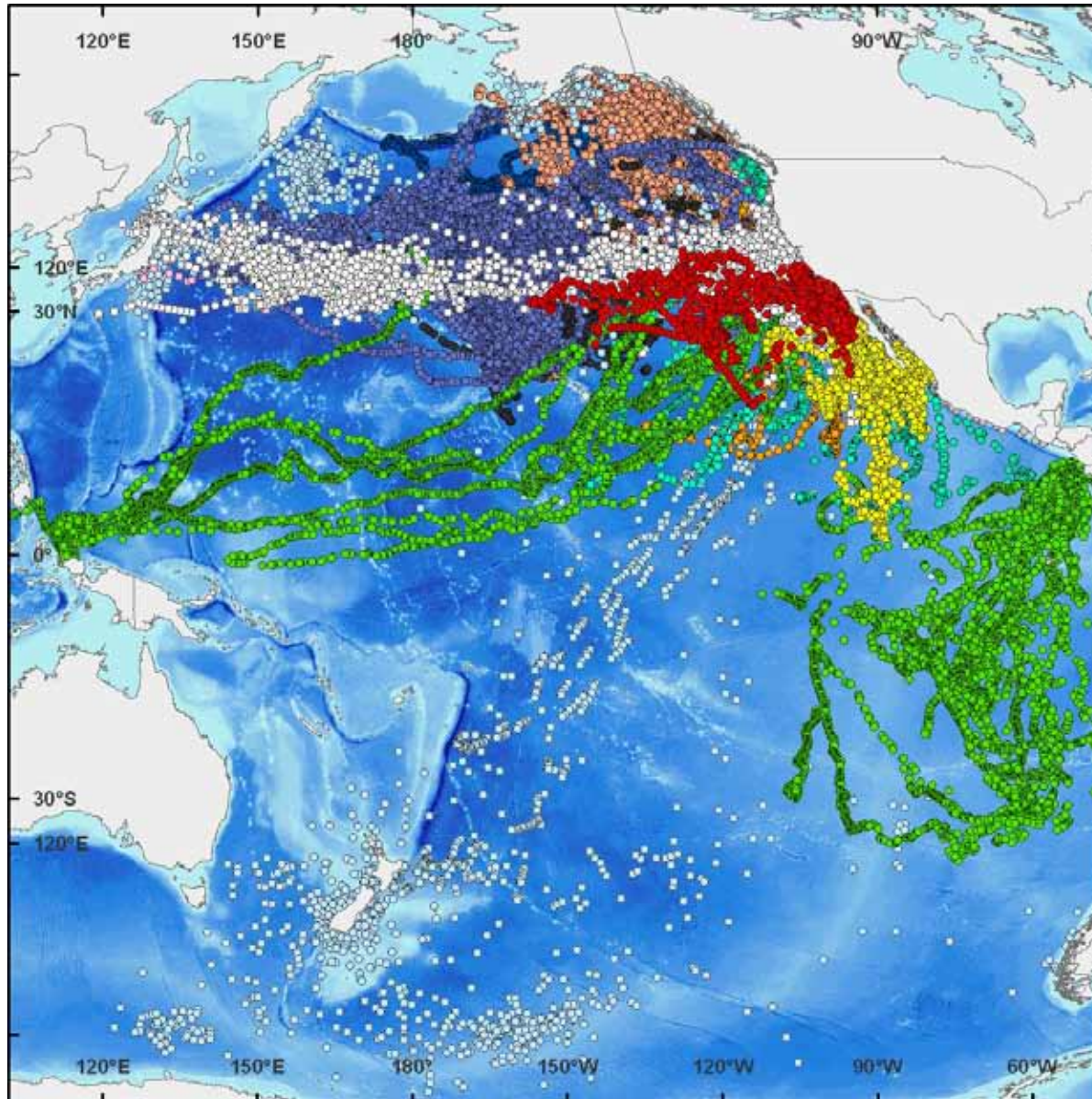
Jorgensen, SJ  
Reeb, C  
Chapple, TK  
Anderson, S  
Perle, C  
Klimley, AP  
Block, BA



  
MONTEREY BAY AQUARIUM

**TOPP**

# Tagging of Pacific Pelagics TOPP



- Black-footed Albatross
- Blue Whale
- California Sea Lion
- Humpback Whale
- Laysan Albatross
- Northern Elephant Seal
- Sooty Shearwater
- Albacore
- Blue Shark
- Humboldt Squid
- Leatherback Turtle
- Loggerhead Turtle
- Mako Shark
- Mola
- Pacific Bluefin
- Salmon Shark
- Thresher Shark
- White Shark
- Yellowfin Tuna

# White sharks

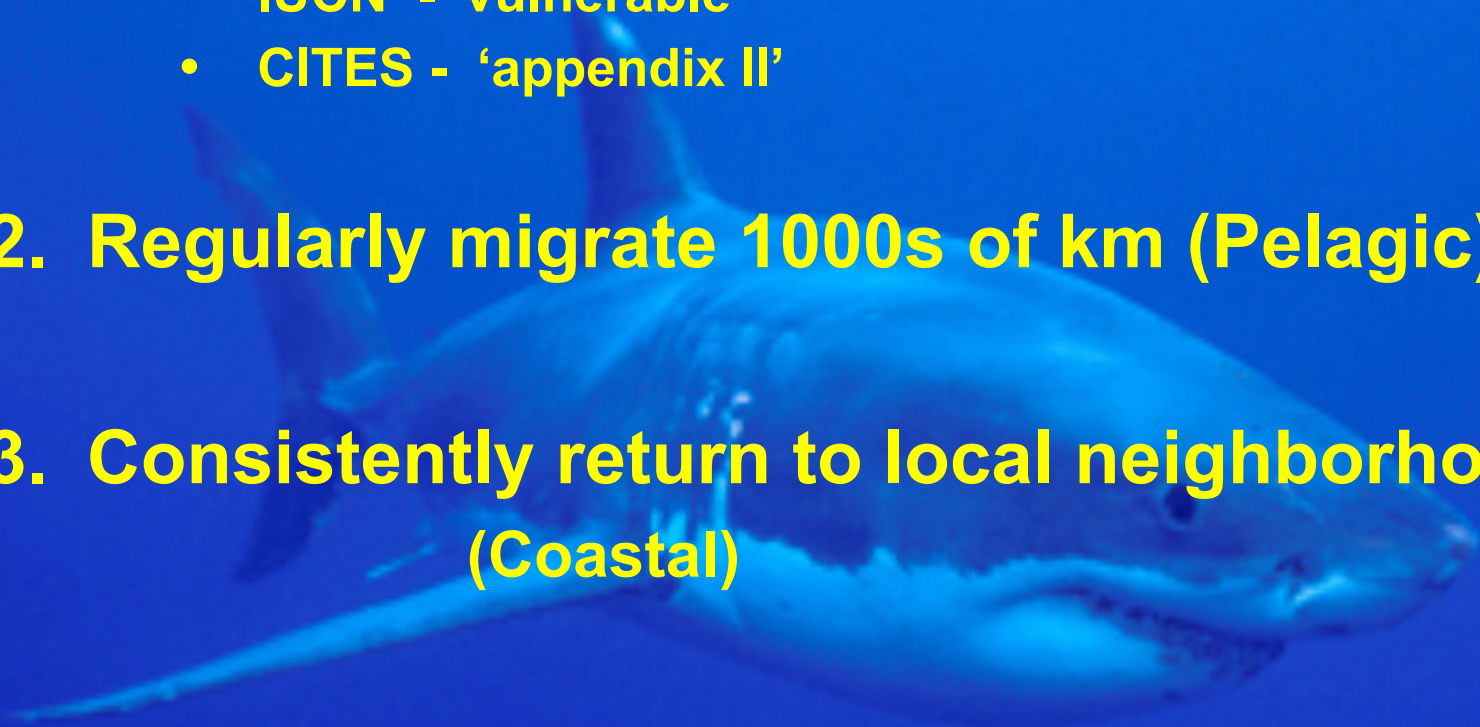
## 1. White shark conservation status:

- IUCN - 'vulnerable'
- CITES - 'appendix II'

## 2. Regularly migrate 1000s of km (Pelagic)

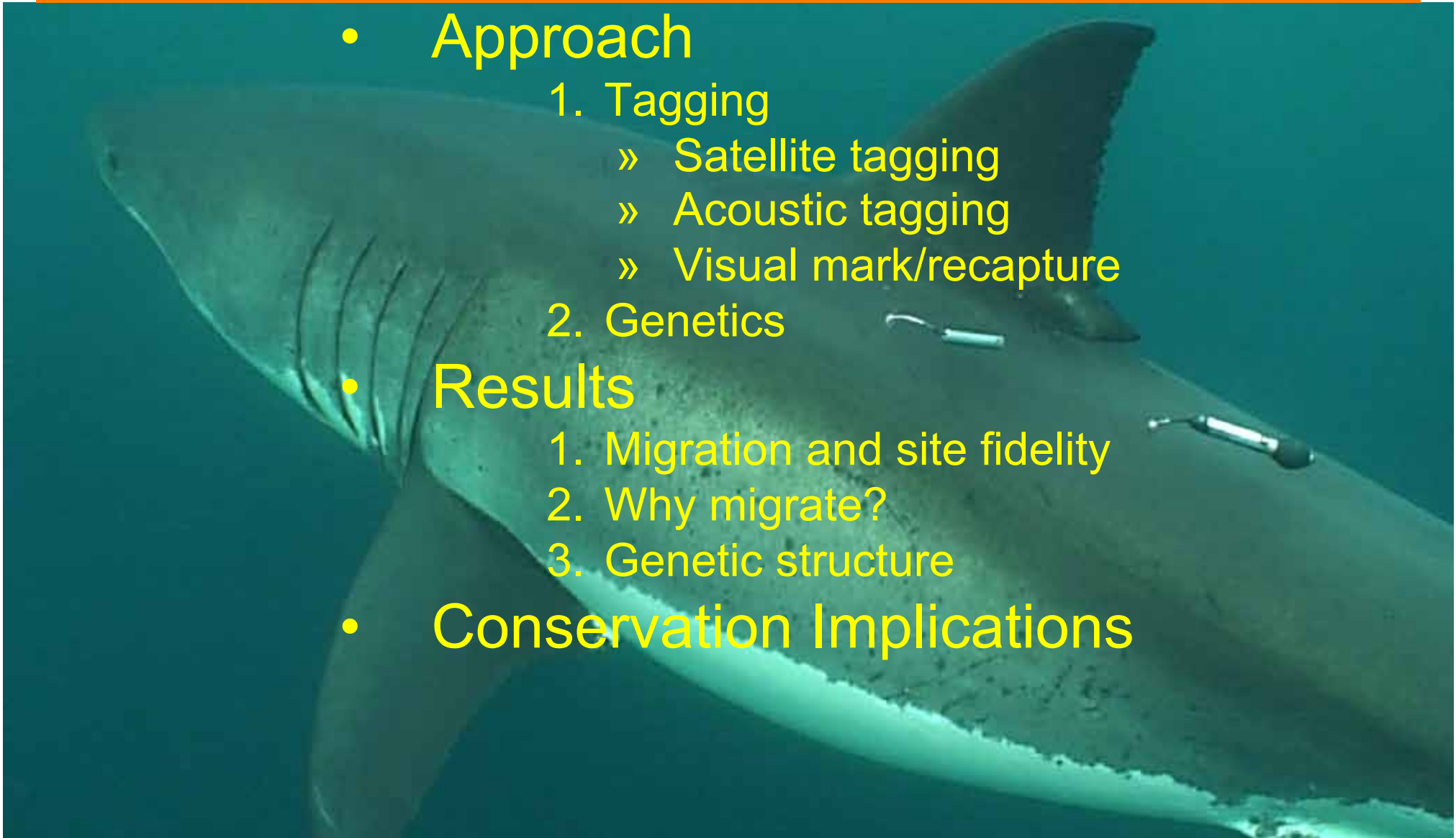
## 3. Consistently return to local neighborhoods (Coastal)

## 4. Isolated population in the Eastern Pacific



# Overview

- Approach
  1. Tagging
    - » Satellite tagging
    - » Acoustic tagging
    - » Visual mark/recapture
  2. Genetics
- Results
  1. Migration and site fidelity
  2. Why migrate?
  3. Genetic structure
- Conservation Implications



# Early data on white sharks

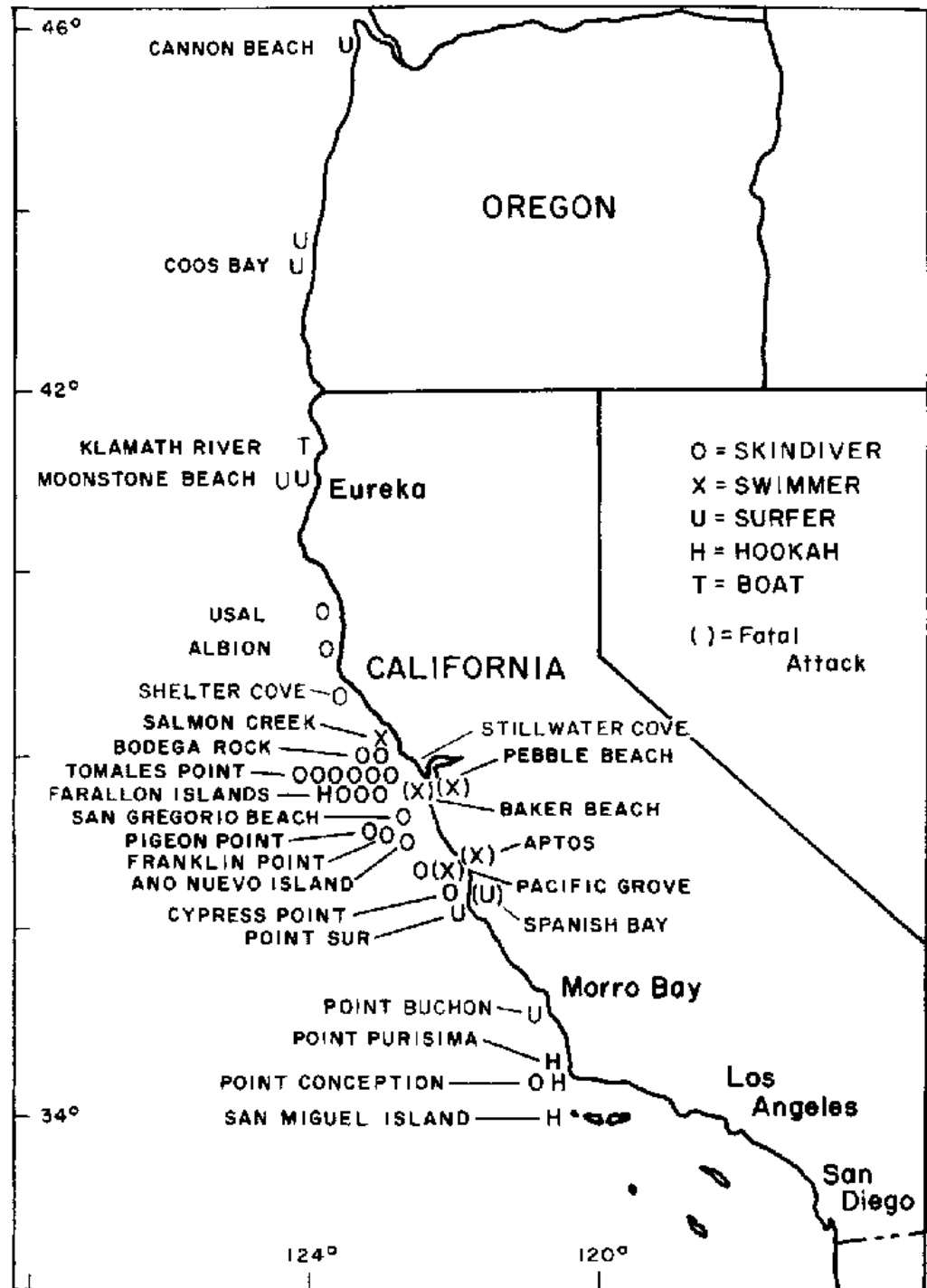
- Length at Birth      1.2 – 1.5 m (4ft)      - Francis 1996
- Maximum length      6.4 m (21ft)      - Ebert 2003
- Maximum age      ~ 27 years      - Cailliet 1985
- Reproductive age      9-10 years      - Cailliet 1985
- Litter size      3 – 14      - Francis 1996



