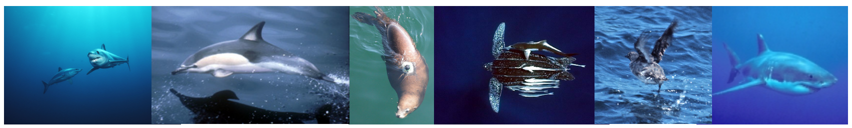
Building a Marine Life Observing System:
Lessons from the Tagging of Pacific Pelagics

TAGGING OF PACIFIC PELAGICS

CENSUS OF MARINE LIFE

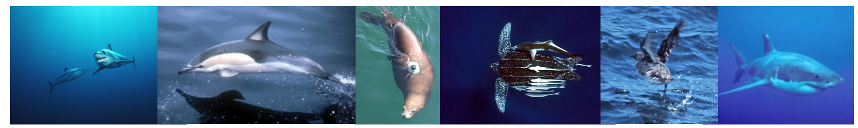
NOAA

topp.org, www.comlsecretariat.org



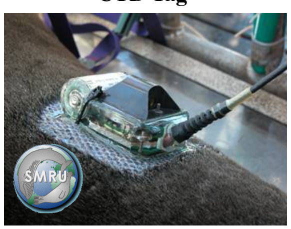
Outline

- ❖ Large-scale biologging in the North Pacific
- ❖ Ocean currents and leatherback turtle migration
- ❖ Habitat use and segregation among foraging Hawaiian albatrosses
- ❖ Elephant seal foraging in fronts and eddies
- ❖ California upwelling and blue whale migration



Technical Approach: Use Multiple Tag Platforms

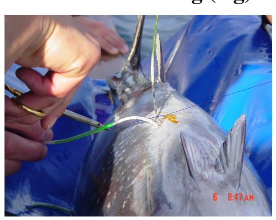
CTD Tag



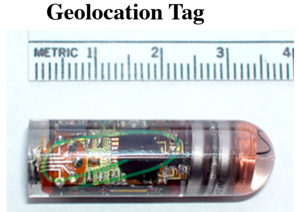
Pop Up Tag

GPS Tag

Geolocation Tag (6 g)



Geolocation Tag

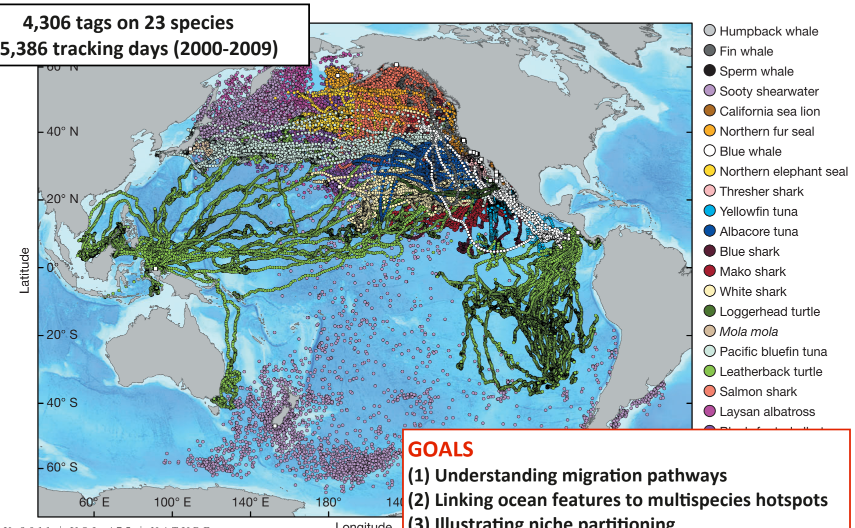


doi:10.1038/nature10082

Tracking apex marine predator movements in a dynamic ocean

B. A. Block[1], I. D. Jonsen[2], S. J. Jorgensen[1], A. J. Winship[2], S. A. Shaffer[3], S. J. Bograd[4], E. L. Hazen[4], D. G. Foley[4], G. A. Breed[2,5], A.-L. Harrison[5], J. E. Ganong[1], A. Swithenbank[1], M. Castleton[1], H. Dewar[6], B. R. Mate[7], G. L. Shillinger[1], K. M. Schaefer[8], S. R. Benson[9], M. J. Weise[5], R. W. Henry[5] & D. P. Costa[5]

4,306 tags on 23 species
265,386 tracking days (2000-2009)



GOALS
(1) Understanding migration pathways
(2) Linking ocean features to multispecies hotspots
(3) Illustrating niche partitioning

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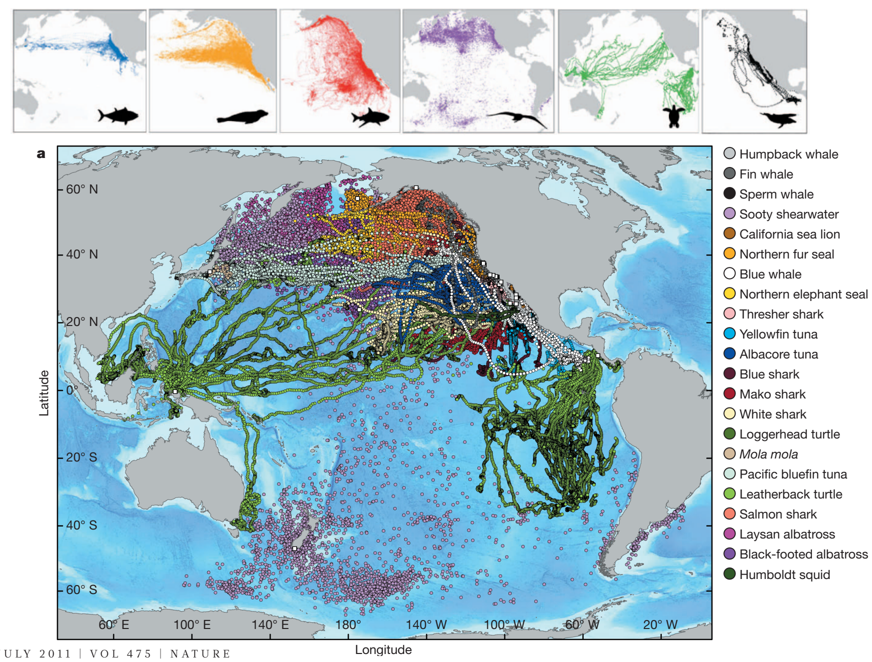
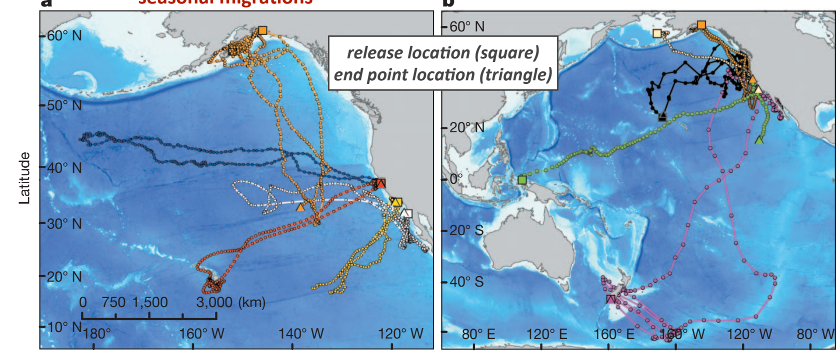


