Electronic Supplementary Material

Migration and Habitat of White Sharks (*Carcharodon carcharias*) in the Eastern Pacific Ocean

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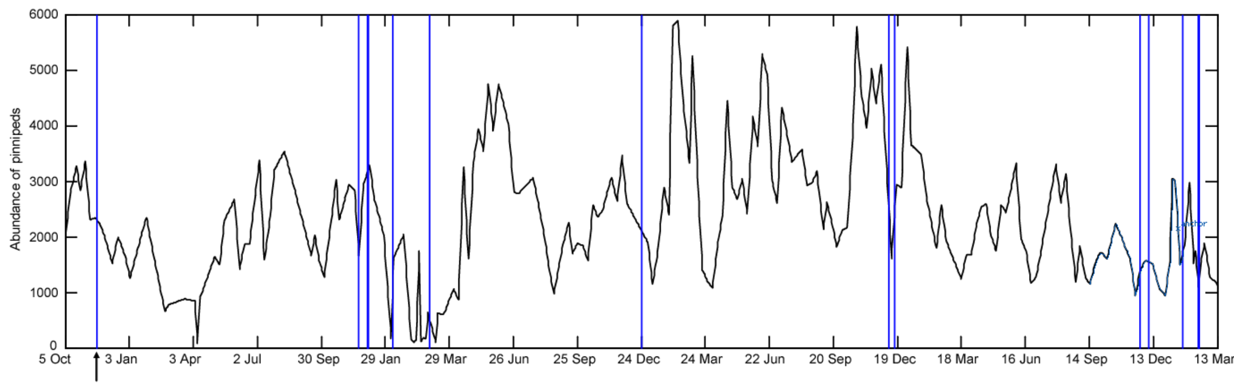
Appendix 1

Satellite Tags That Failed to Report, 1999-2004

Tagging date	*Total Length (cm)*	*Sex*	*Maturity*
16-Oct-00	518	?	Mature
16-Oct-00	518	F	Mature
09-Nov-00	518	F	Mature
09-Nov-00	381	?	n/a
12-Nov-02	430	M	Mature
08-Oct-03	442	M	Mature
23-Oct-03	n/a	F	n/a
31-Oct-03	488	M	Mature
13-Oct-04	381	?	n/a