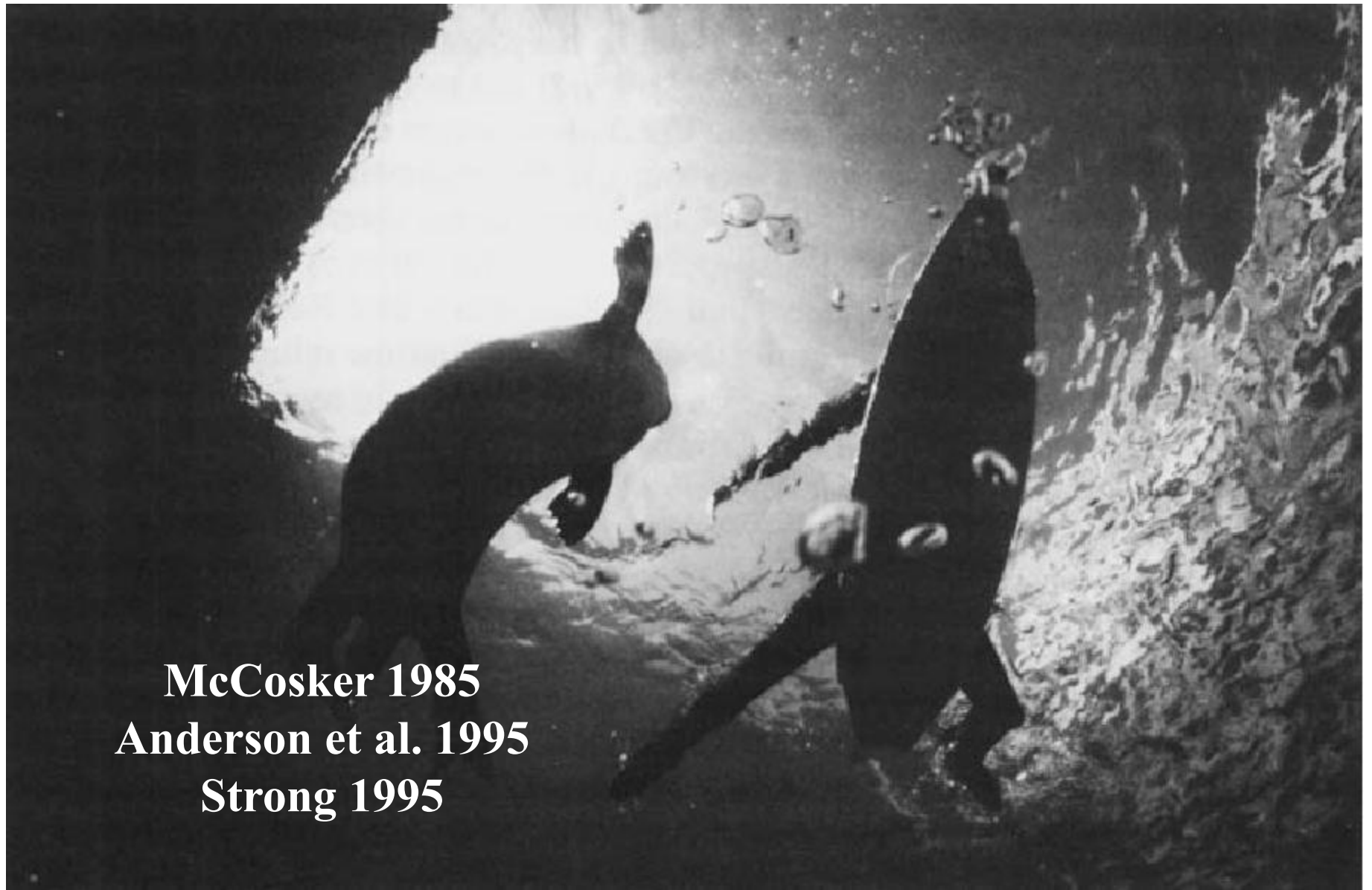
**Captured in Cuba  
mid 1940's**

# White shark attacks mapped

- Klimley 1985



# White sharks - visual predators



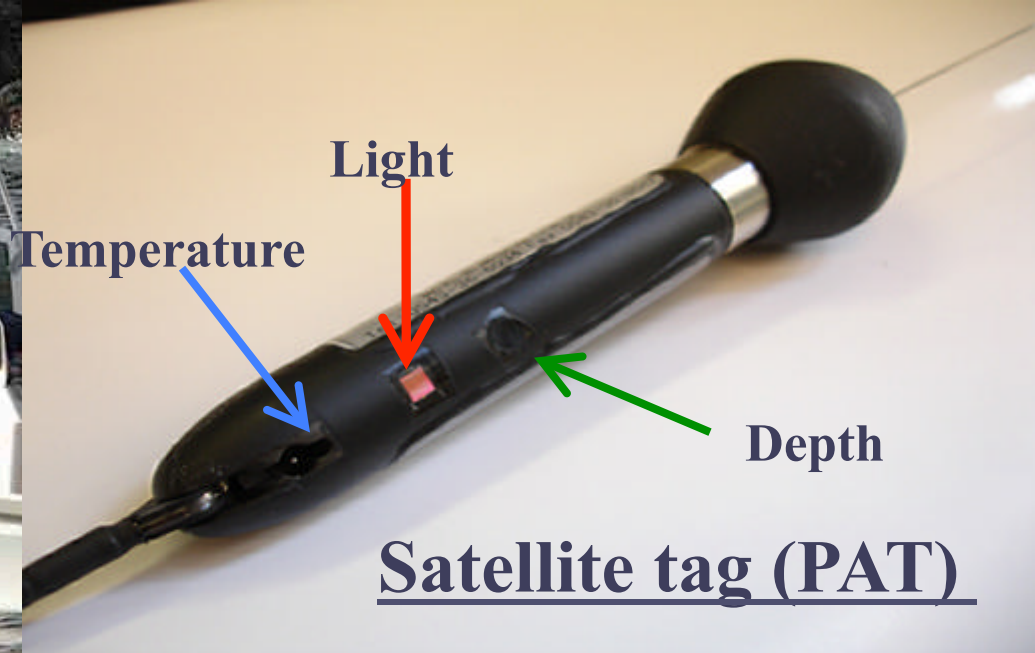
**McCosker 1985**

**Anderson et al. 1995**

**Strong 1995**

# Tagging

Seal decoy

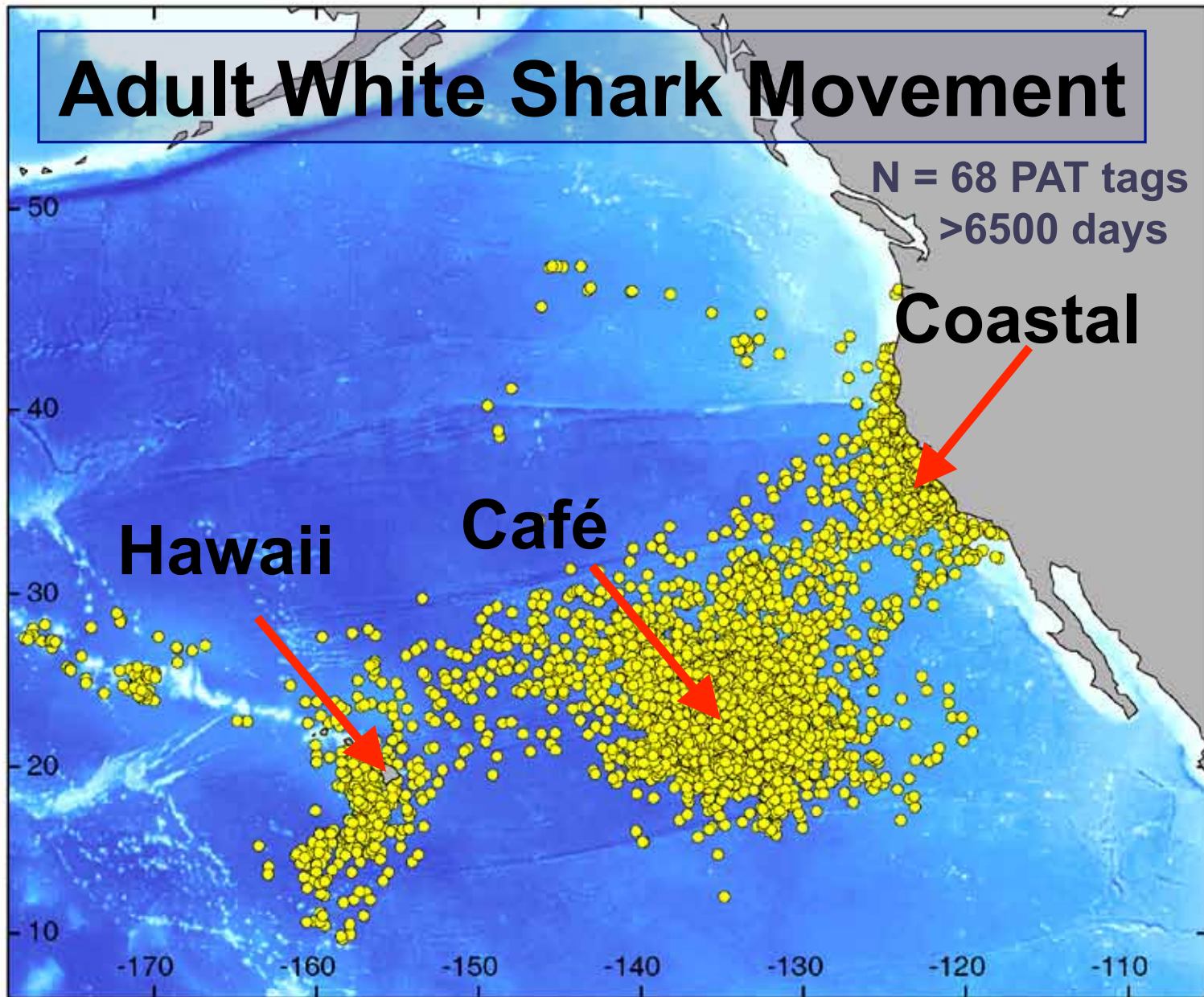


Satellite tag (PAT)



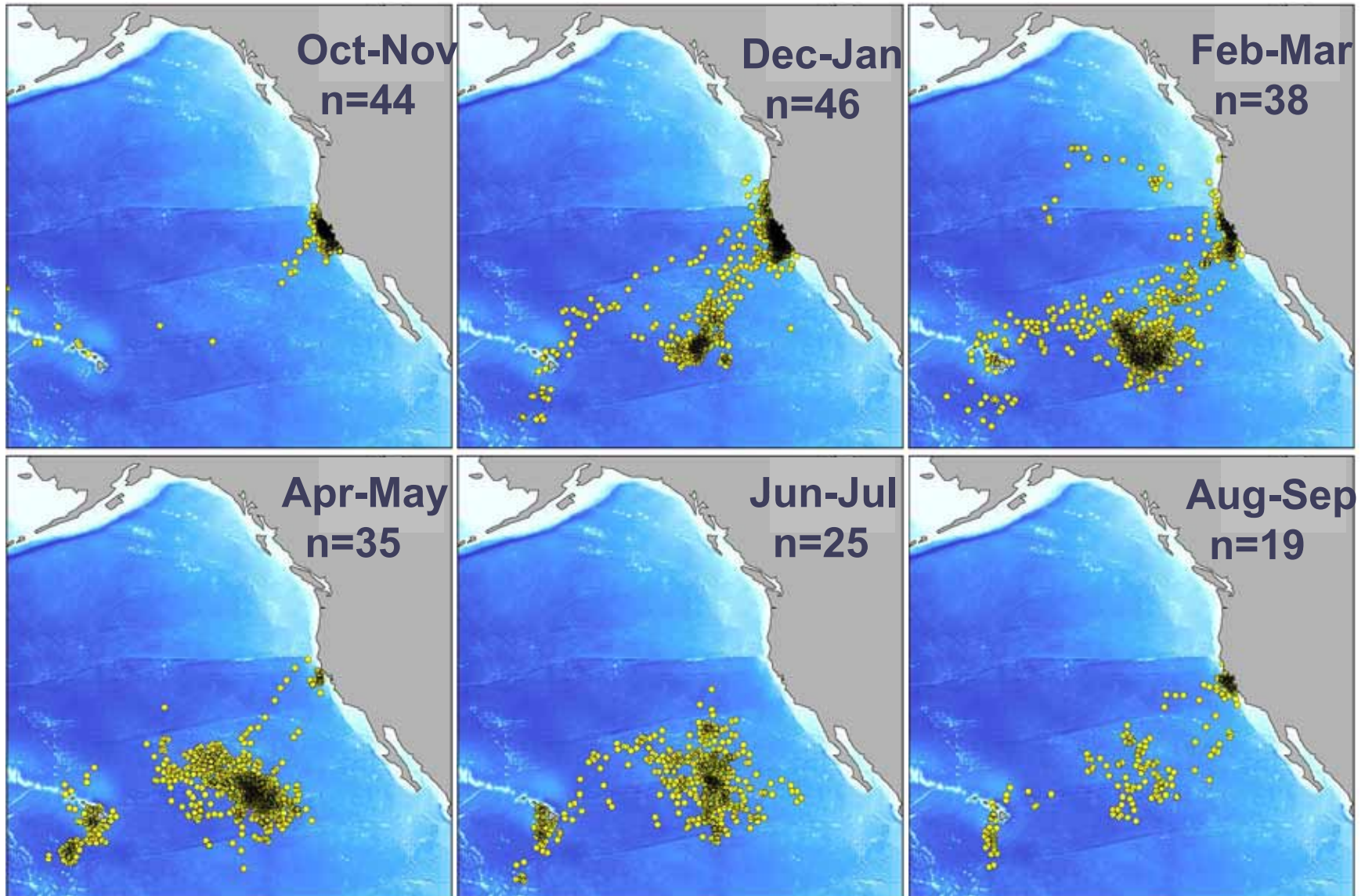


# Adult White Shark Movement

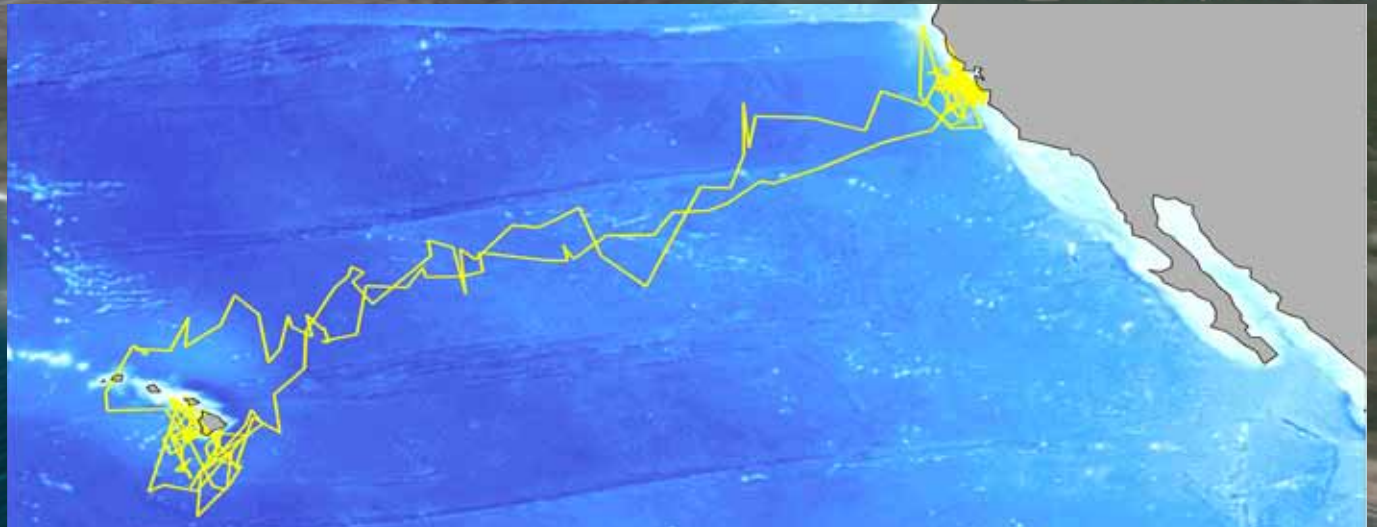


*Jorgensen et al. Proceedings of the Royal Society. 2010;  
Boustany et al 2002; Weng et al 2006*

# Seasonal Adult White Shark Migrations



# White Shark Site fidelity



TAGGED Dec 15, 05

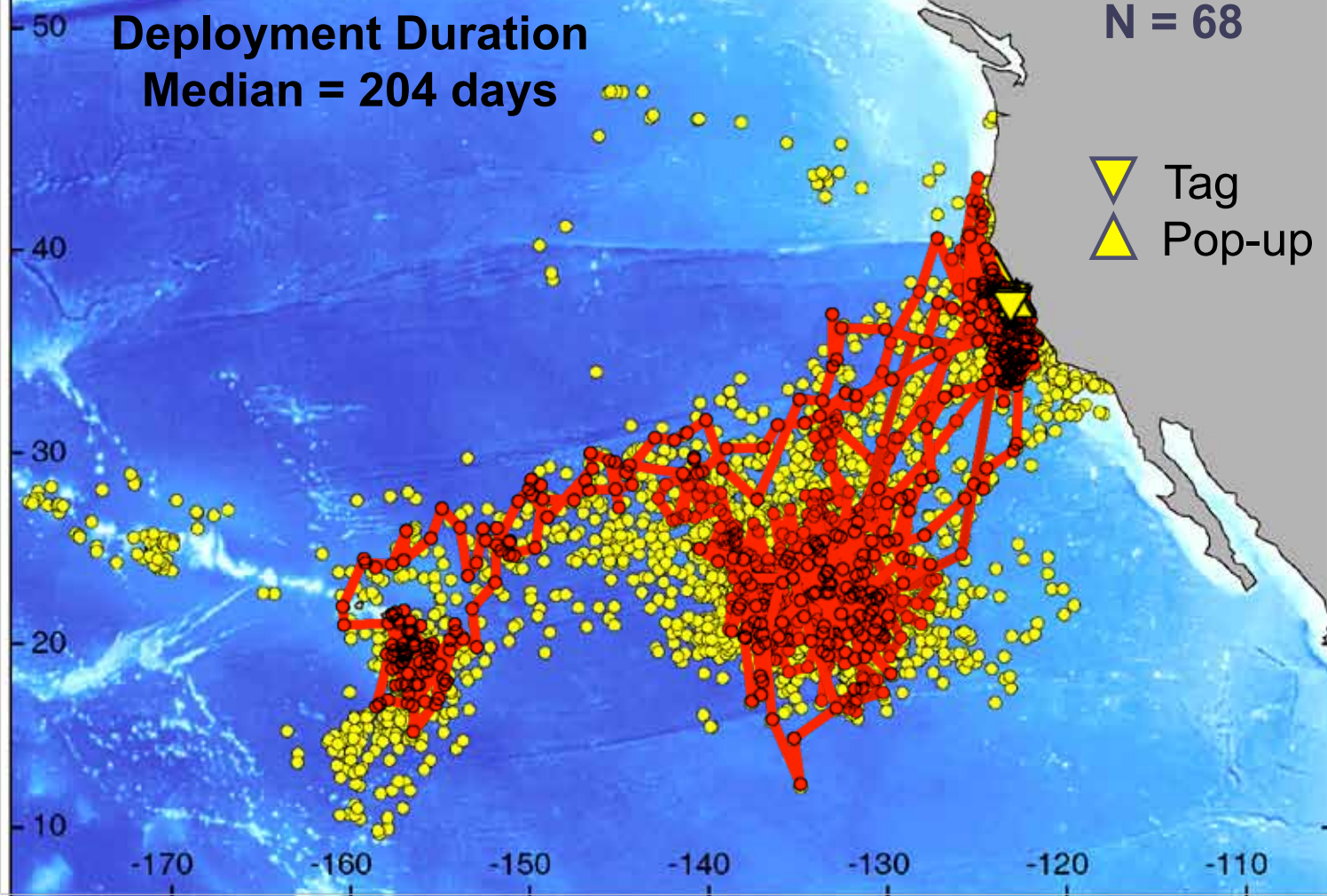
POP-UP Oct 11, 06

Ano Nuevo Island

Two red dots on the satellite map indicate the shark's location at two key points: one north of the study area labeled 'TAGGED Dec 15, 05' and another further south labeled 'POP-UP Oct 11, 06'. The text 'Ano Nuevo Island' is placed near the southern dot.