CCLME = California Current Large Marine Ecosystem

Pelagic Predators return to CCLME after seasonal migrations

Pelagic Predators attracted to CCLME

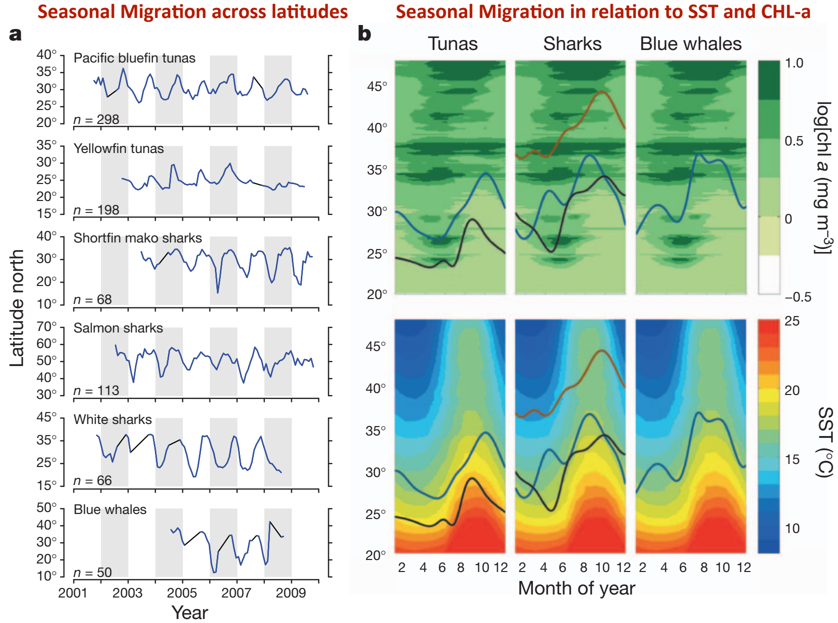


(tunas, sharks, elephant seals, salmon sharks)

(turtles, sooty shearwaters, fur seals, albatrosses, salmon sharks)

Seasonal Migration across latitudes

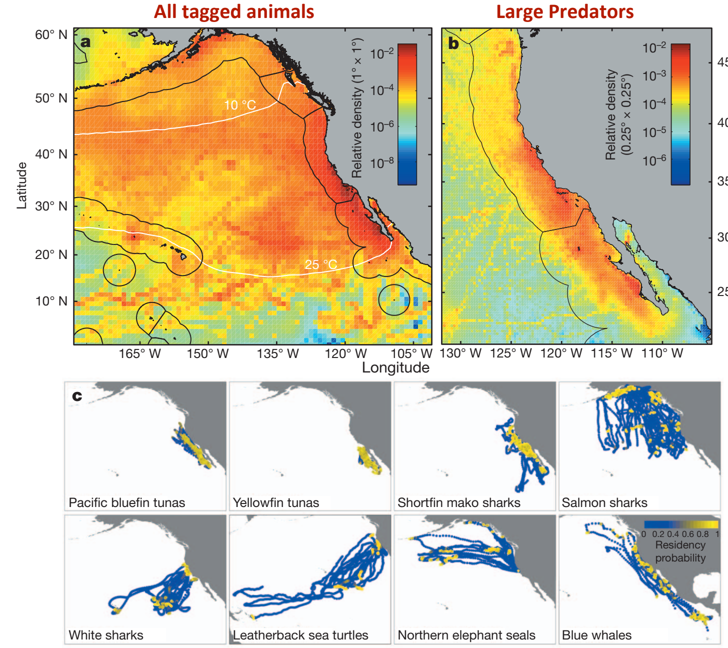
Seasonal Migration in relation to SST and CHL-a