Appendix 2

Dates of departure for offshore migrations

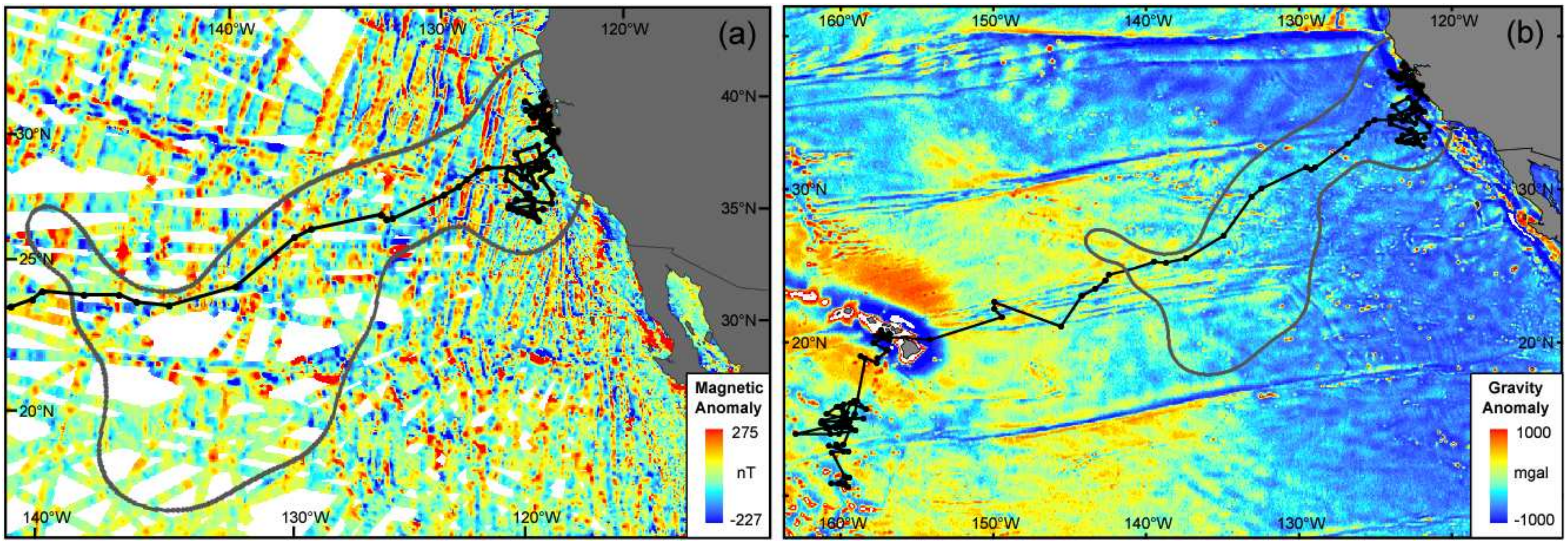


Abundance of pinnipeds at Southeast Farallon Island (black) are significantly correlated with the departure dates of 15 white sharks (blue). Arrow shows the date of an orca attack on a white shark.

The dates on which sharks (*n*=15) initiated offshore migrations followed periods of decreasing pinniped abundance at Southeast Farallon Island, and the abundance on those dates was significantly lower than the median abundance during the month preceding the departure (Wilcoxon rank sum test, h =1, p = 0.03). The decline of pinniped abundance, or perhaps hunting success, may influence the sharks' decision to initiate migration.

Appendix 3

Navigation during migration and geological cues



The track of shark 18-F (black) and the winter 95% density contour for all sharks (grey) over (a) magnetic anomalies, and (b) gravity anomalies for the eastern North Pacific.

Variations in magnetic intensity in the region of the migration corridor exceed variations measured by Klimley (1993), which were correlated with directed movements of hammerhead sharks (*Sphyrna lewini*), suggesting that magnetic navigation is possible. Klimley (1993) hypothesized that vertical movements of hammerhead sharks would allow them to sense altitudinal variations in the earth's magnetic field, and migrating sharks did undertake such movements, though not in a regular pattern. Magnetic inclination and declination vary gradually across the region (Peddie 1993), and could provide direction but no obvious landmarks. The track of shark 18-F, for which geolocations were obtained almost daily during the migration, and magnetic anomaly fields of the region, show little correlation; however, it remains possible that the heterogeneous magnetic anomaly patterns could be used as a map (a). The winter 95% density contour, showing the migration corridor for all sharks, was in agreement with the track of shark 18-F, forming an envelope around it. The pattern of movement evident from both 18-F's track and the 95% density contour show oblique movement across the magnetic anomaly lineations created by the Cenozoic spreading center of the east Pacific, which are oriented approximately north-south in the eastern portion of the migration corridor. Further west the magnetic anomaly data become increasingly sparse, but lineations appear to be oriented northwest-southeast, again meaning that shark movements are oblique. The final movements of shark 18-F to the Main Hawaiian Islands were beyond the extent of the magnetic anomaly data. The offshore focal area lies over the Molokai Fracture Zone, and has a complex pattern of magnetic lineations in different orientations as well as zones without lineations.

Gravity anomalies show lineations along the major fracture zones of the eastern North Pacific (b), which are oriented east-west (Sandwell and Smith 1997; Smith and Sandwell 1997). The migration to the offshore focal area does not line up with any of these lineations, crossing the Murray fracture zone, while the latter part of shark 18-F's migration to Hawaii occurs over the Molokai Fracture Zone. The Clarion fracture zone lies to the south of the offshore focal area. A direct movement from California to Hawaii would occur along the Molokai Fracture Zone, so the track of shark 18-F is not considered to be strong evidence for the use of bathymetric lineations in navigation. Bonfil et al. (2005) measured the long distance movement of a white shark from South Africa to Australia and noted that there appeared to be few topographic features than would aid navigation along the shark's track. Bonfi et al. (2005) did not consider magnetic data.