# Adult White Shark Movement



*Jorgensen et al. Proceedings of the Royal Society. 2010*

# Acoustic Tags and Receivers



Tags



Tomales pt.

Point Reyes

Farallones 2

Farallones 1

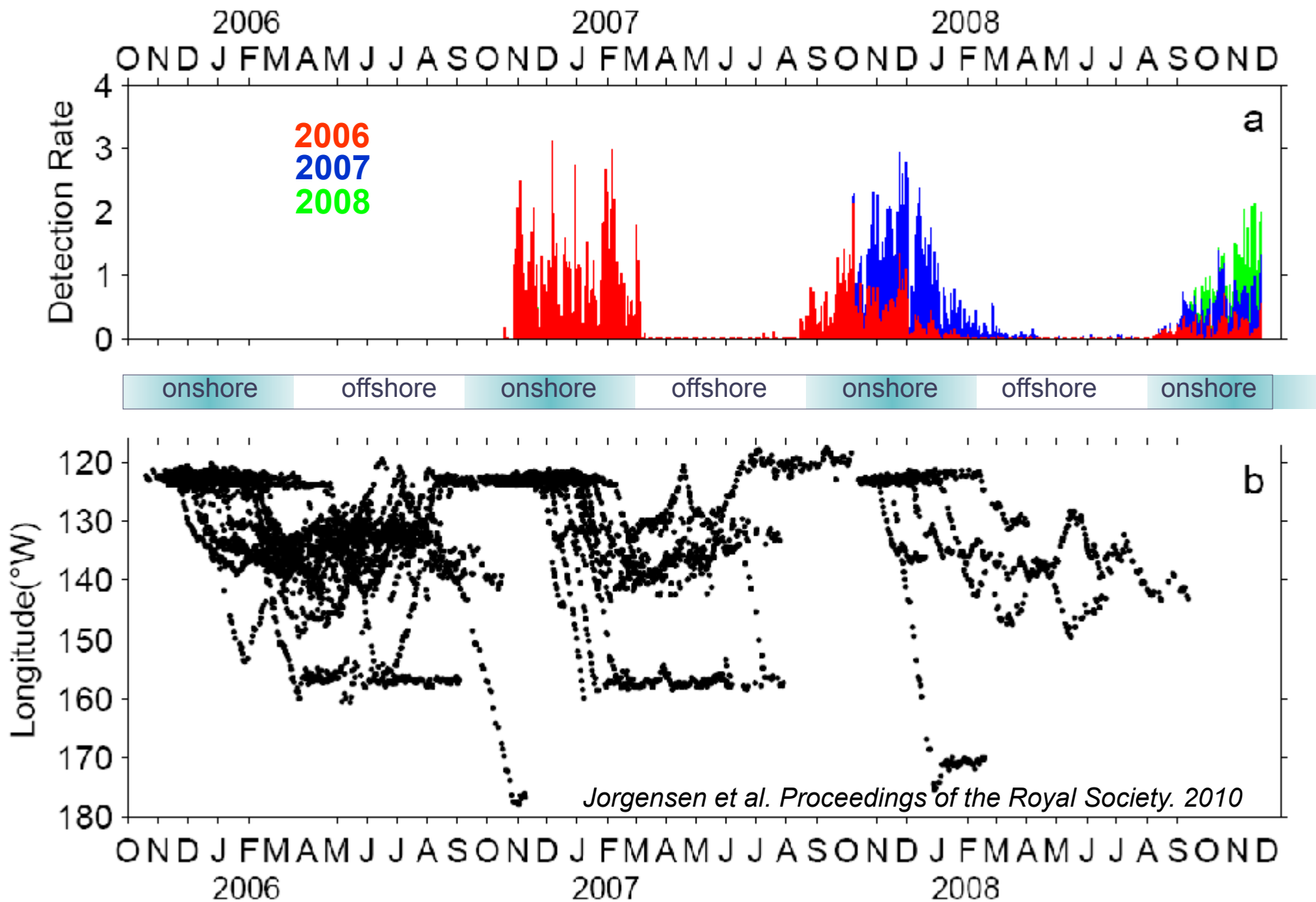
Angel Island

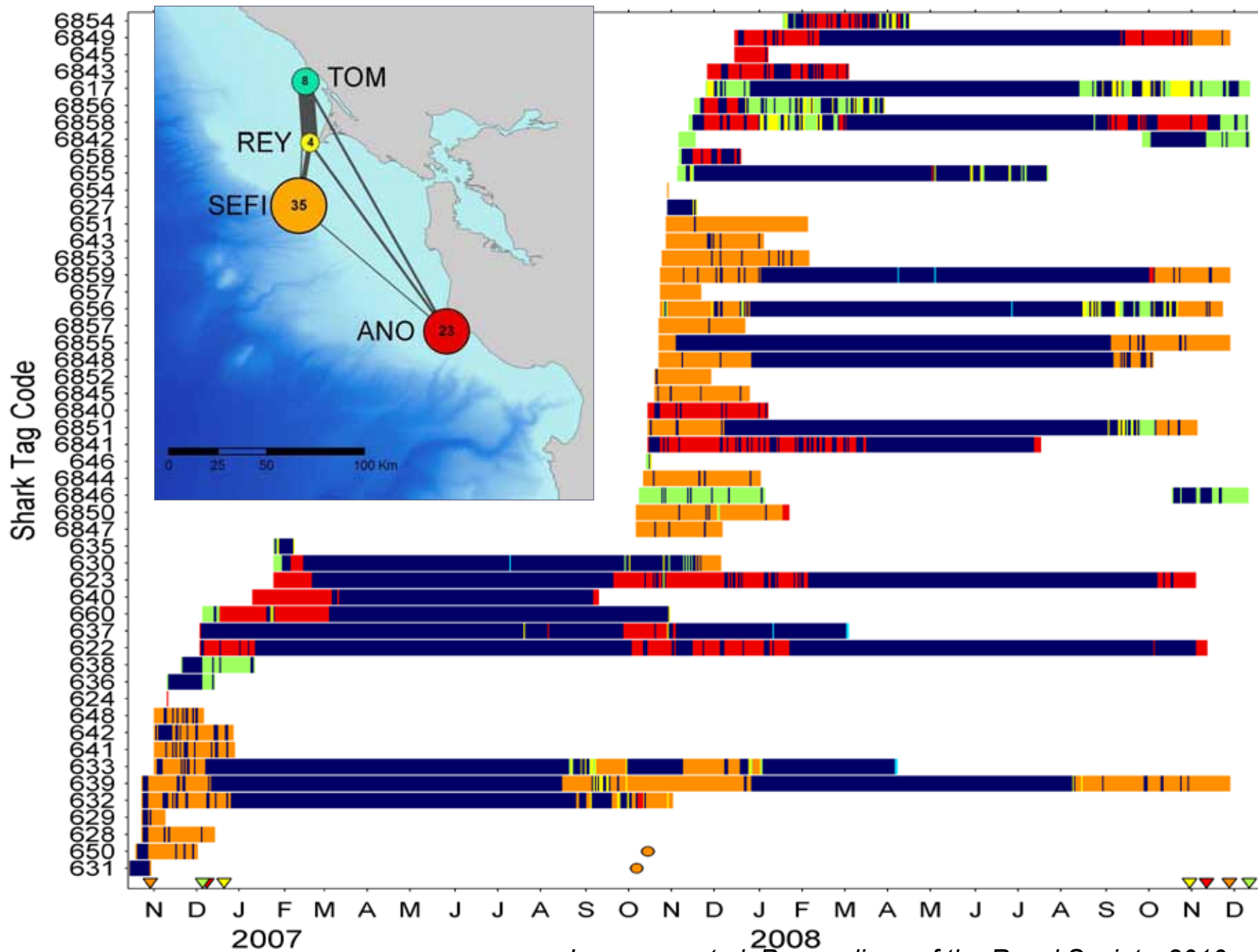
S.F.