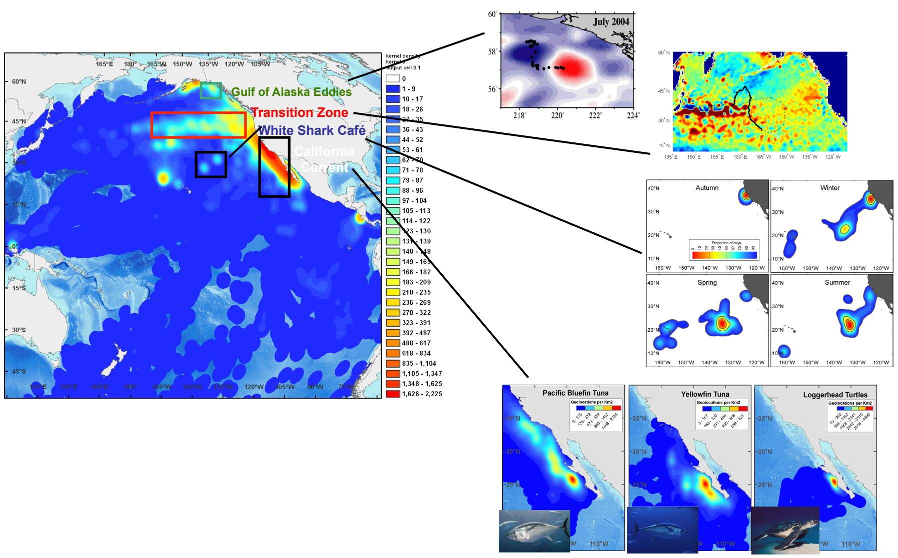
Predator Density Maps

All tagged animals

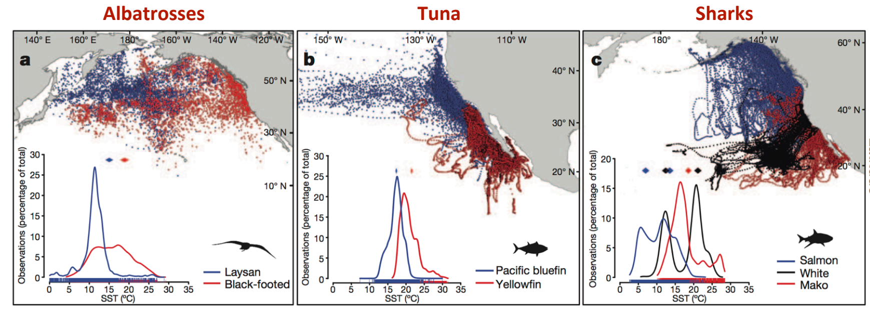
Large Predators



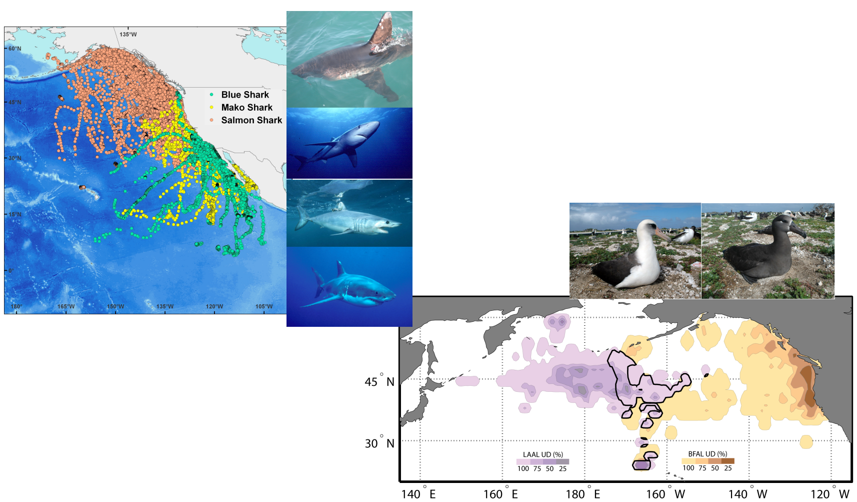
Hot spots for foraging, migration and reproduction



Niche separation within three predator guilds



Habitat overlap and niche partitioning



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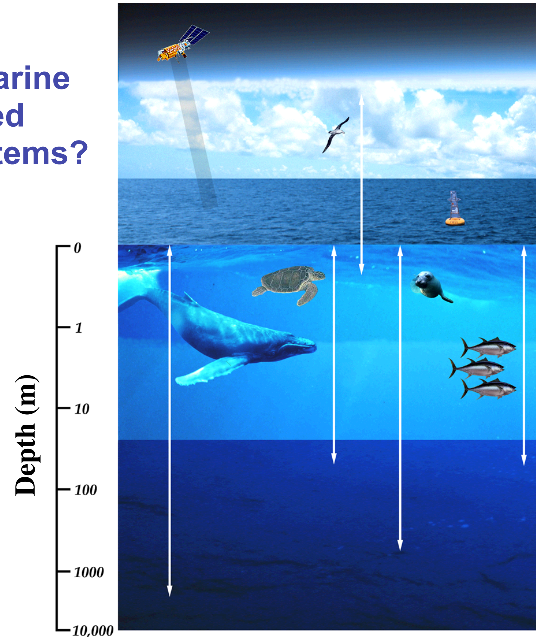
Important Findings →

Pelagic marine predators face unprecedented challenges and uncertain futures. Overexploitation and climate variability impact the abundance and distribution of top predators in ocean ecosystems[1–4]. Improved understanding of ecological patterns, evolutionary constraints and ecosystem function is critical for preventing extinctions, loss of biodiversity and disruption of ecosystem services. Recent advances in electronic tagging techniques have provided the capacity to observe the movements and long-distance migrations of animals in relation to ocean processes across a range of ecological scales[5,6]. Tagging of Pacific Predators, a field programme of the Census of Marine Life, deployed 4,306 tags on 23 species in the North Pacific Ocean, resulting in a tracking data set of unprecedented scale and species diversity that covers 265,386 tracking days from 2000 to 2009. Here we report migration pathways, link ocean features to multispecies hotspots and illustrate niche partitioning within and among congener guilds. Our results indicate that the California Current large marine ecosystem and the North Pacific transition zone attract and retain a diverse assemblage of marine vertebrates. Within the California Current large marine ecosystem, several predator guilds seasonally undertake north–south migrations that may be driven by oceanic processes, species-specific thermal tolerances and shifts in prey distributions. We identify critical habitats across multinational boundaries and show that top predators exploit their environment in predictable ways, providing the foundation for spatial management of large marine ecosystems.

What role for apex marine predators in integrated ocean observing systems?