References

Bonfil R, Meyer M, Scholl MC, Johnson R, O'Brien S, Oosthuizen H, Swanson S, Kotze D, Paterson M (2005) Transoceanic migration, spatial dynamics, and population linkages of white sharks. Science 310: 100-103

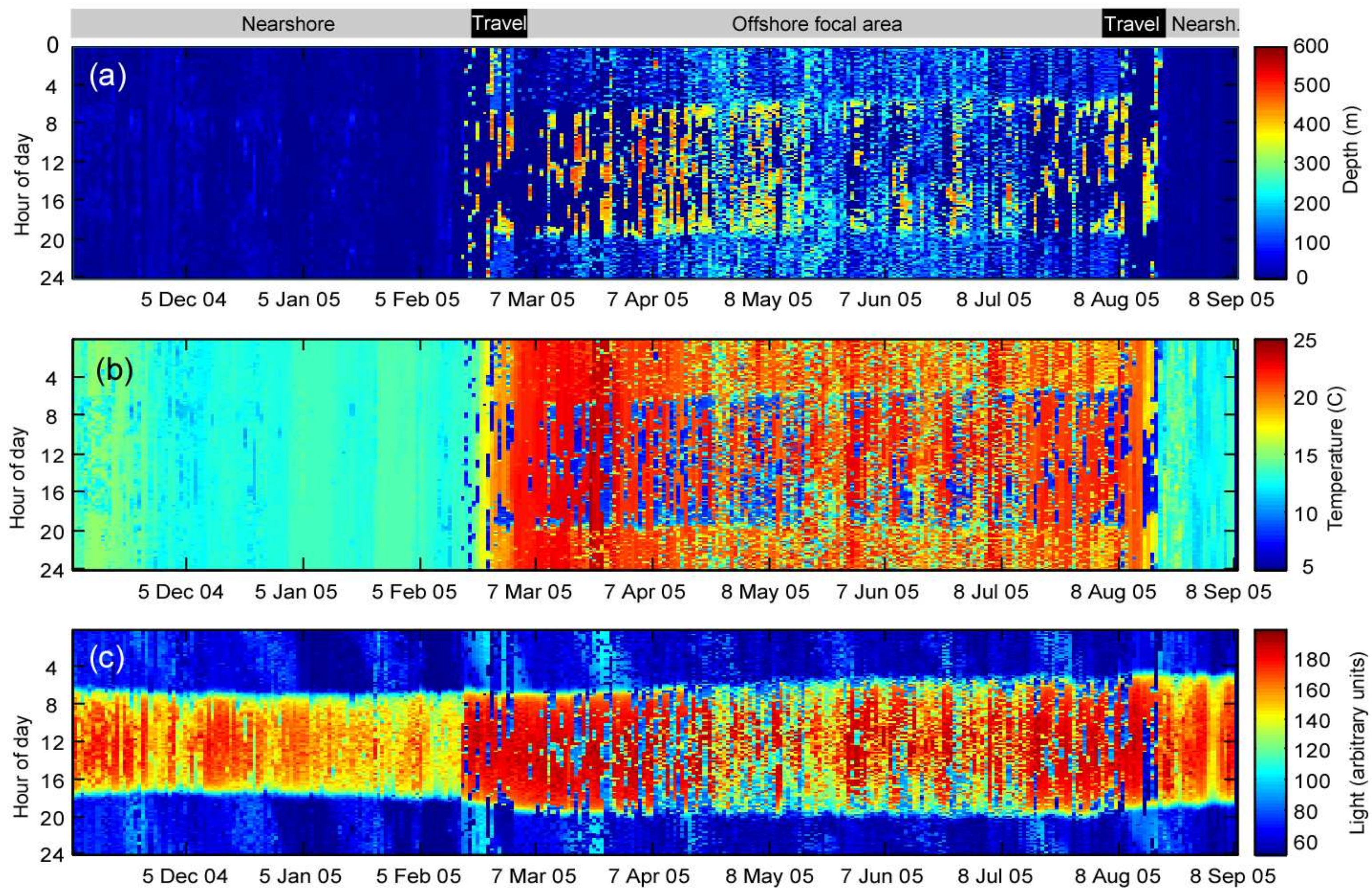
Klimley AP (1993) Highly directional swimming by scalloped hammerhead sharks, *sphyrna lewini*, and subsurface irradiance, temperature, bathymetry, and geomagnetic field. Mar Biol 117: 1-22

Peddie N (1993) The magnetic field of the earth, 1990: Inclination chart. US Geological Survey

Sandwell D, Smith W (1997) Marine gravity anomaly from geosat and ers-1 satellite altimetry. J Geophys Res B 102: 10039-10054