100 miles

Ano Nuevo 2

Ano Nuevo 1





# Individual ID



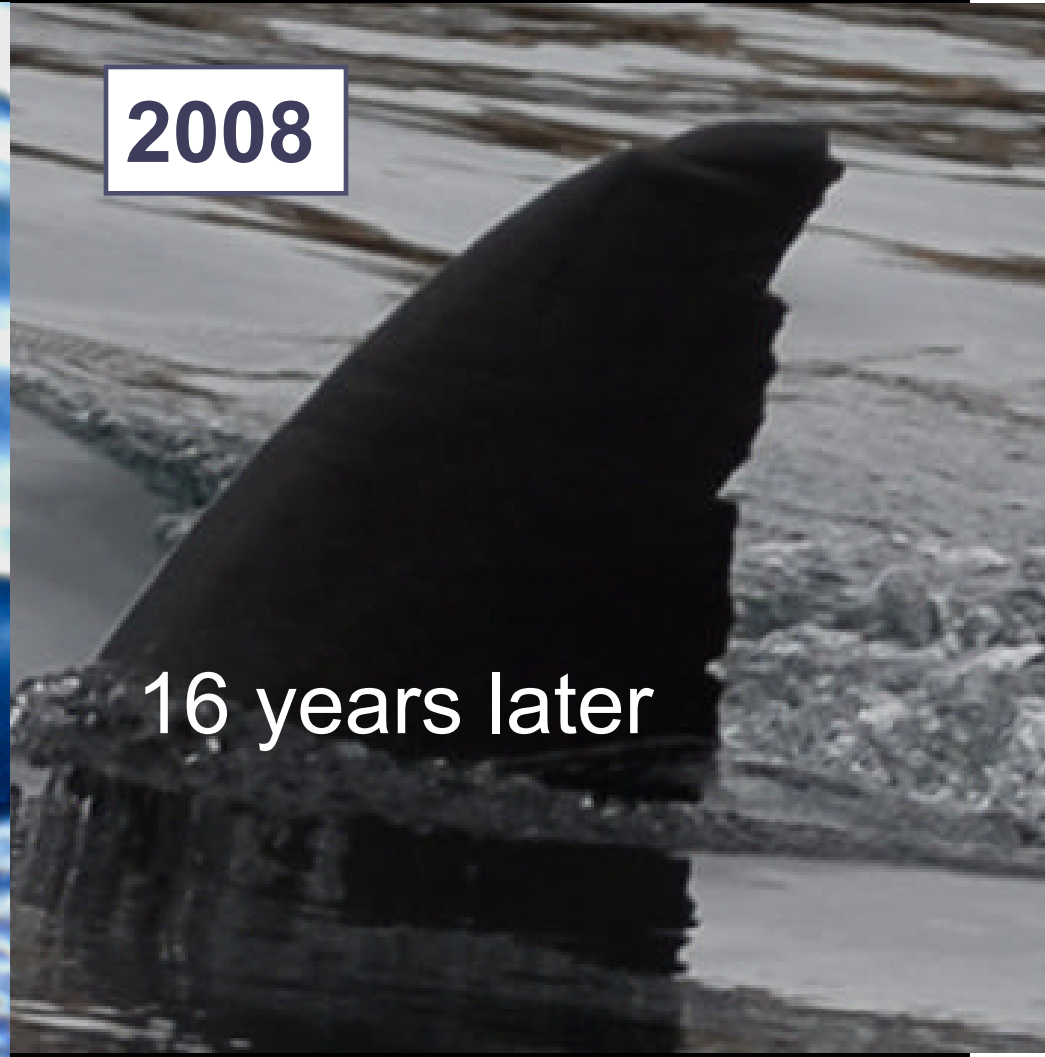


# Historical Fin Matches

1993



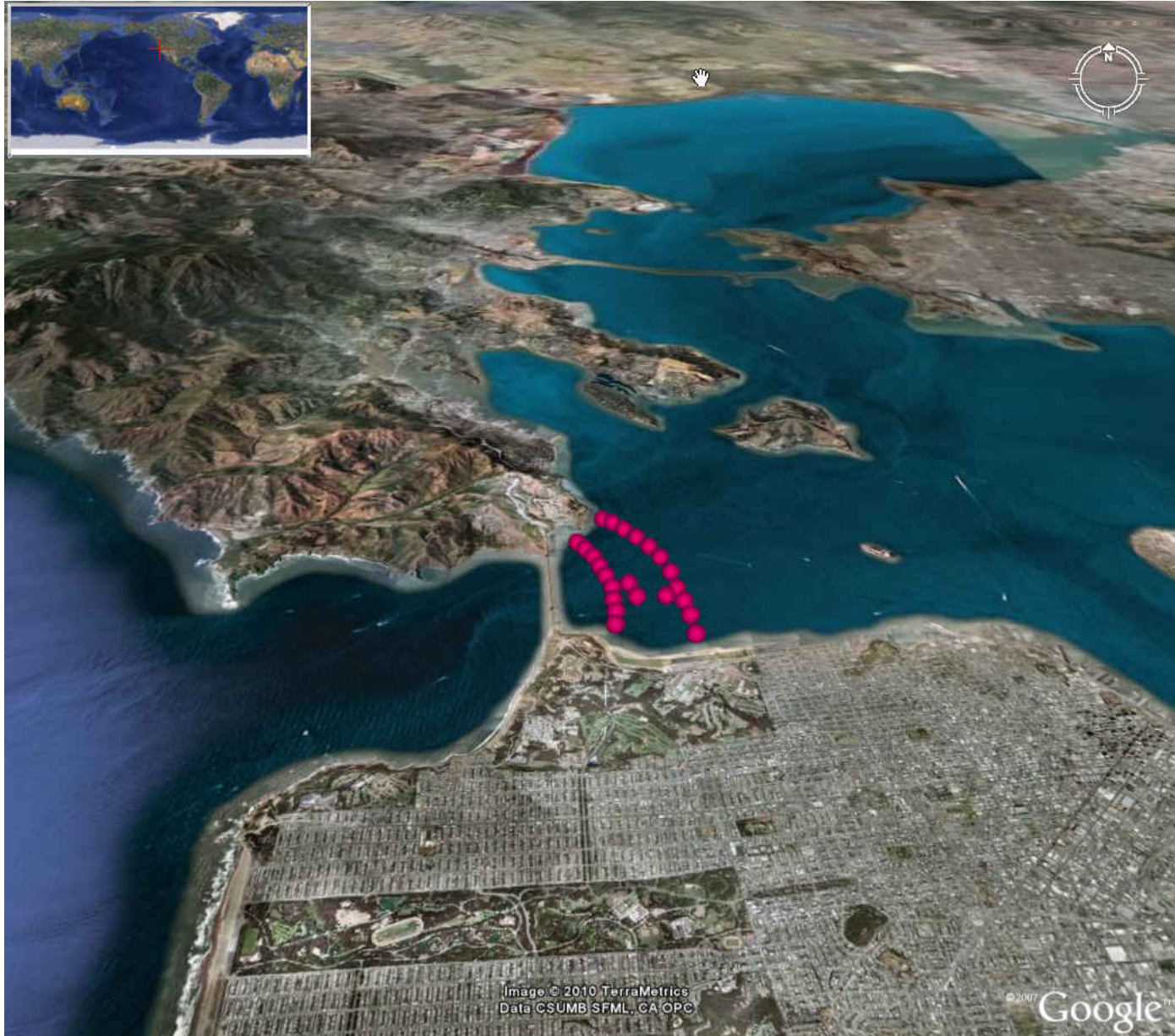
2008



16 years later

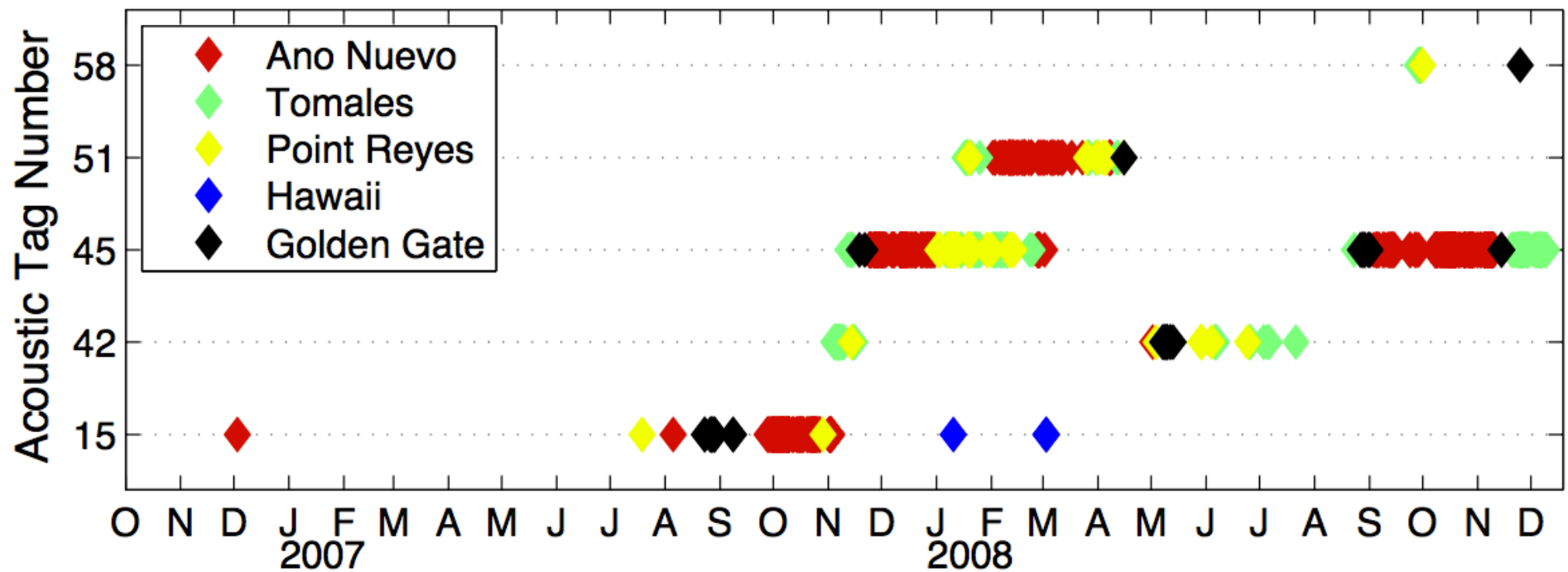
50% of re-sights > 6 years ; Longest = 23 years

# Acoustic receivers in San Francisco Bay



NOAA

# Five white sharks detected in San Francisco Bay



# White Sharks at the Golden Gate



Photoshop & Internet (2003)



Mega Shark v. Giant Octopus (2009)

# San Jose Mercury News



## Great white shark facts

*Carcharodon carcharias*

**Length:** Average is 15 feet; can grow to more than 21 feet

**Weight:** Up to 5,000 pounds

**Life span:** 20 years or more

**Speed:** Up to 25 mph for short distances

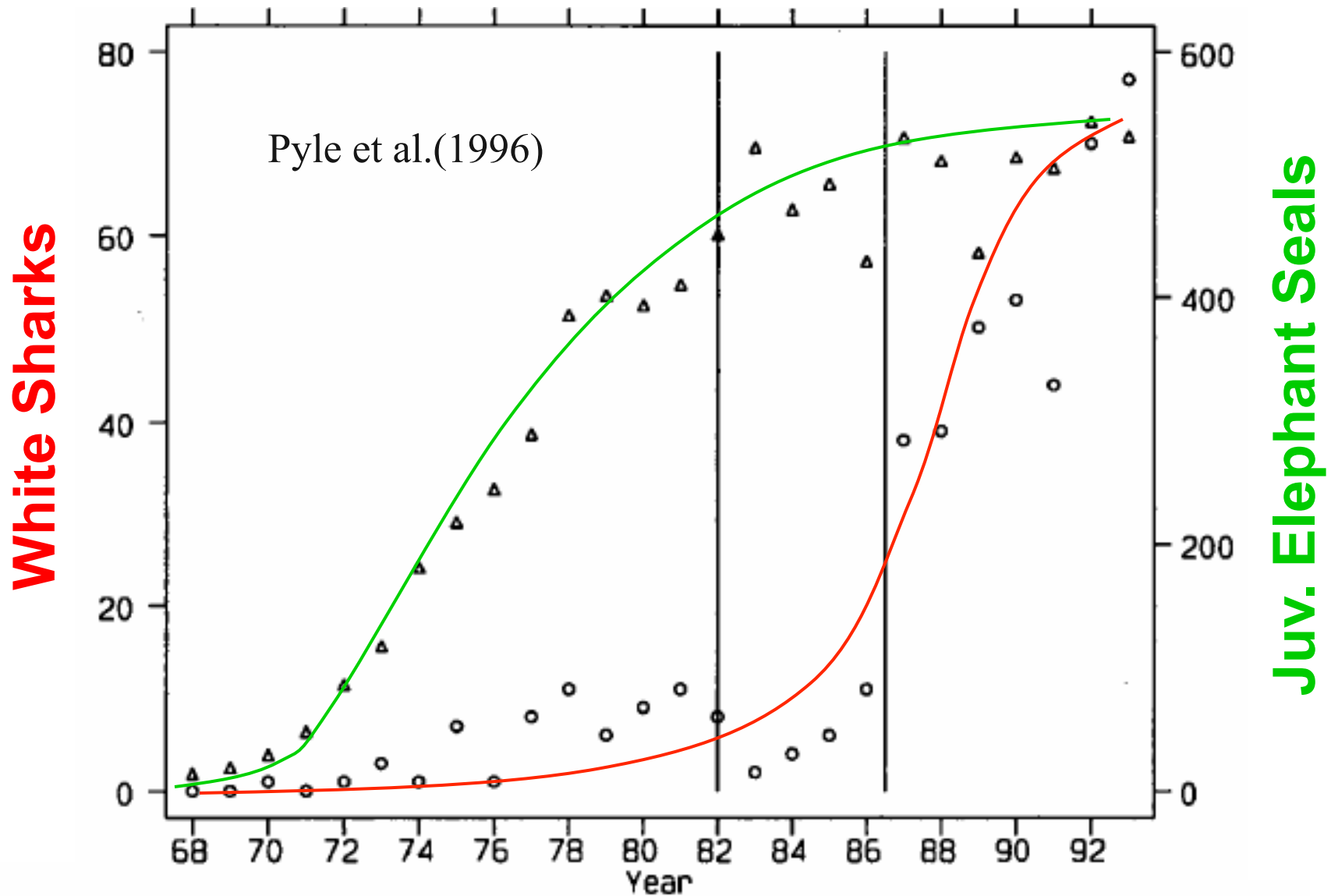
**Range:** Worldwide to ocean depths of 4,200 feet; highly migratory

**Diet:** Seals, sea lions, fish, dolphins and turtles

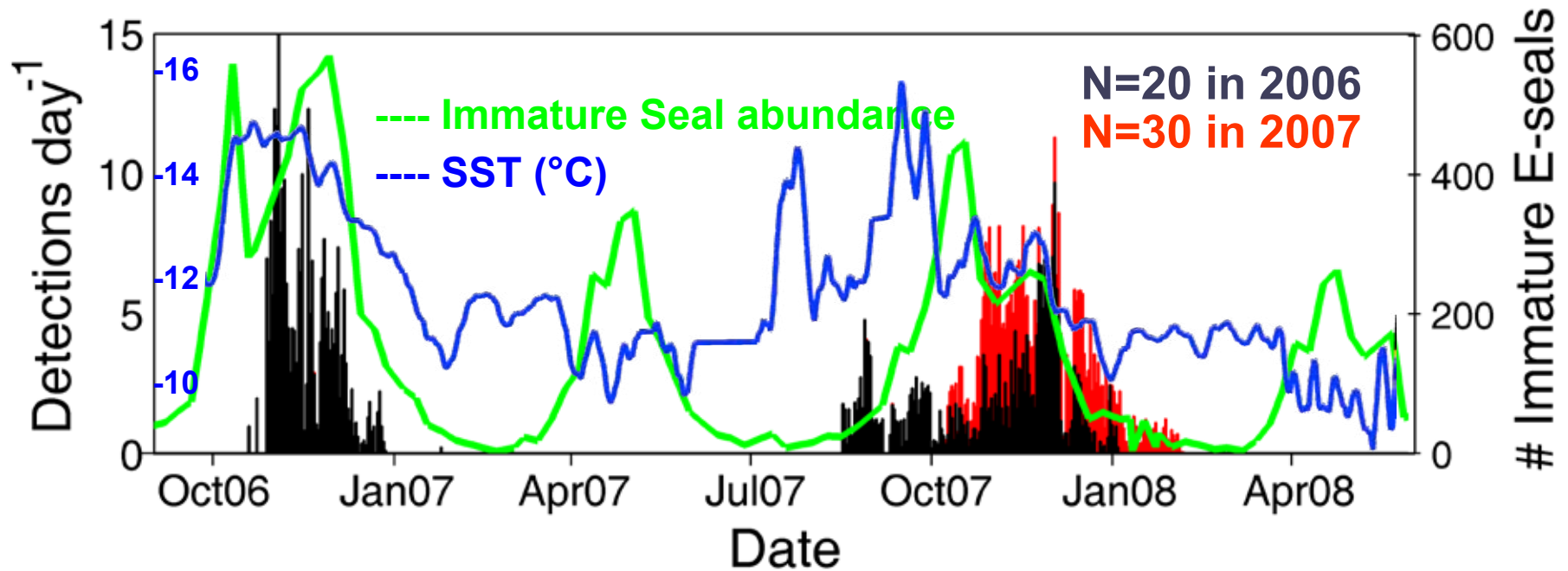
**Protection status:** Endangered

Tags send data to satellites and listening devices placed off the California coast.

# Predator / Prey Abundance at SEFI



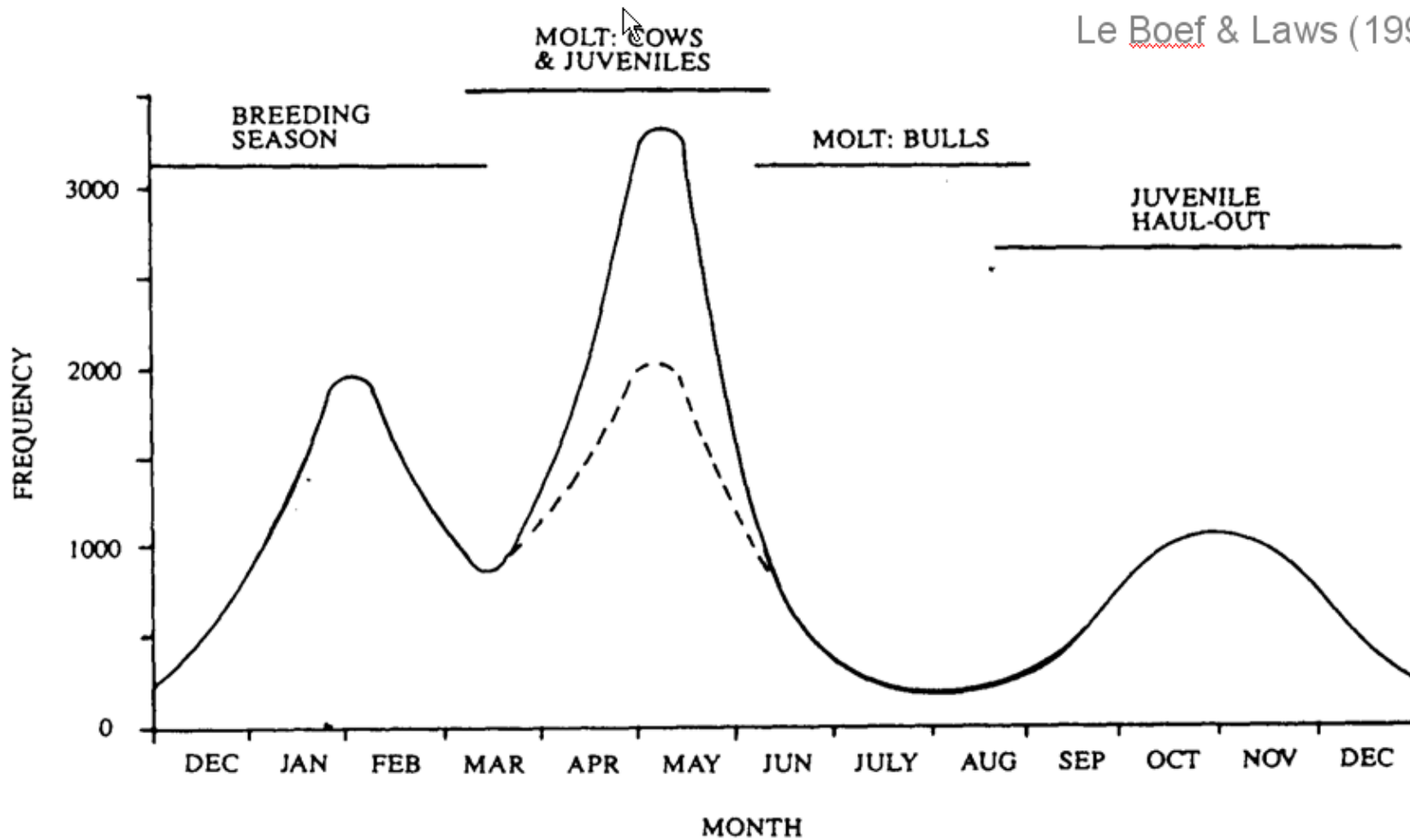
# White Sharks and Elephant Seals at SE Farallon Islands



- White sharks – endothermic (core temp. ~ 26° C)
- Trade-off ? Prey availability and cost of foraging in cold water

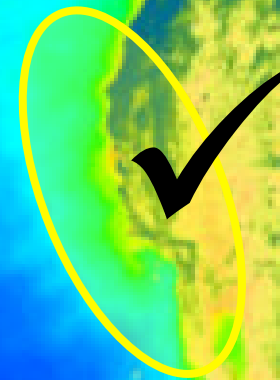
# Elephant seals at Año Nuevo

Le Boef & Laws (1994)