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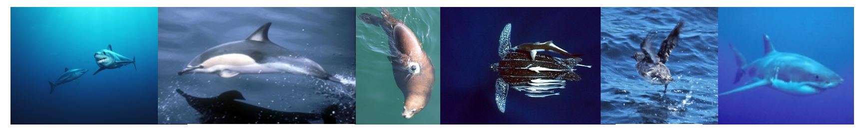
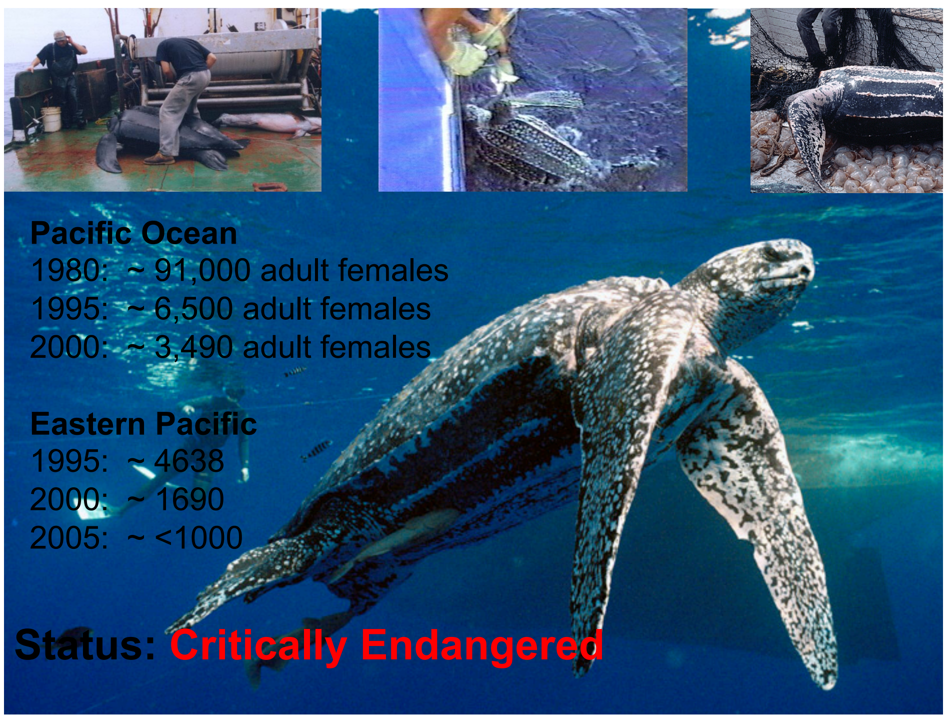
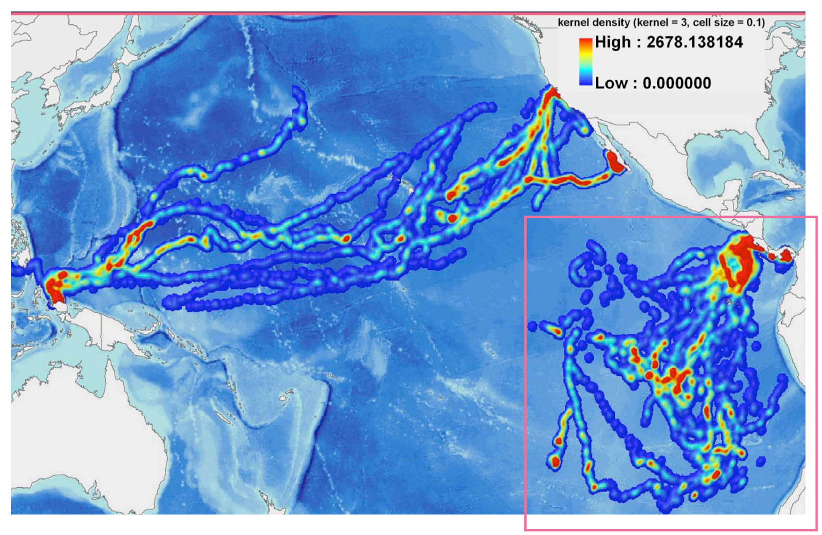
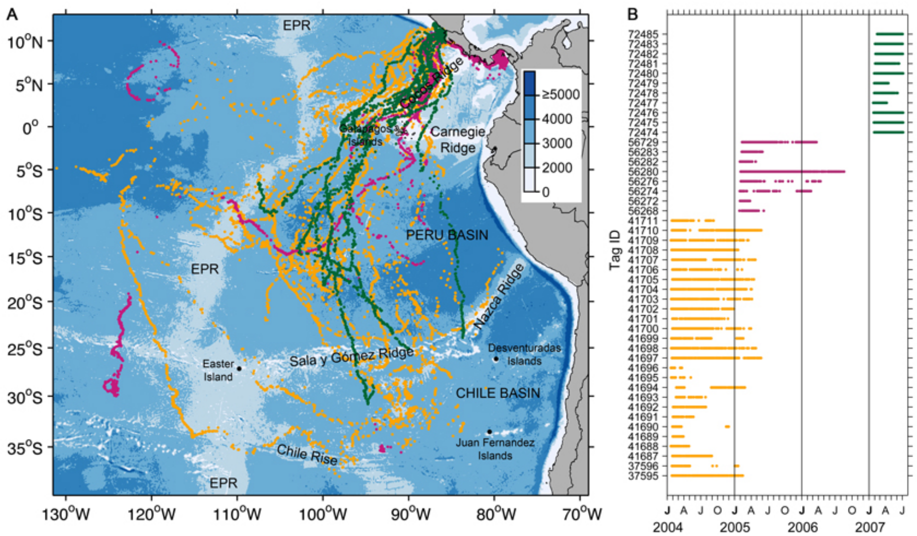