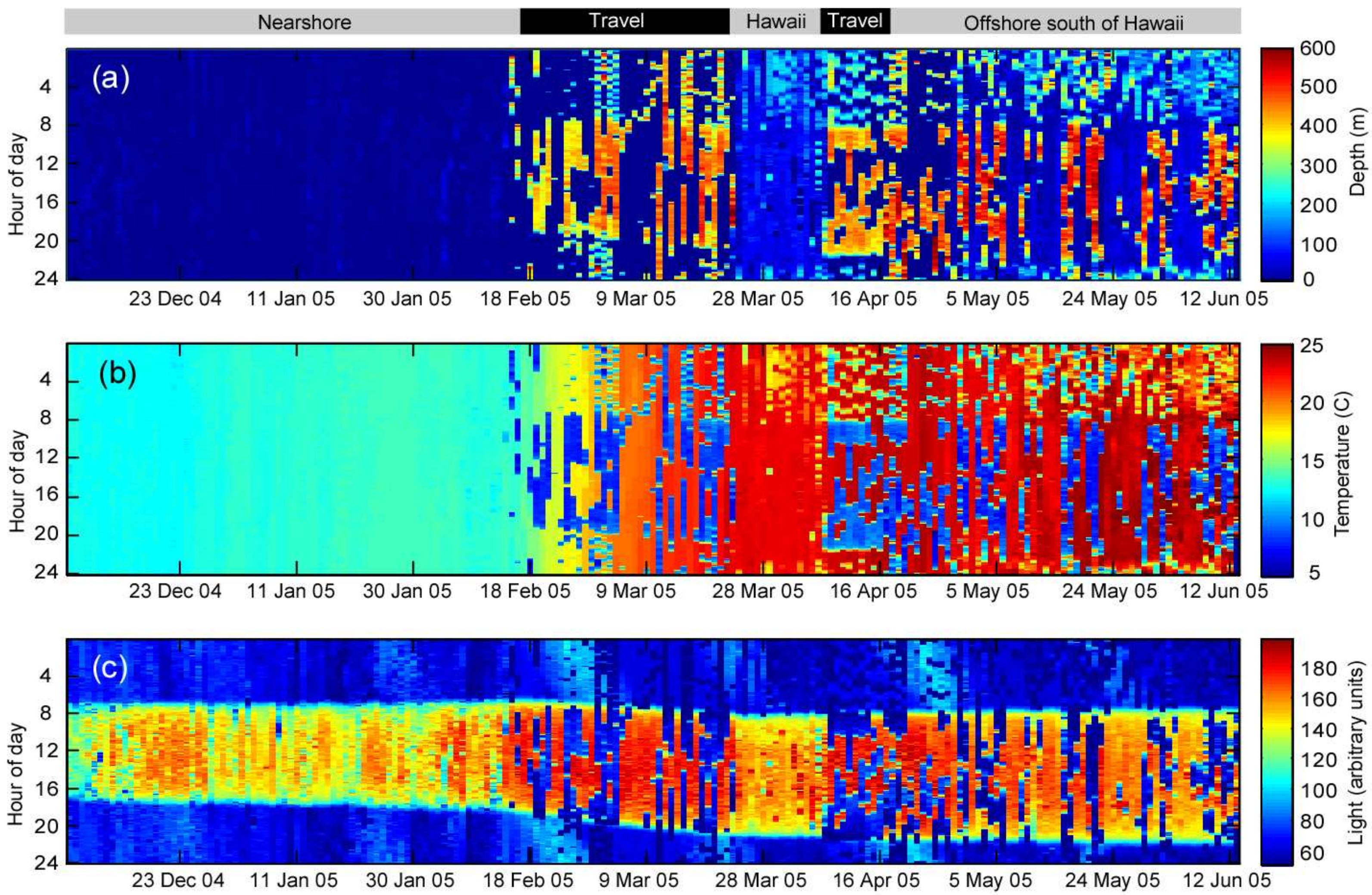
Smith W, Sandwell D (1997) Global sea floor topography from satellite altimetry and ship depth soundings. Science 277: 1956-1962

Appendix 4



Archival data for shark 17-U comprising (a) depth, (b) temperature and (c) light during the 305 d track. Vertical axes show time of day, horizontal axes show time.

Appendix 5



Archival data for shark 18-F comprising (a) depth, (b) temperature and (c) light during the 194 d track. Vertical axes show time of day, horizontal axes show time.