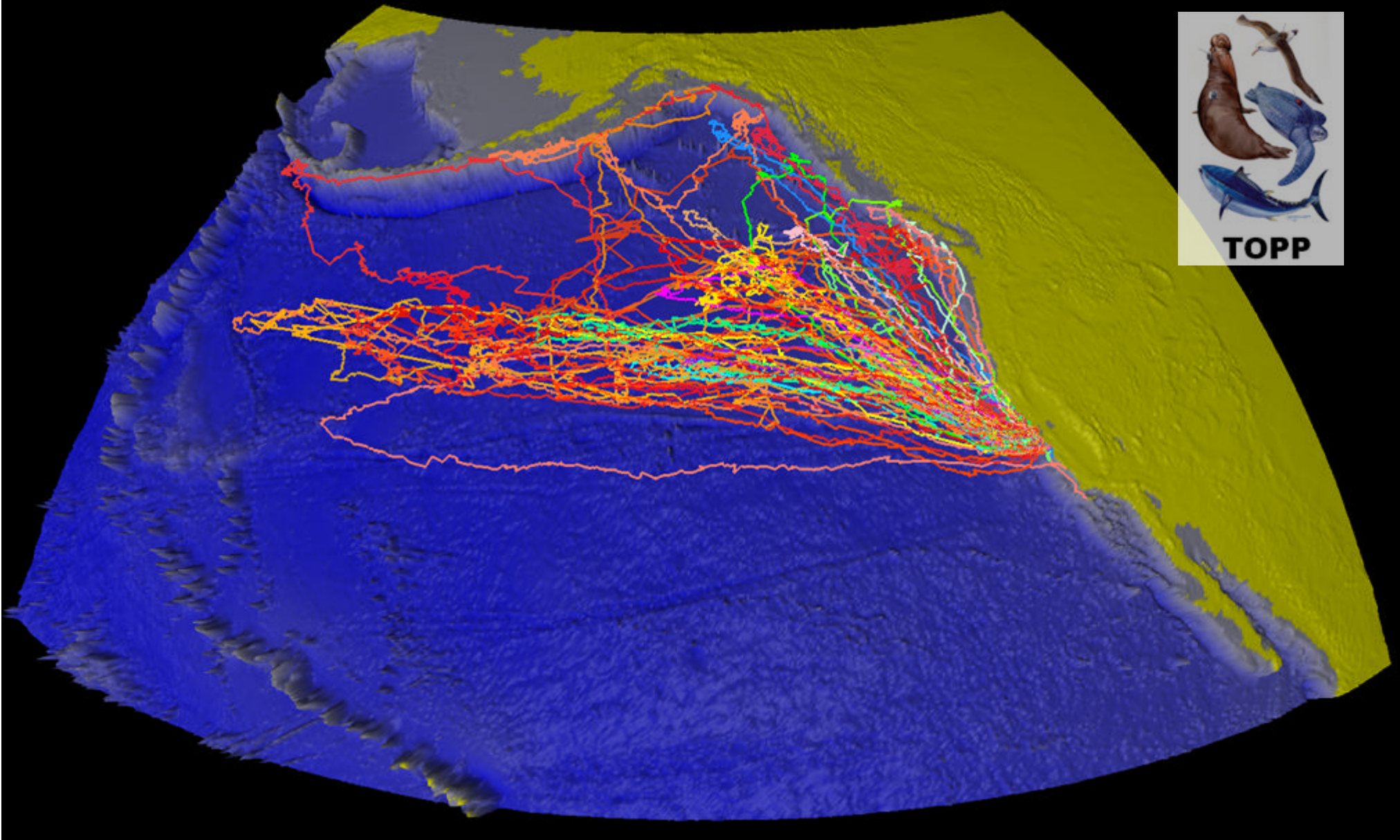




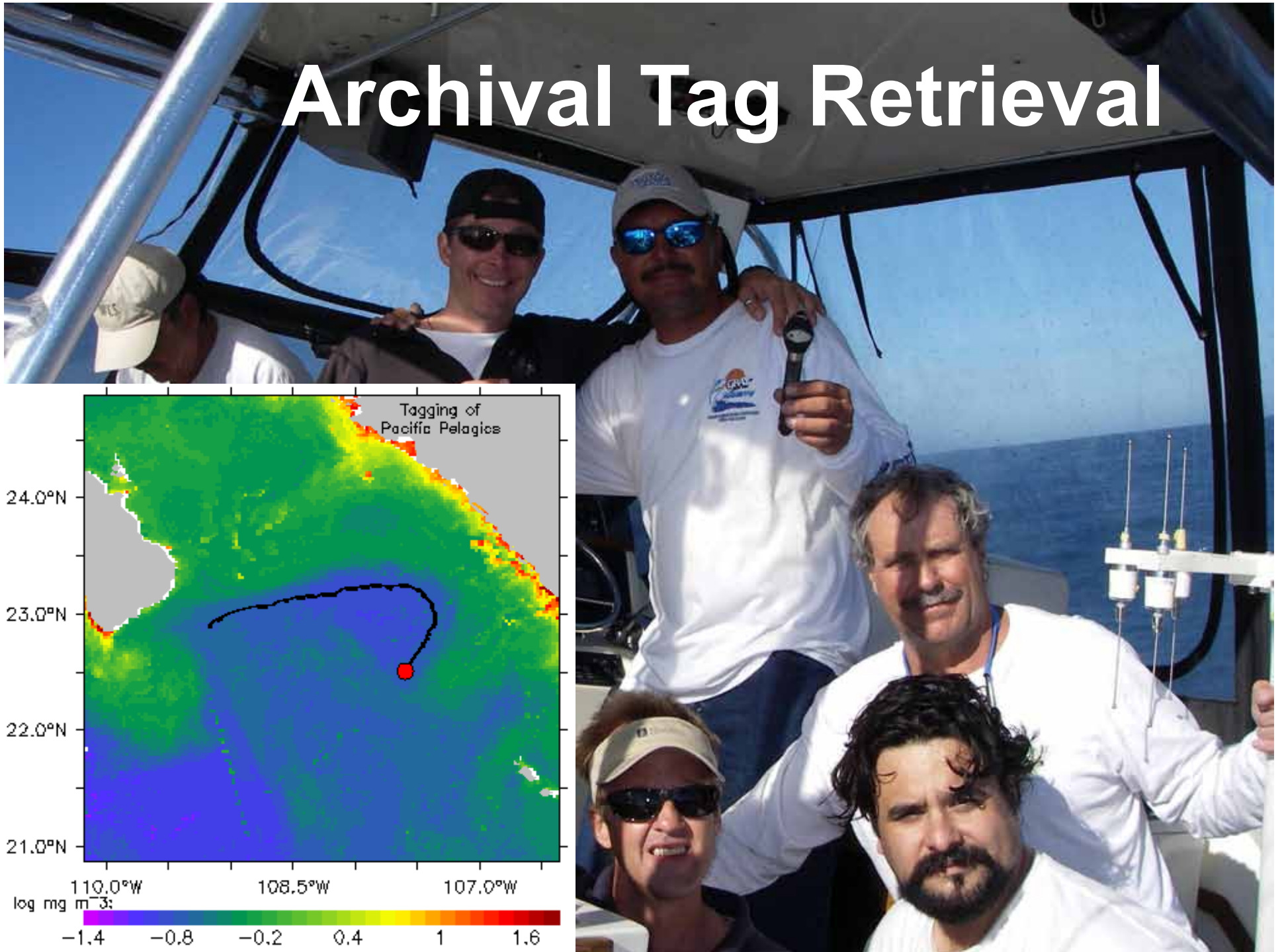
# Why migrate ?