Pan-Pacific hot spots of two populations of leatherback turtles



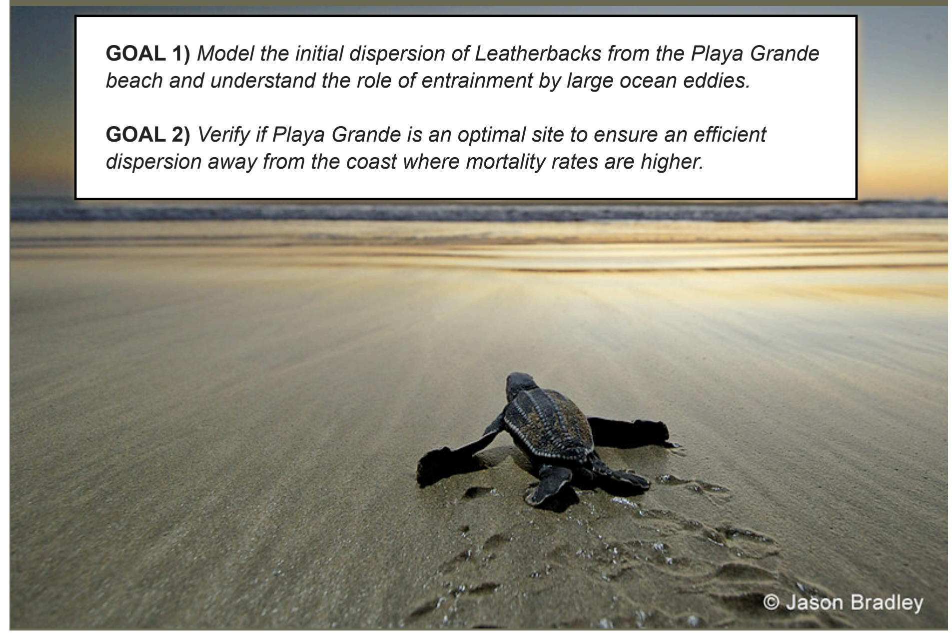
The Leatherback Turtles



Modeling the life cycle of Leatherback Turtles

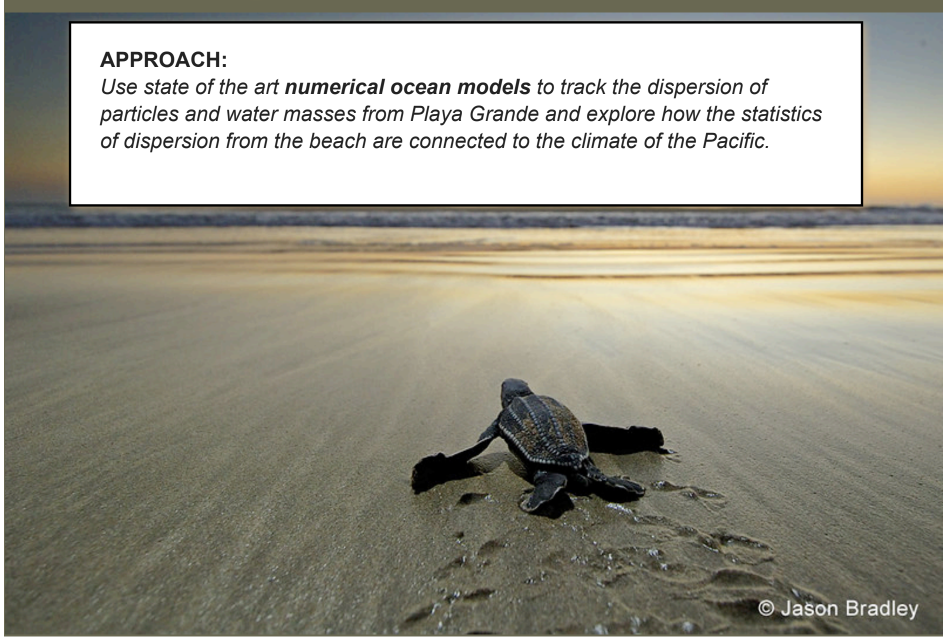
GOAL 1) *Model the initial dispersion of Leatherbacks from the Playa Grande beach and understand the role of entrainment by large ocean eddies.*

GOAL 2) *Verify if Playa Grande is an optimal site to ensure an efficient dispersion away from the coast where mortality rates are higher.*



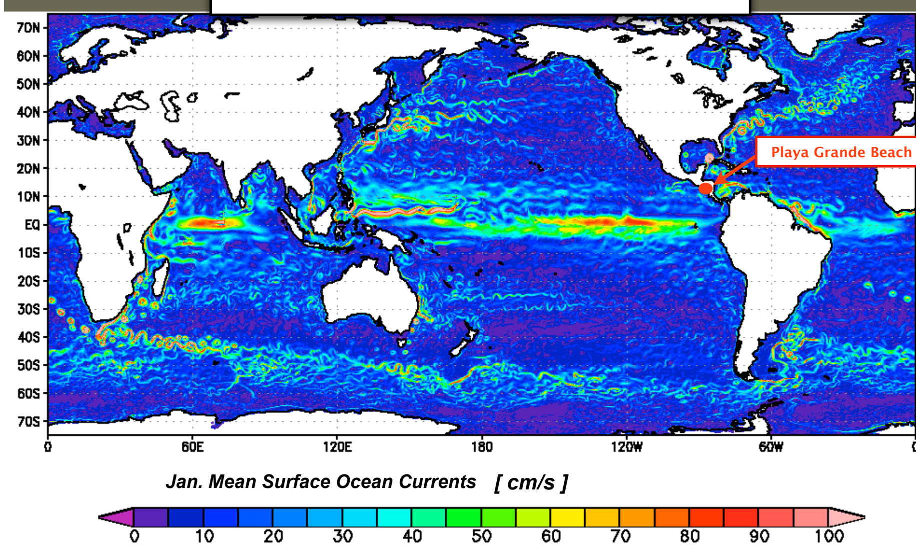
Modeling the life cycle of Leatherback Turtles

APPROACH:
*Use state of the art **numerical ocean models** to track the dispersion of particles and water masses from Playa Grande and explore how the statistics of dispersion from the beach are connected to the climate of the Pacific.*



Modeling the life cycle of Leatherback Turtles

The global ocean circulation model
10 km resolution historical simulation 1950-2010



Modeling the life cycle of Leatherback Turtles

The global ocean circulation model

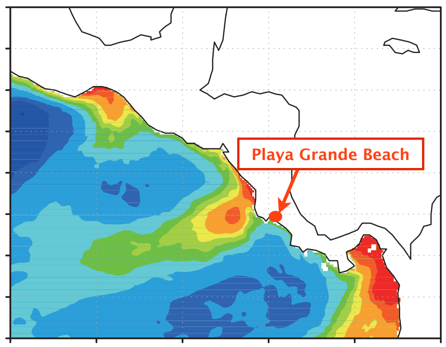
10 km resolution historical simulation 1950-2010

Zoom View of Playa Grande

The offshore advection of Chlorophyll-a in the model is associated with dispersion

Is this accurate?

Ocean Model



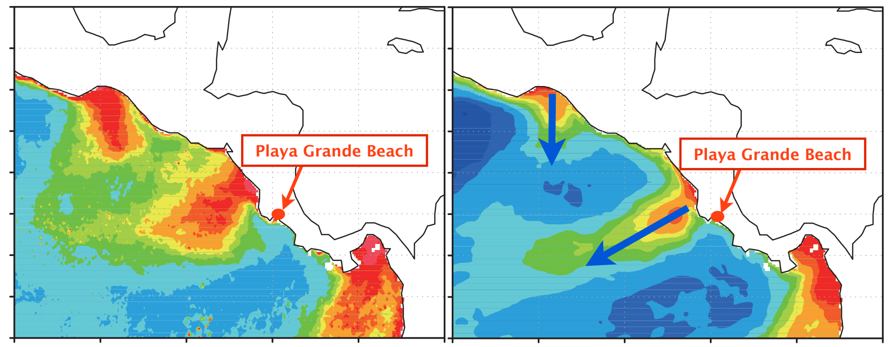
March Average Surface Chlorophyll-a

Modeling the life cycle of Leatherback Turtles

The global ocean circulation model

10 km resolution historical simulation 1950-2010

Satellite **Ocean Model**



March Average Surface Chlorophyll-a

The model simulation captures very well the ocean eddies "highways"

Modeling the life cycle of Leatherback Turtles

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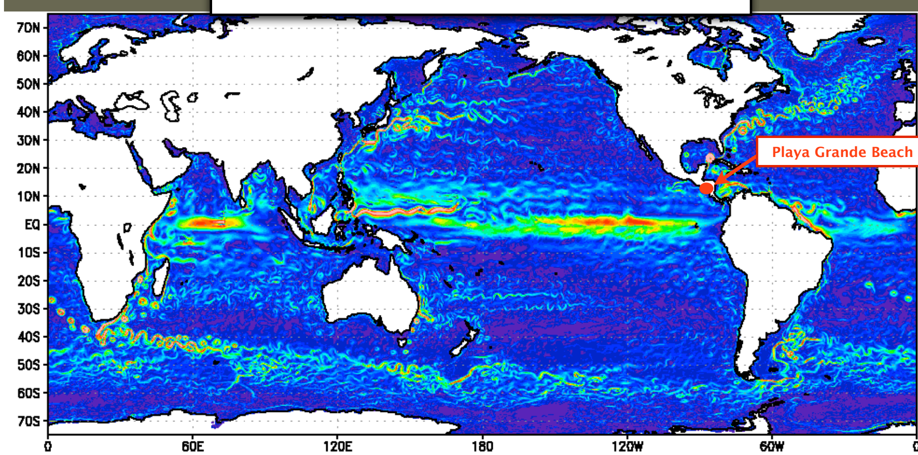
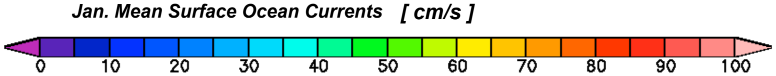
10 km resolution historical simulation 1950-2010



Jan. Mean Surface Ocean Currents [cm/s]



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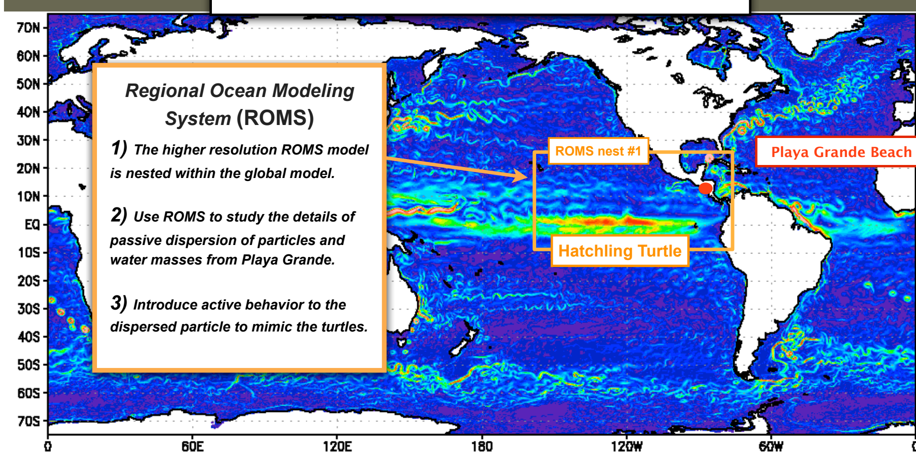
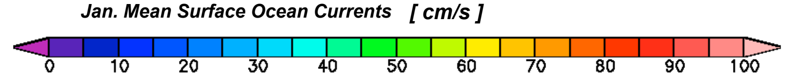


Jan. Mean Surface Ocean Currents [cm/s]

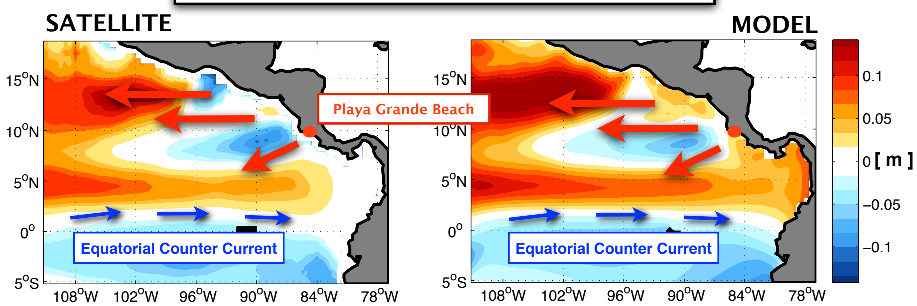


Modeling the life cycle of Leatherback Turtles

The Regional Ocean Modeling System

10 km resolution historical simulation 2000-2008

Mean Circulation from Sea Level



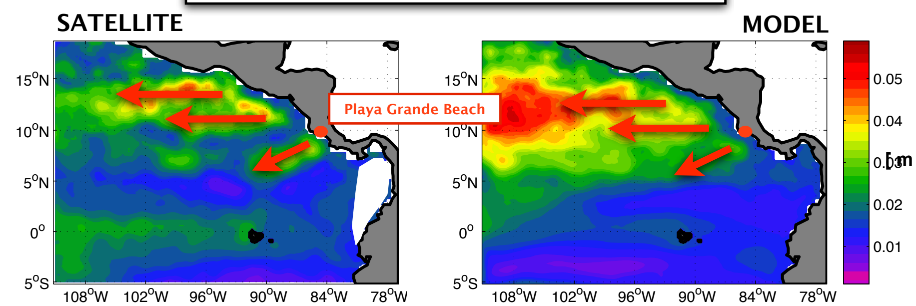
***Hypothesis**: Playa Grande beach located on the **ocean eddies "highways"** allowing the turtle to be transported away from the coast very efficiently.*