# Elephant seals

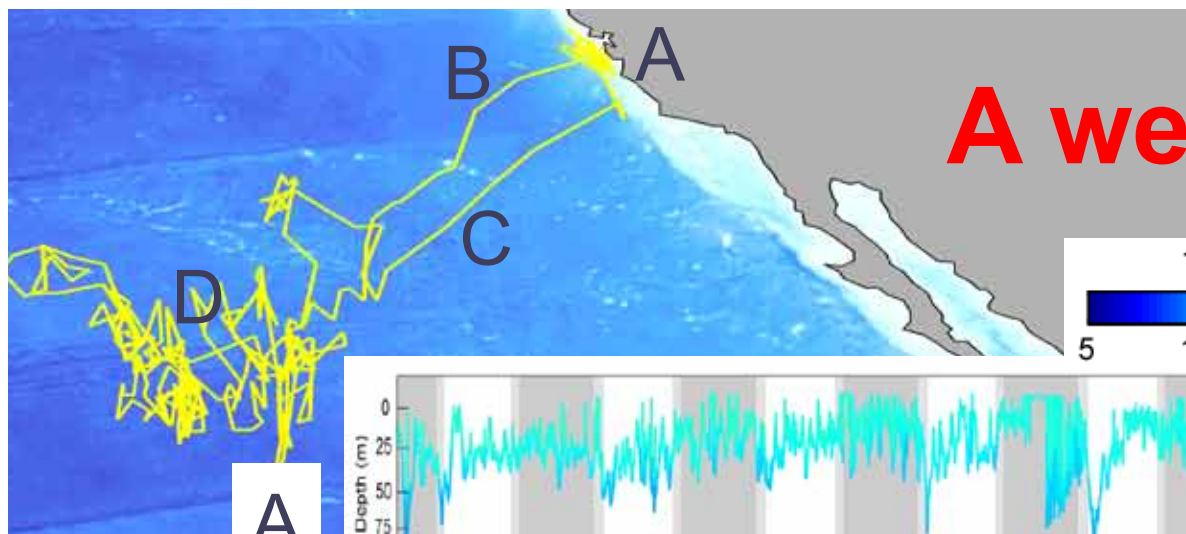


# Archival Tag Retrieval

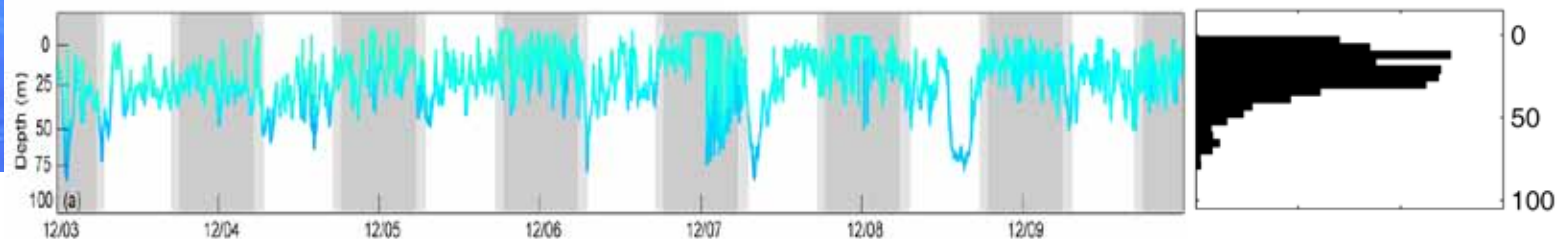


# A week in the life...

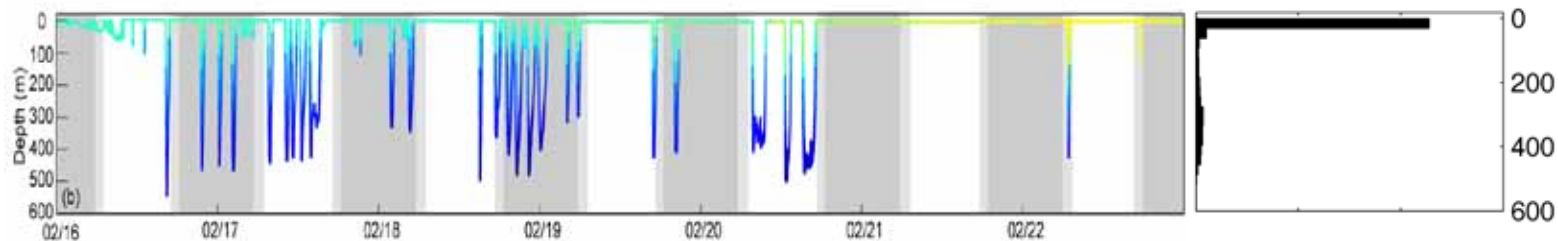
Weng et al. 2007



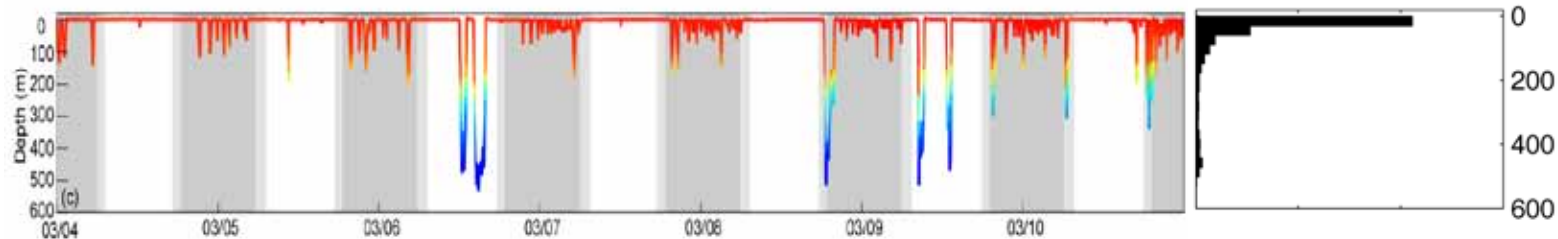
A



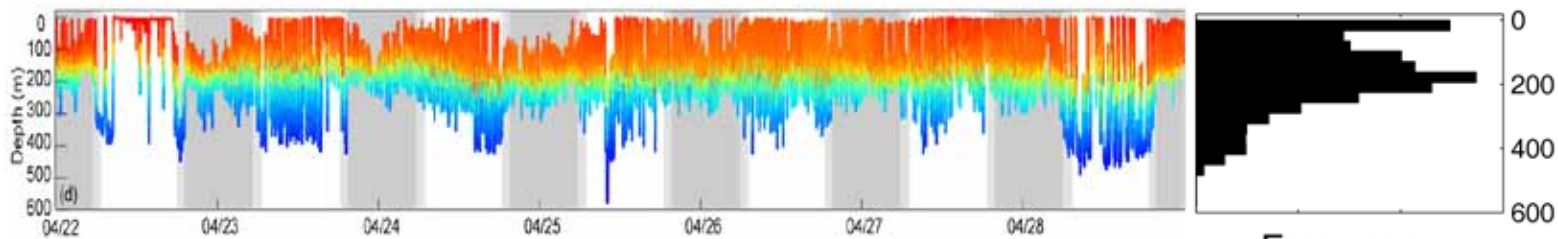
B



C

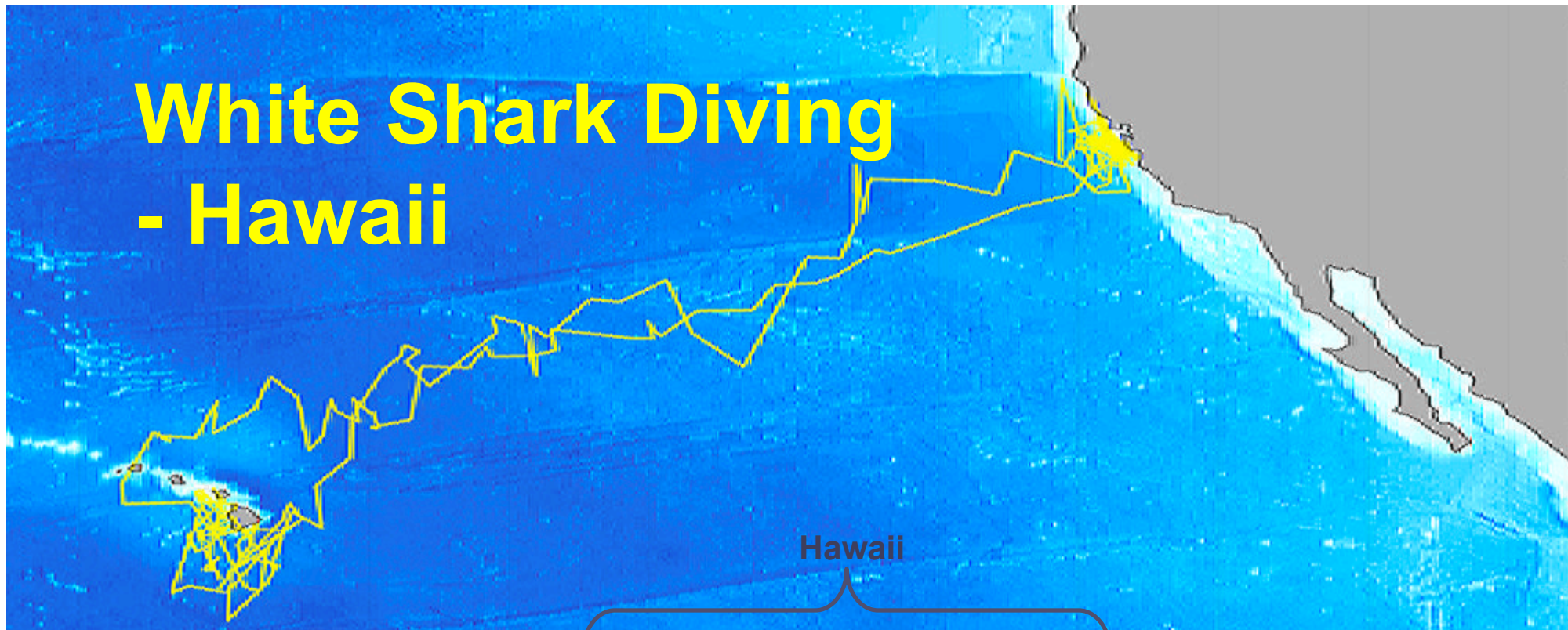


D

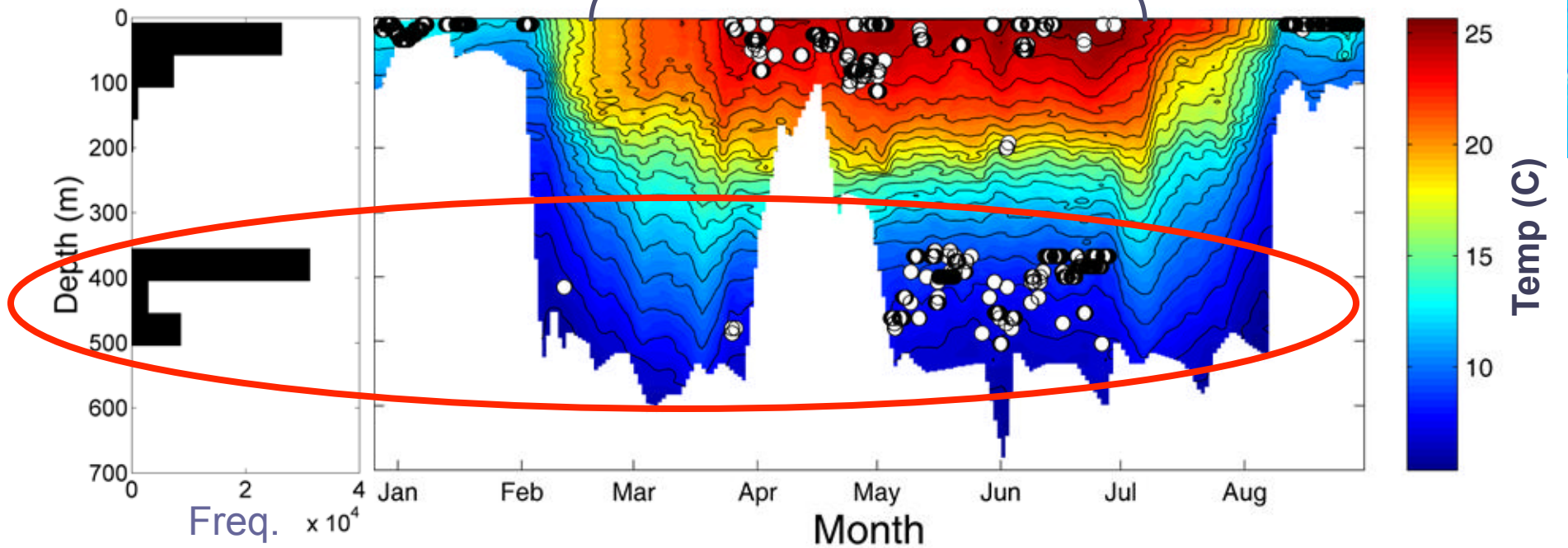


Frequency

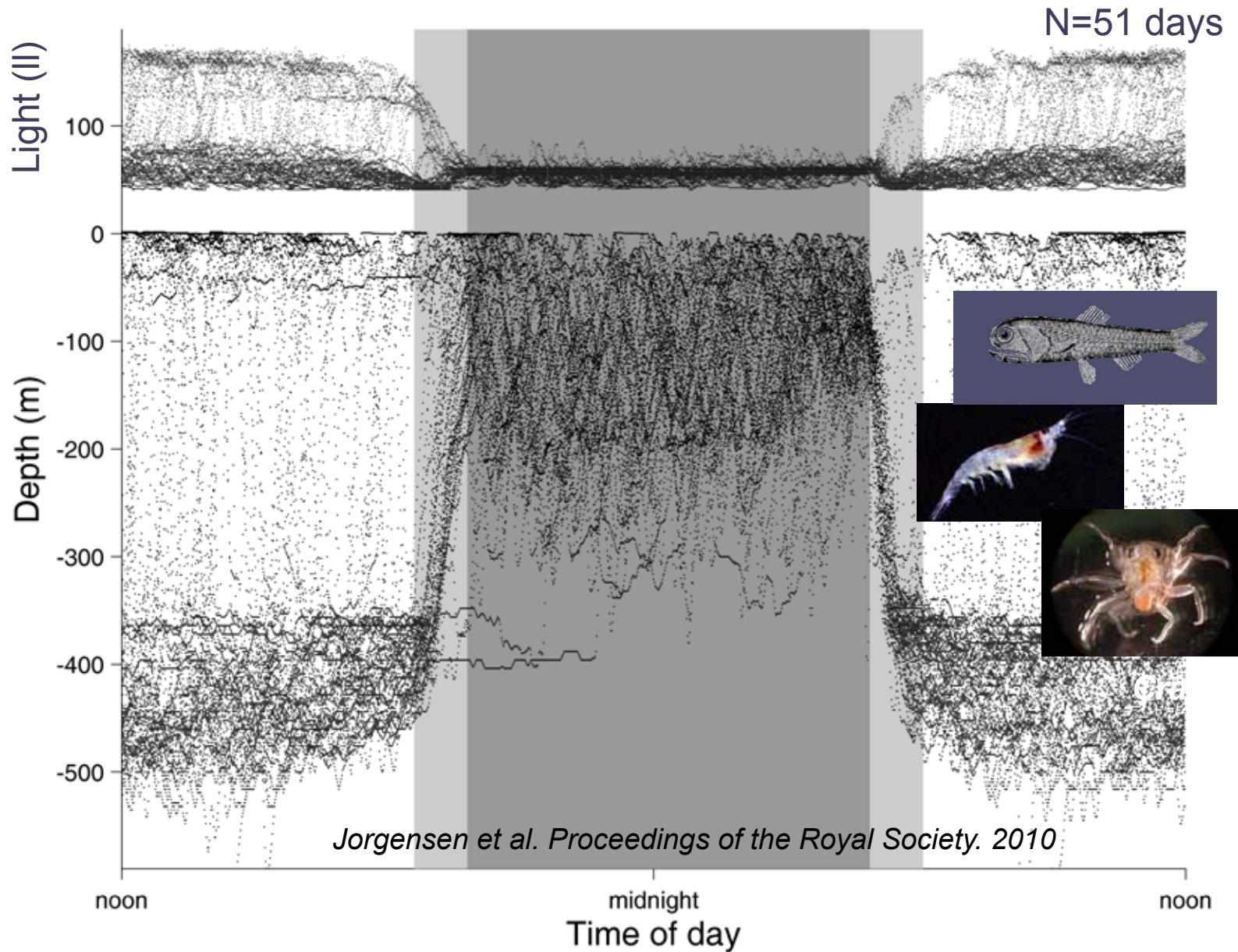
# White Shark Diving - Hawaii



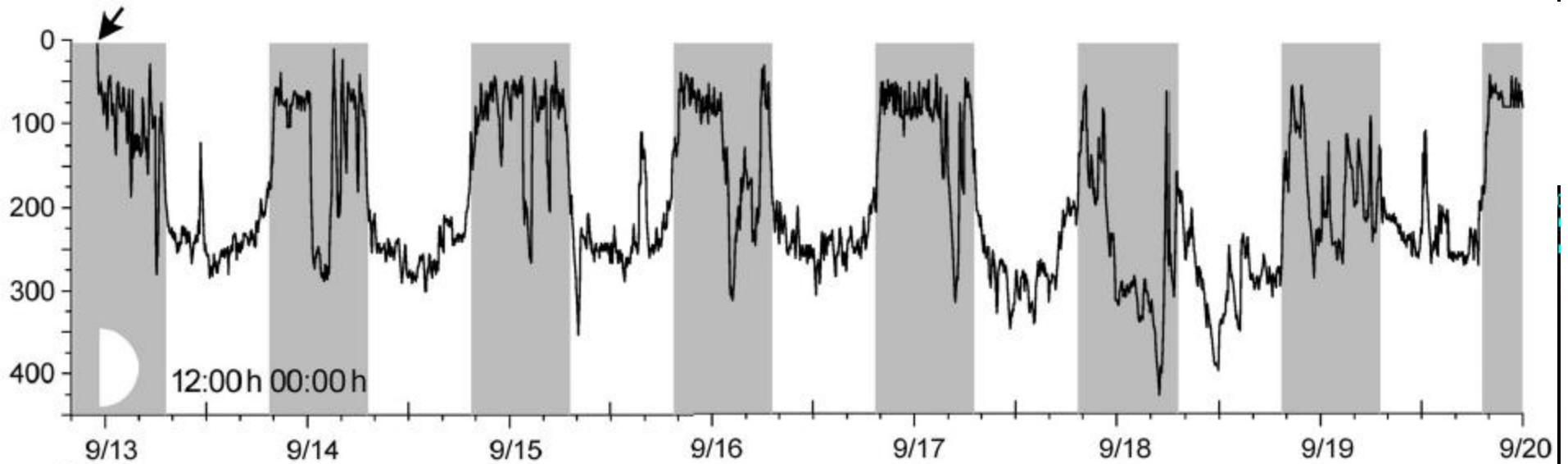
Hawaii



# White Shark Diel (day/night) Vertical Migration

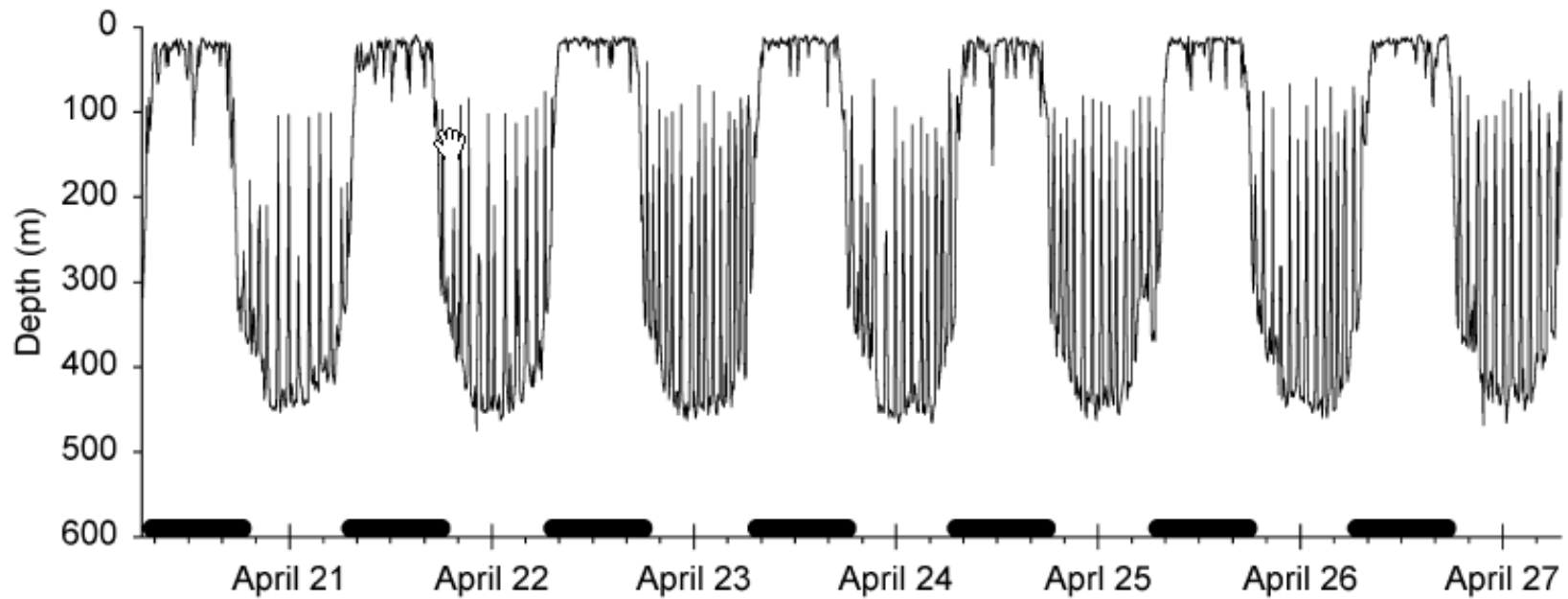


# Jumbo Squid Vertical Movement



Gilly et al., 2006