Modeling the life cycle of Leatherback Turtles

The Regional Ocean Modeling System

10 km resolution historical simulation 2000-2008

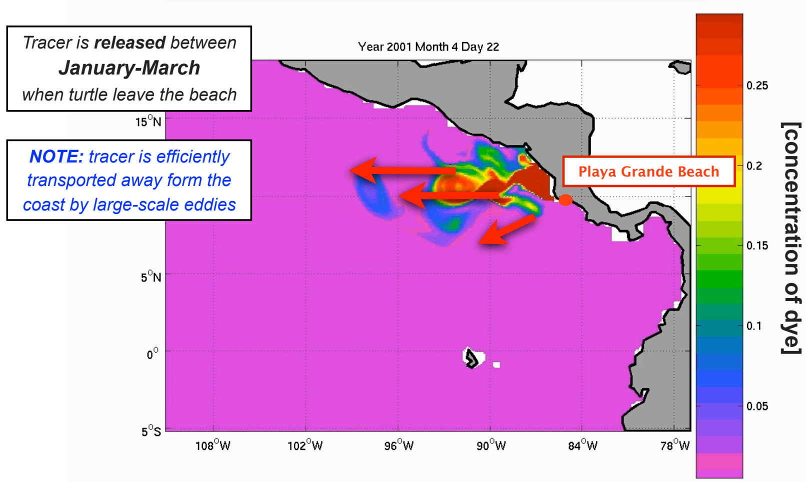
Variance of Sea Level



Regions of high variance in sea level denote ocean eddies "highways"

Modeling the life cycle of Leatherback Turtles

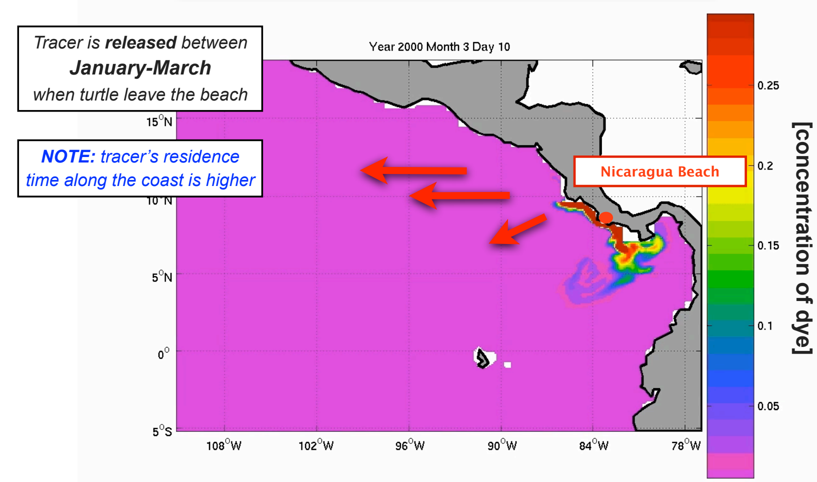
Dispersion from Playa Grande



red arrow denote mean ocean eddies "highways"

Modeling the life cycle of Leatherback Turtles

Dispersion from Nicaragua Beach

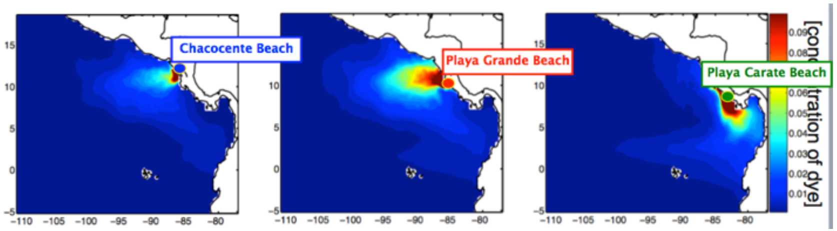


red arrow denote mean ocean eddies "highways"

Dispersion Statistics

statistics are compiled using release experiment from 2000-2008

Probability Density Function of Passive Tracer



Modeling the life cycle of Leatherback Turtles

Preliminary Modeling Results

Hypothesis: *Playa Grande beach located on the* ***ocean eddies "highways"*** *allowing the turtle to be transported away from the coast very efficiently.*

RESULTS:

✓ *The dispersion statistics of the circulation model show that passive tracers released at Playa Grande are rapidly and efficiently entrained by large ocean eddies and transported offshore away from the coast.*

✓ *Beaches south of Playa Grande show a longer residence time of the passive tracer along the coast, hence minimizing the chances of turtle survivor.*

✓ *The strength of the offshore transport from Playa Grande has an interannual modulation driven by El Niño activity in the preceding fall/winter hence providing the basis for some predictability.*

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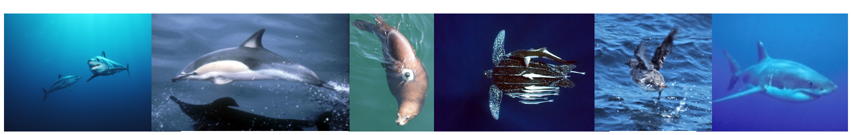


Hawaiian Albatrosses

Body Size: 2.5 to 3.0 kg

Pop Center: NWHI

Est. Pop.: 590,000 pairs

Status: Vulnerable

Body Size: 3.0 to 3.5 kg

Pop Center: NWHI

Est. Pop.: 61,000 pairs

Status: Threatened

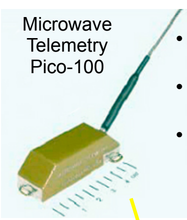
Questions

- Do sympatrically breeding albatrosses partition oceanic resources when not breeding?
- If so, are there specific oceanographic habitats 'favored' by each species?