# Bigeye tuna diving near Hawaii

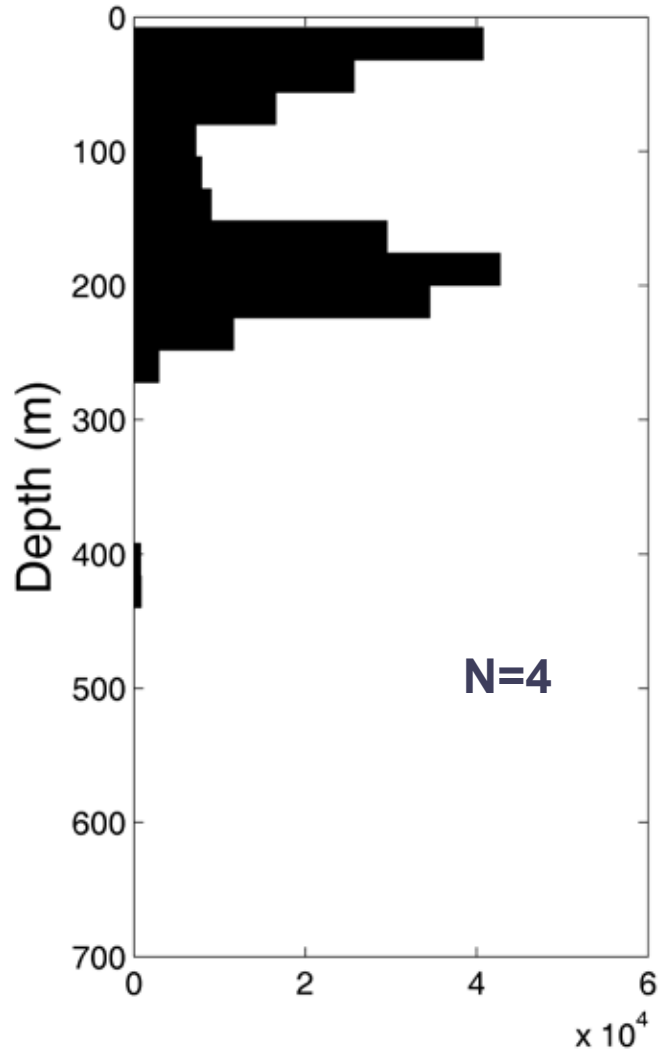


Musyl et al., 2003

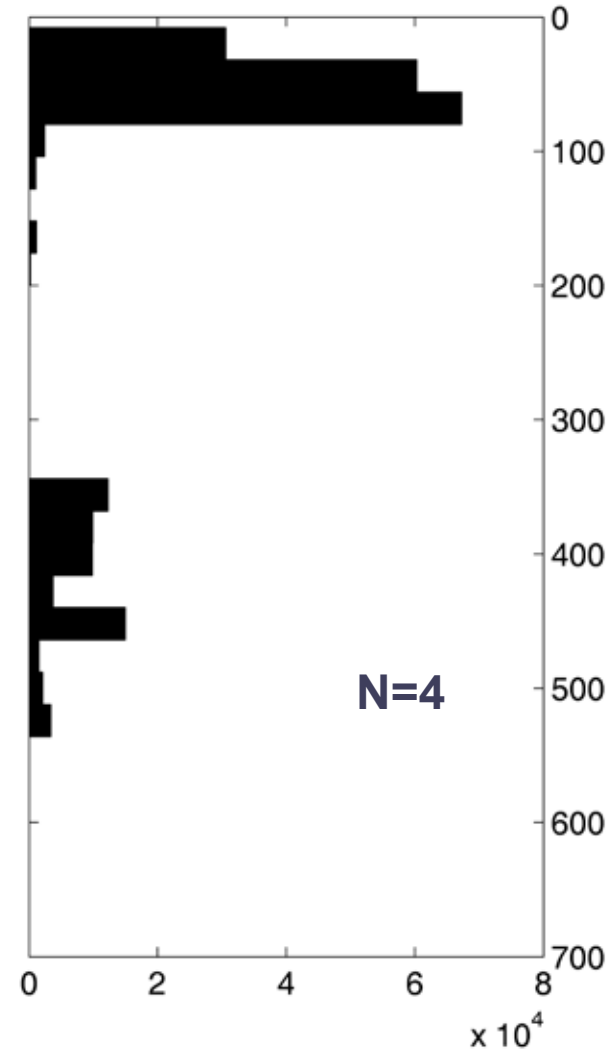


# Offshore Diving Modes

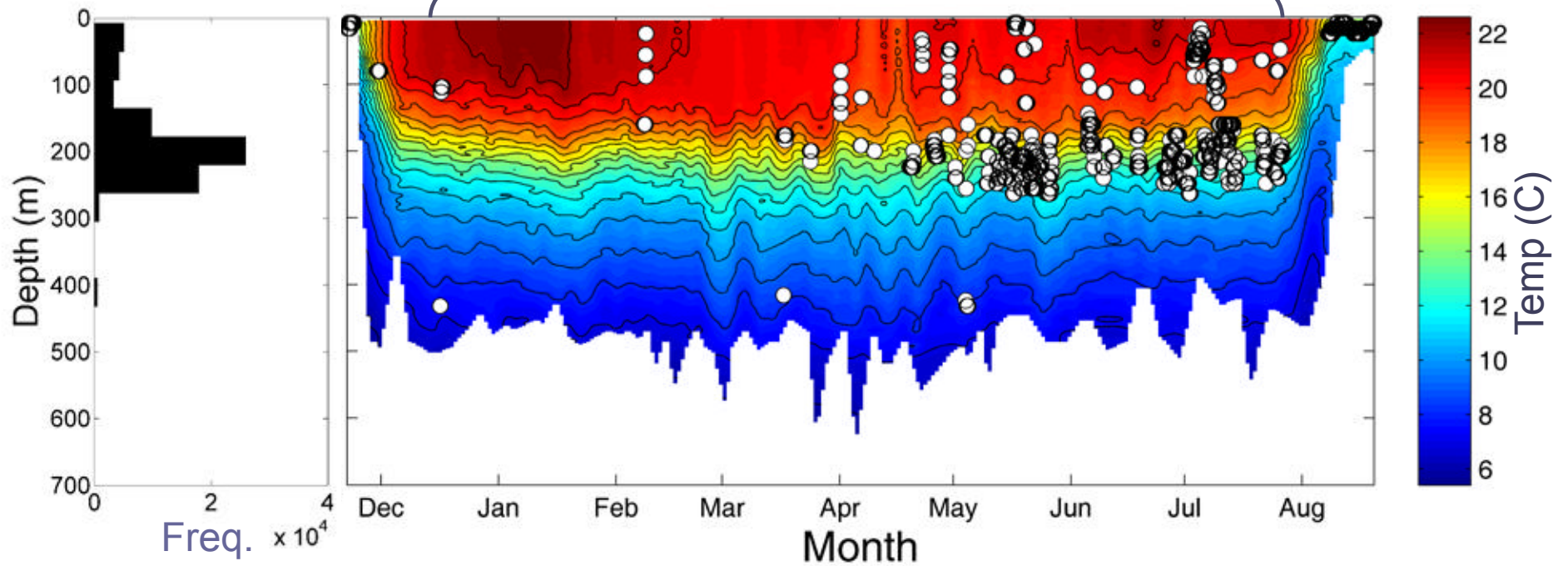
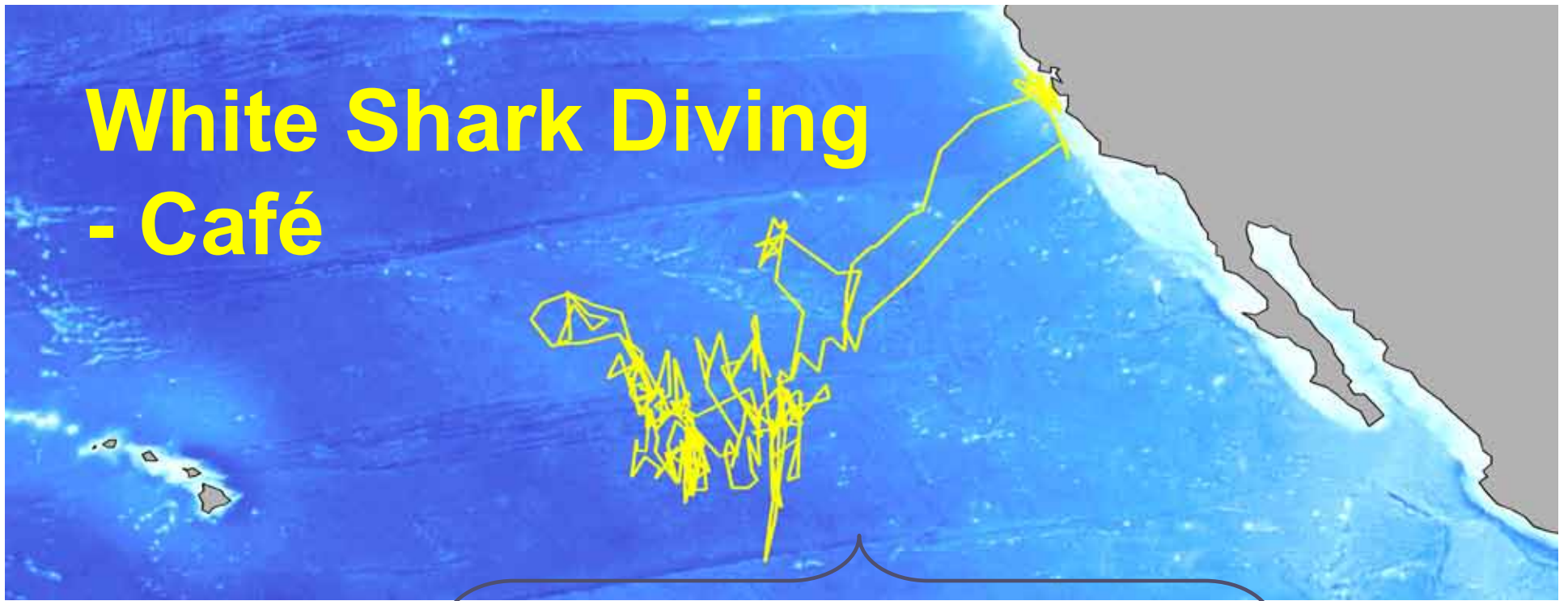
## Cafe



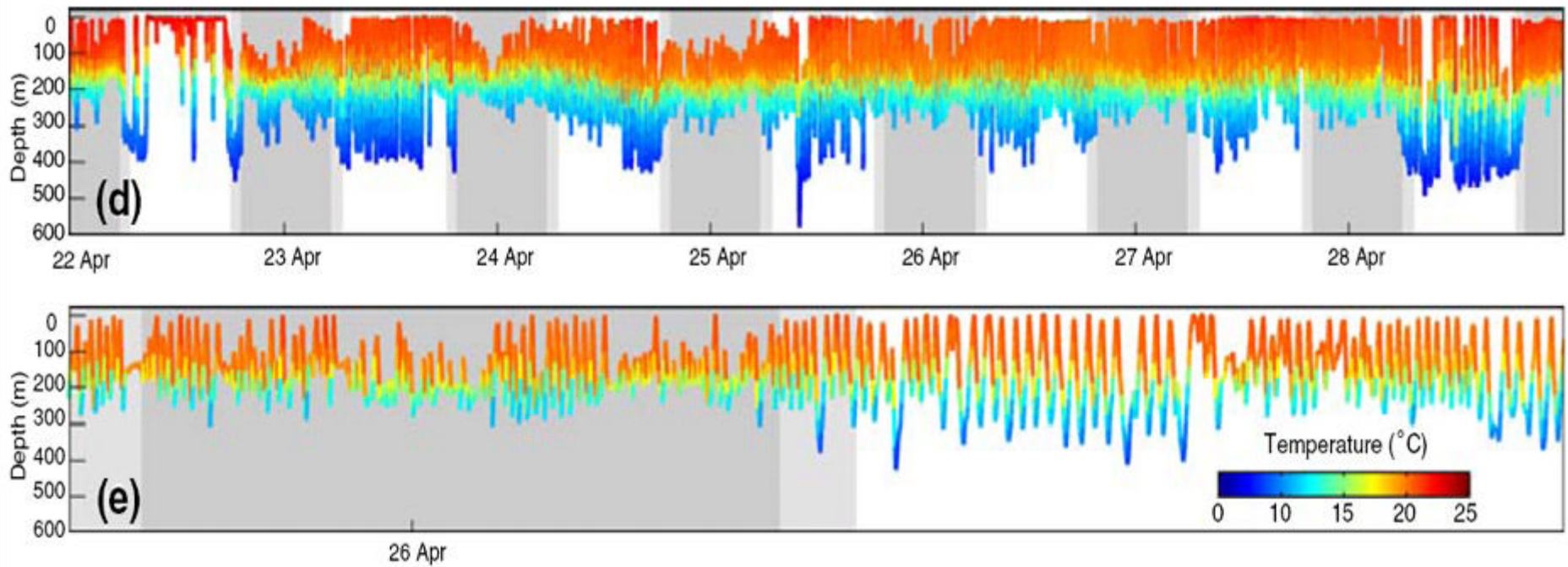
## Hawaii



# White Shark Diving - Café

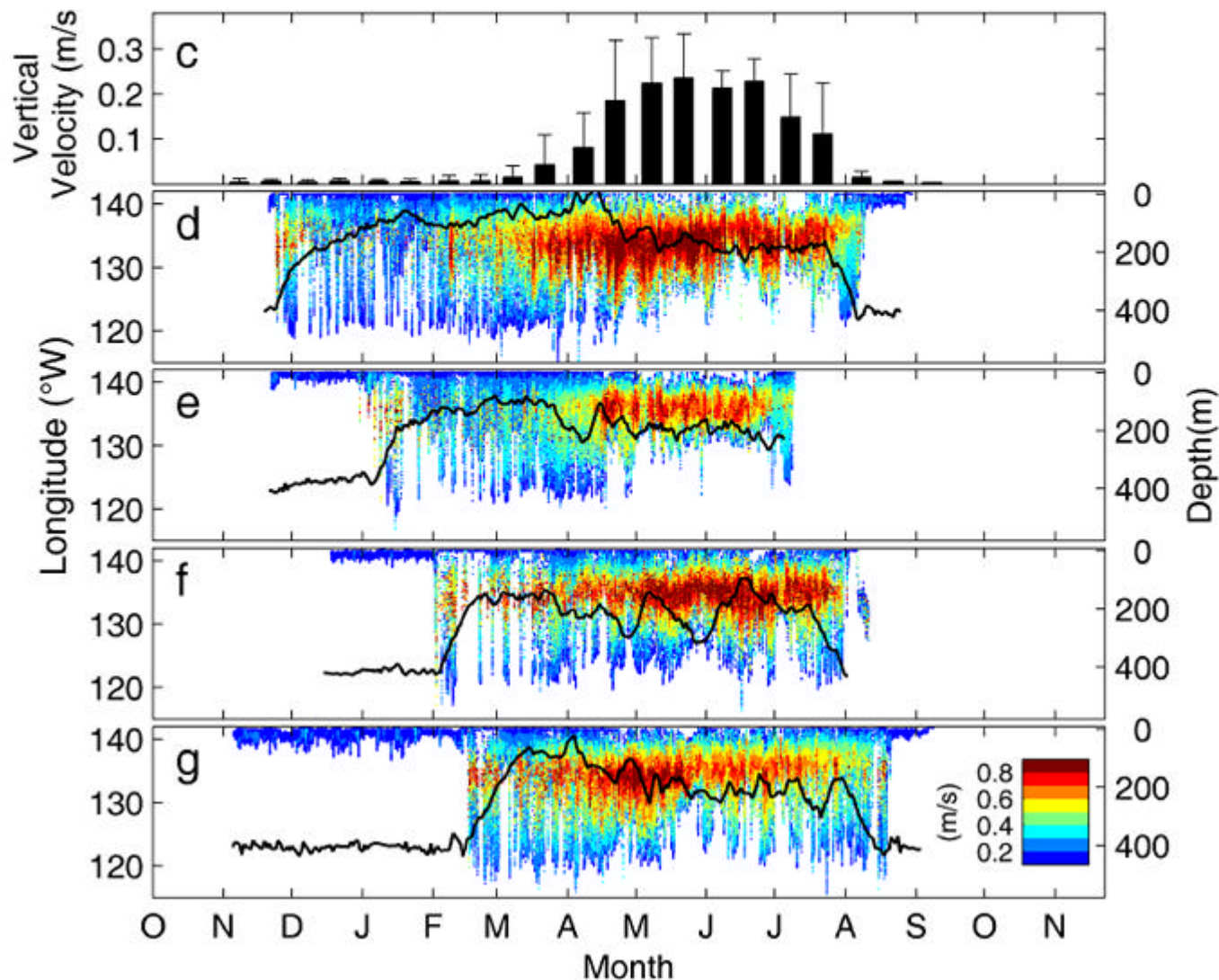


# White Shark Diving – Café



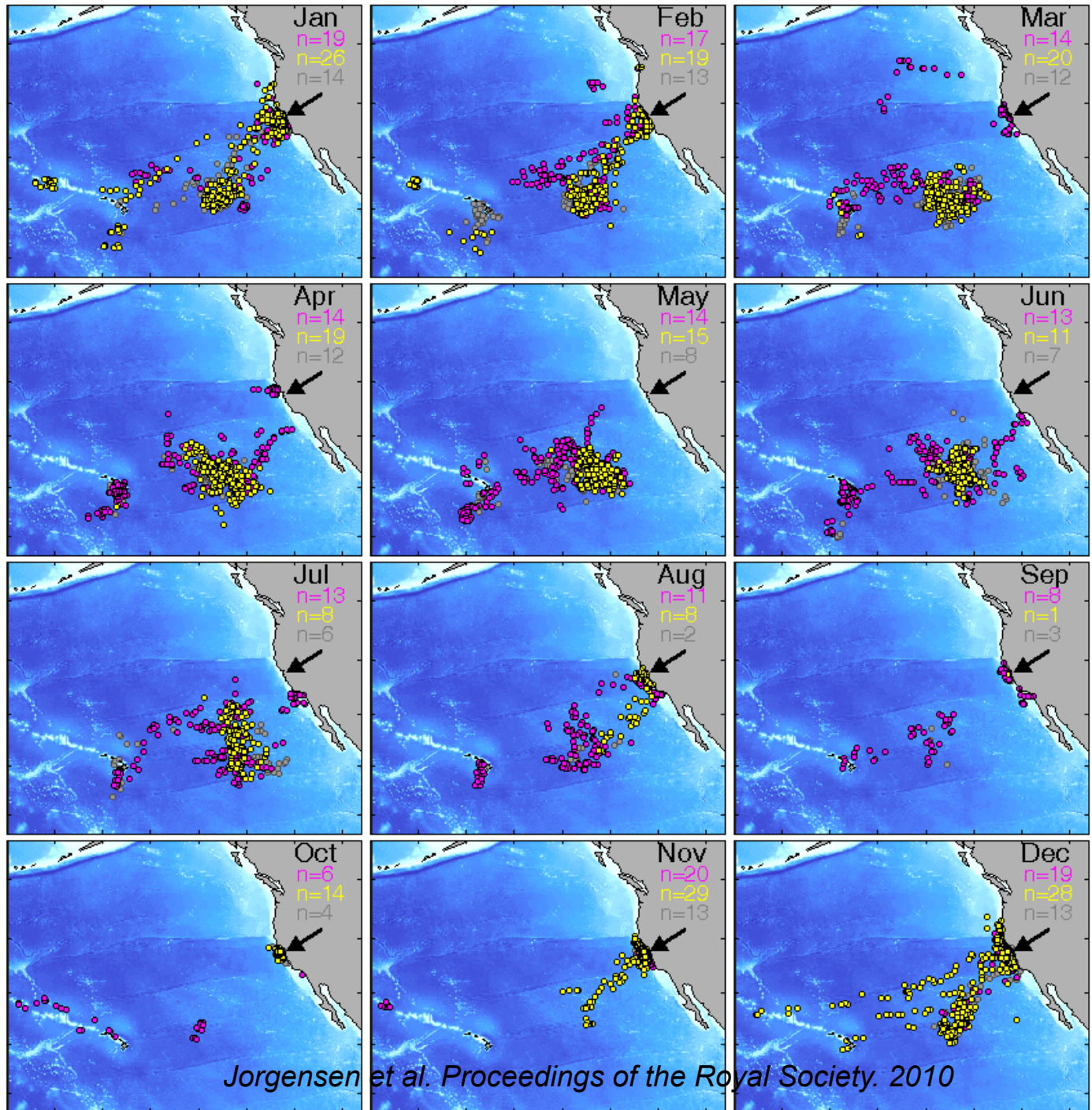
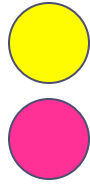
*Weng et al. Marine Biology 2007*

# Oscillatory diving – Café



*Jorgensen et al. Proceedings of the Royal Society. 2010*

**Male**  
**Female**



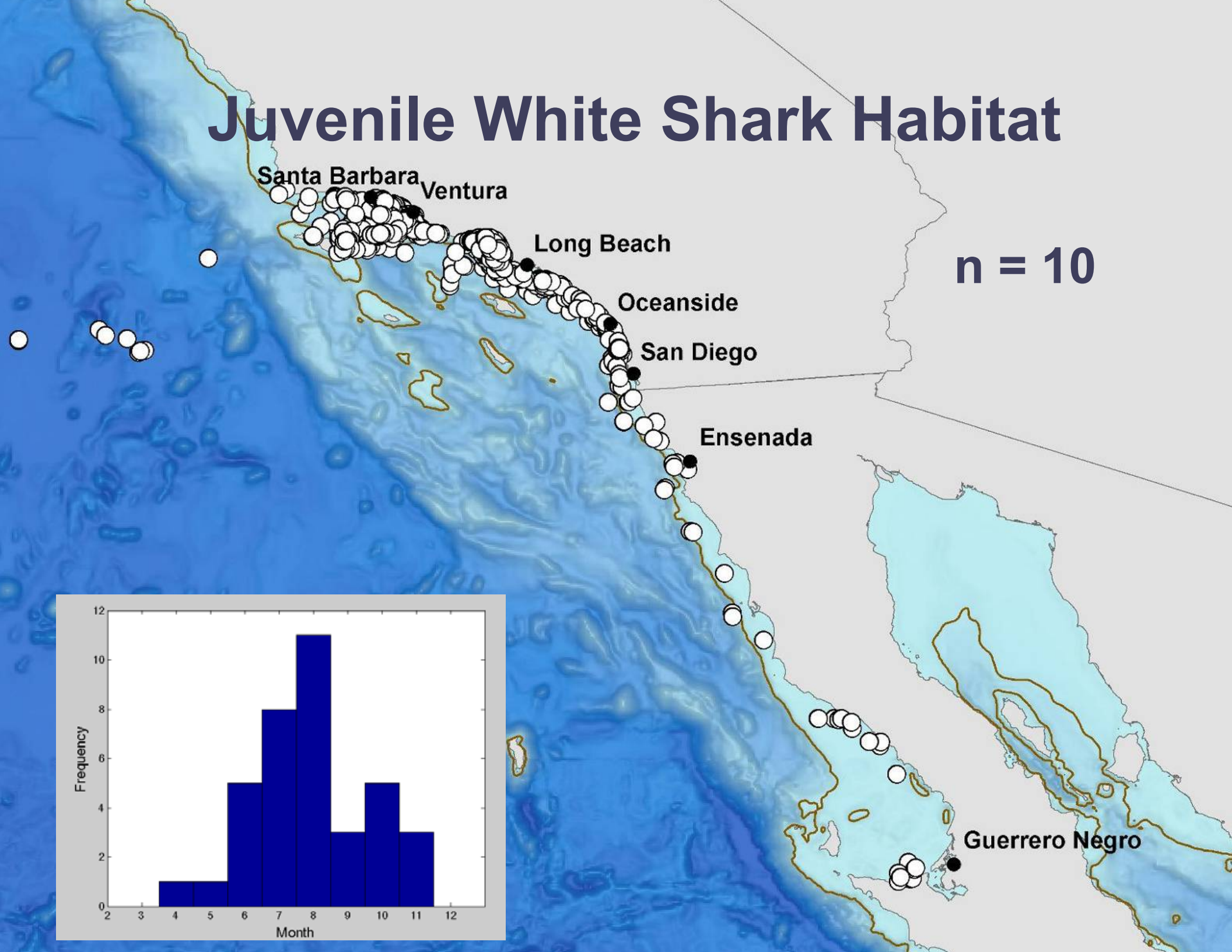
Jorgensen et al. Proceedings of the Royal Society. 2010

# Summary



- **Coast - temperature trade-off**
- **Hawaii - DSL foraging**
- **Café - foraging , mating or both**

# Juvenile White Shark Habitat

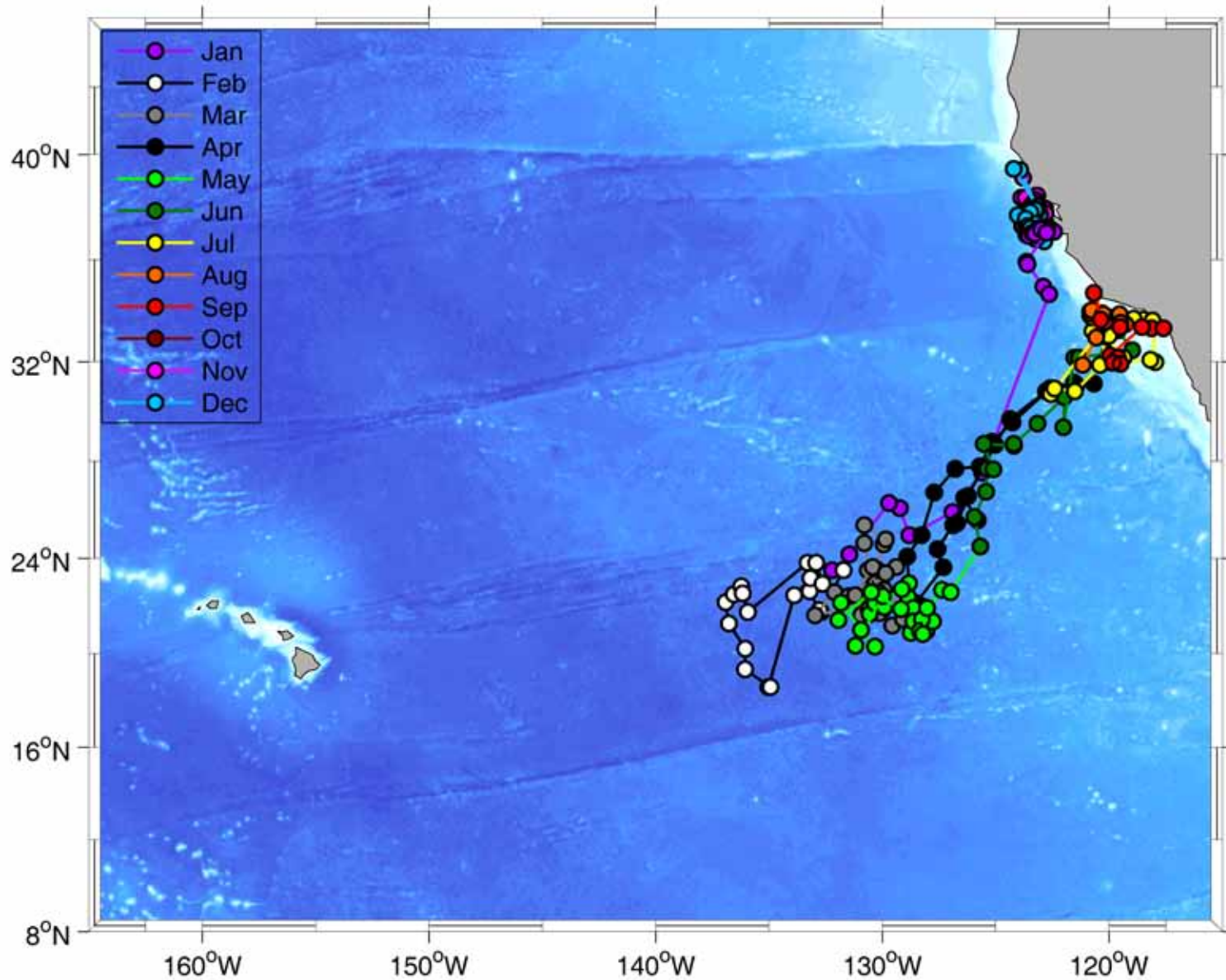


**Female w/ healing mating marks PAT-tagged Oct 6**



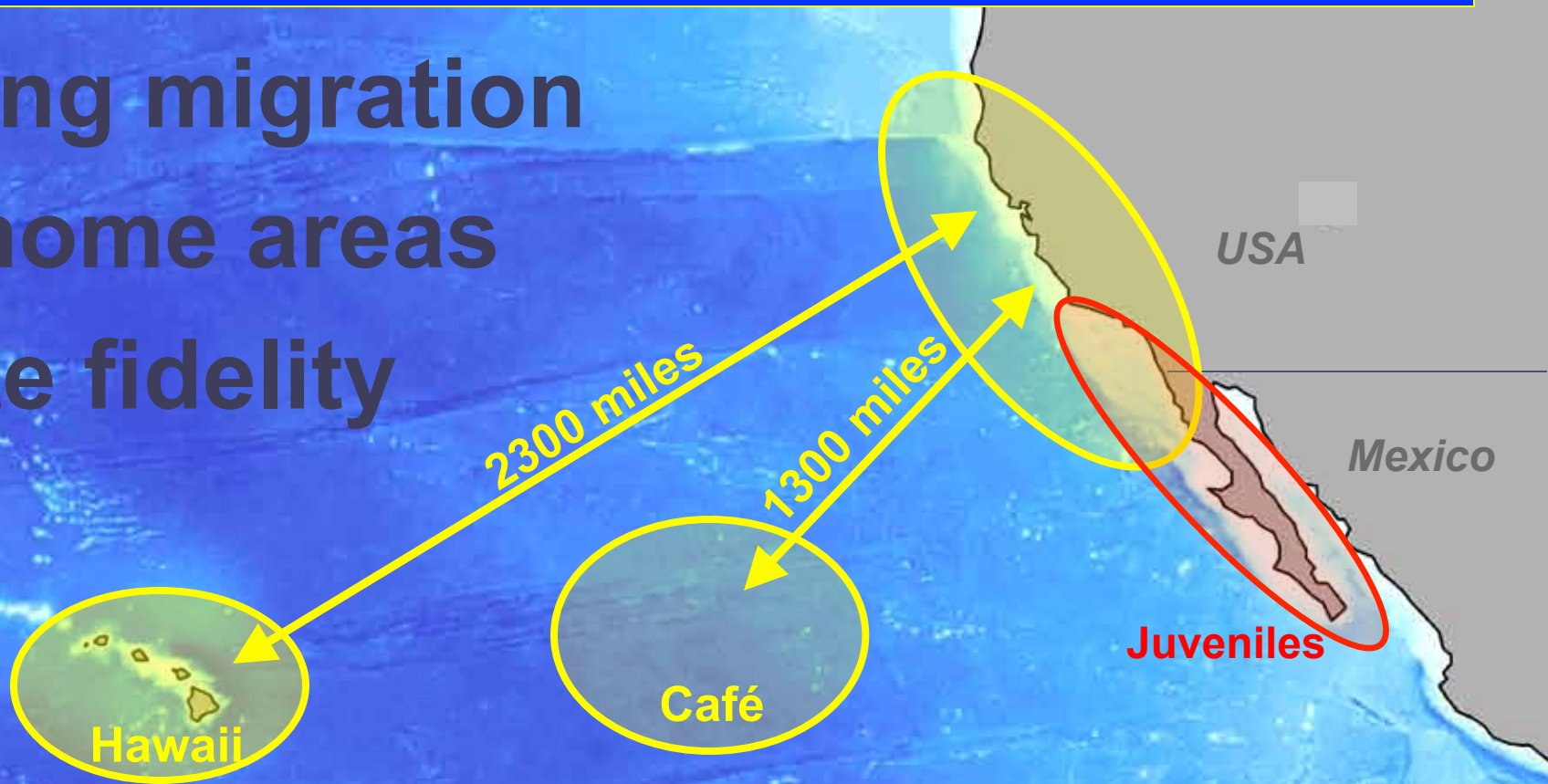


# Female tracked 362 days to SCB

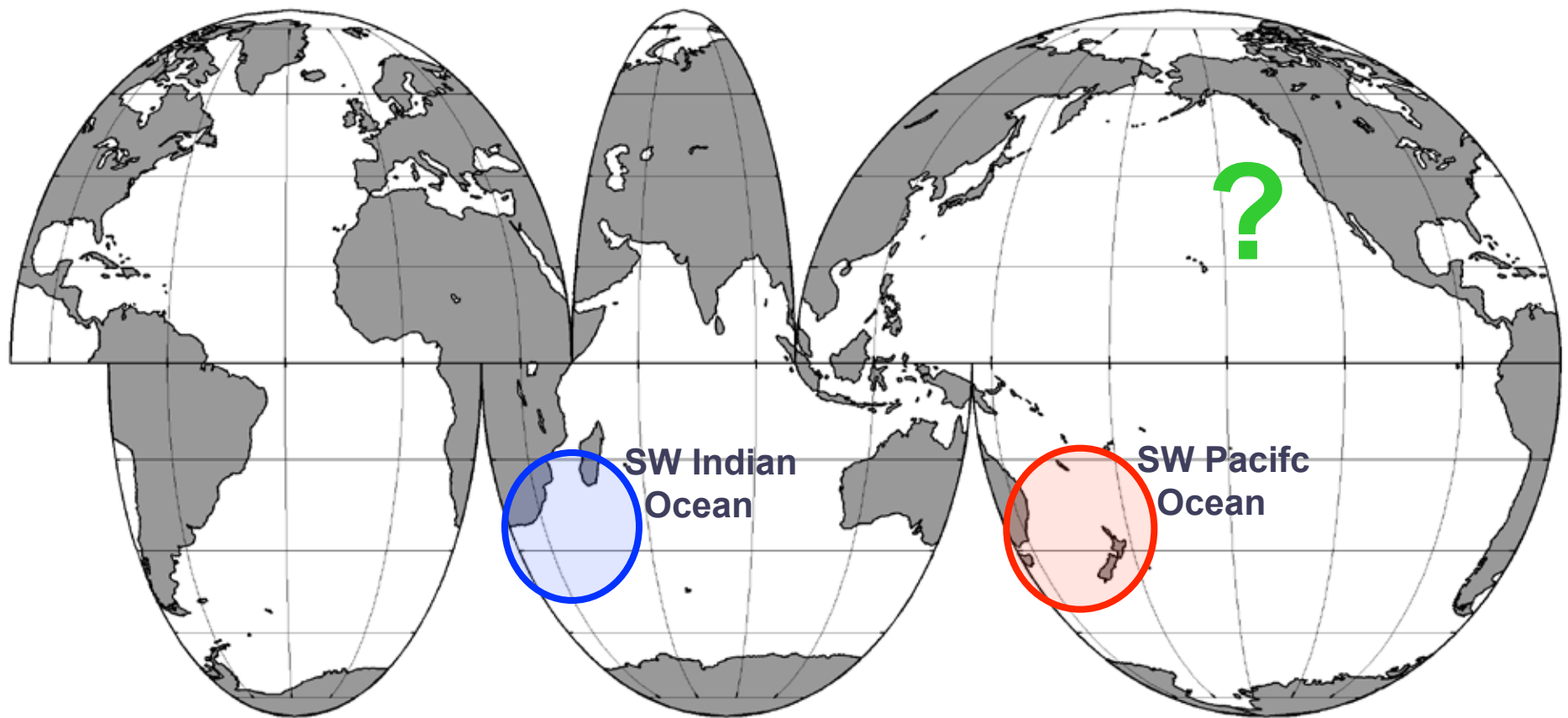


# White Shark Movement Synopsis

- Long migration
- 3 home areas
- Site fidelity

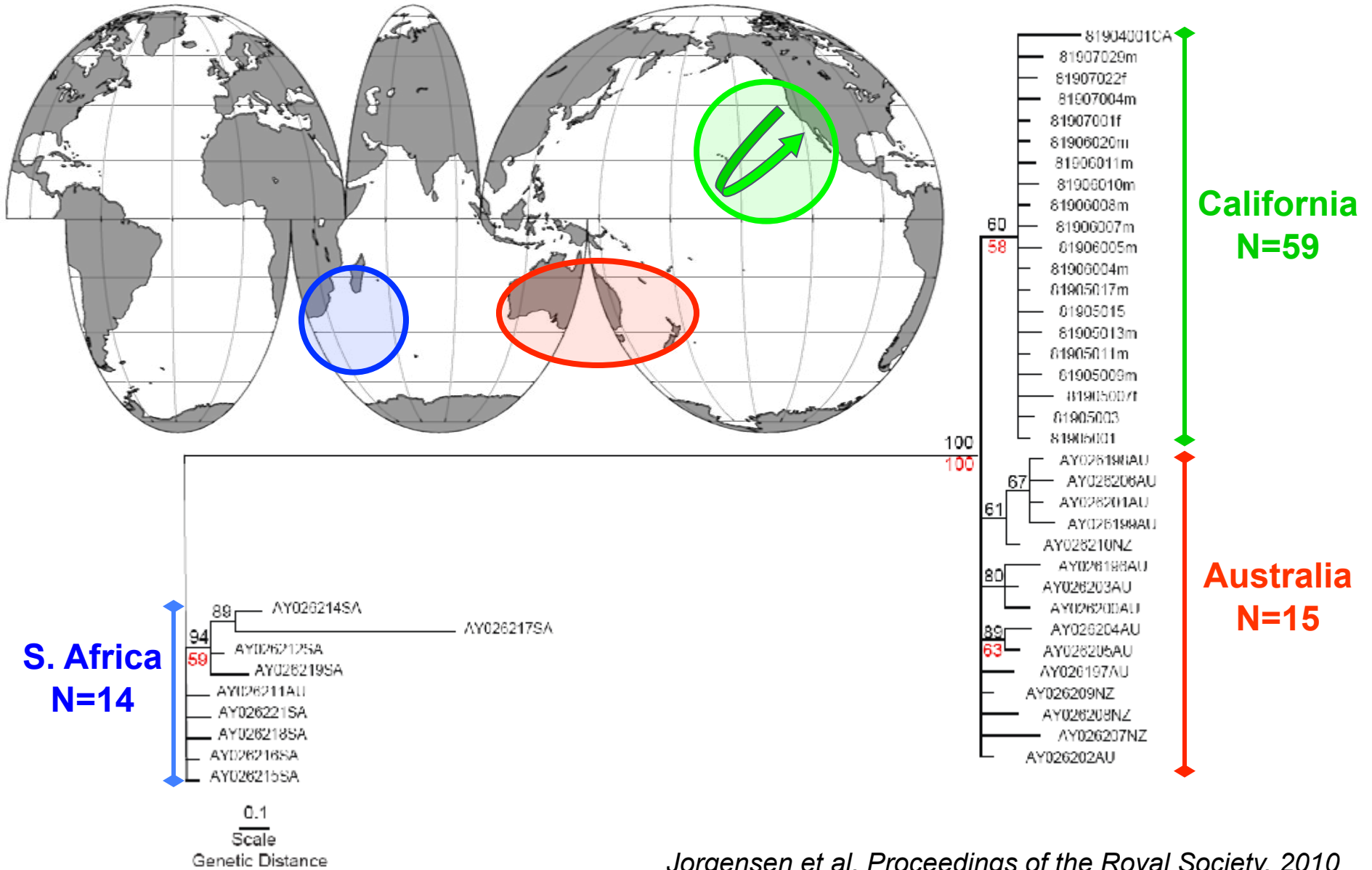


# White Shark Genetic Structure



2 white shark clades - Pardini et al., 2001

# White Shark Genetic Structure



# Conservation Implications

1. Limited dispersal and site fidelity
  - Easier to census population
  - Monitoring in National Marine Sanctuaries
2. Isolated population = more vulnerable
  - No immigration/emigration
  - Vulnerable if numbers are low

# Acknowledgements



## Special Thanks:

GFNMS, MBNMS, P. Kanive, A. Brown, J. McKenzie, Cpt. Homer and crew, J. O'Sullivan, C. Logan, S. Sommeron, C. Fritz-Cope, K. Holland, R. Starr, C. Meyer, J. Barlow, T. Brandt, A. Carlisle, S. McAfee, S. Lucas, A. Boustany, P. Castilho, C. Farwell, J. O'Sullivan, C. Harrold, J. Ganong, R. Matteson, M. Castleton, S. Teo, D. Kohrs, G. Strout, K. Weng, C. Wisner, A. Swithenbank, G. Shillinger, T. O'Leary and many more