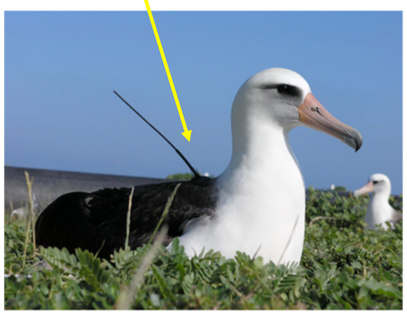
In biology, two species or populations are said to be sympatric when they occur in the same area and are able to encounter each other.[1] This contrasts with parapatric forms, which have adjacent but nonoverlapping ranges, and allopatric forms, which have separated ranges.[2] When closely related but distinct species are sympatric, this may indicate that sympatric speciation has occurred, a controversial mode of speciation in which a population splits into two sympatric, initially interbreeding species.[3]

Fieldwork

Tagging



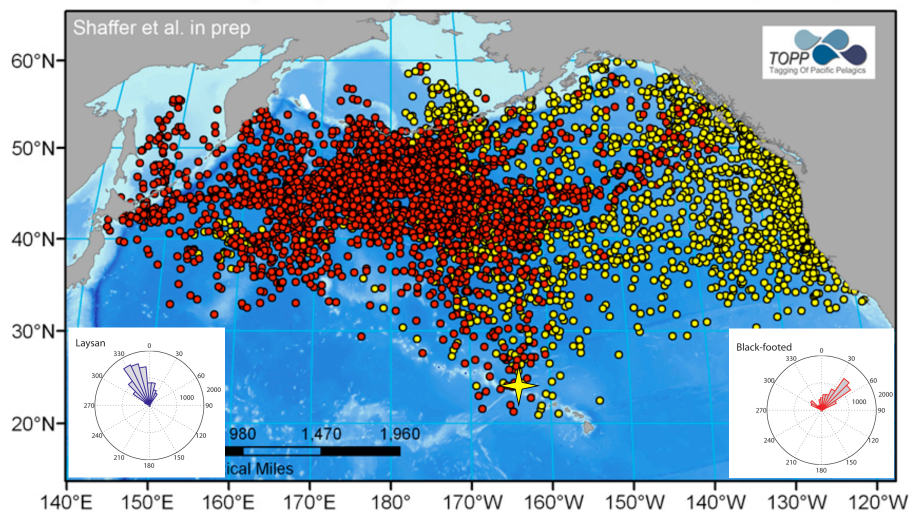
- Satellite transmitters (20-40 g)
- 7-20 at-sea locations per day
- Attached to feathers with tape



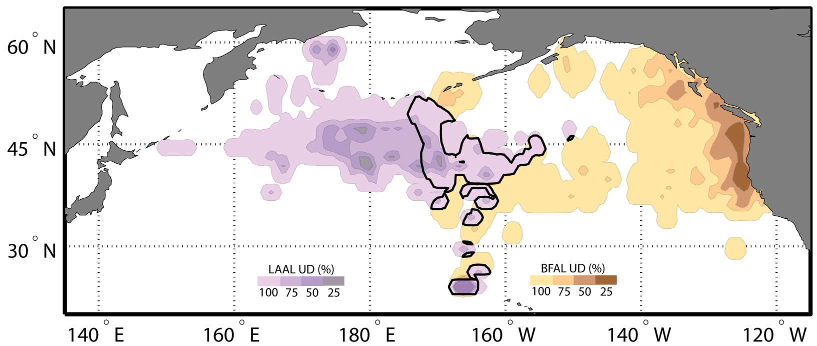
- GLS/Temp. loggers (10 g)
- 9 min sampling rate
- Cable ties/epoxy

Post-breeding Distribution (2005-2006)

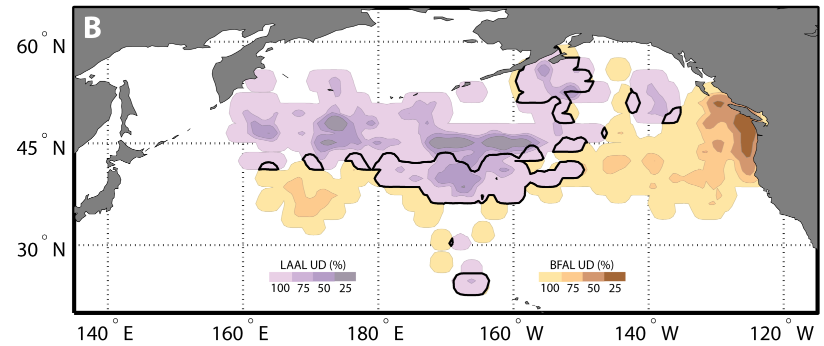
Red: Laysan (n = 17) Yellow: Black-footed (n = 21)



Home Range (2005)

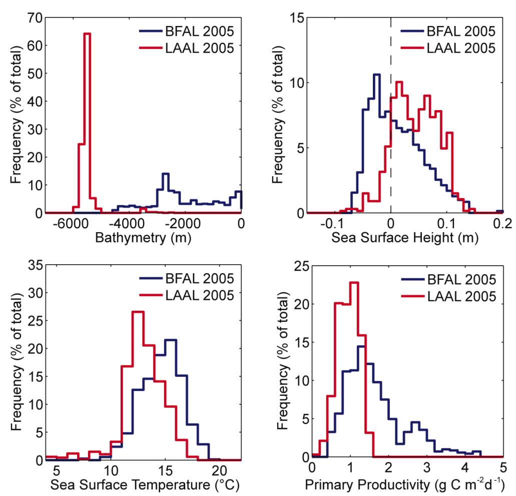


Home Range (2006)



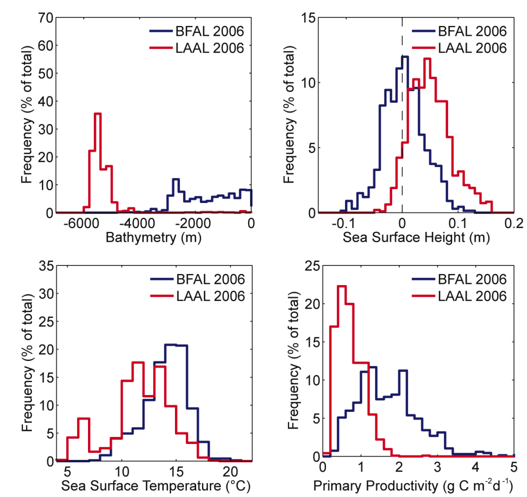
Shaffer et al., 2010

Core Habitat (2005)



50% UD for each variable

Core Habitat (2006)



50% UD for each variable

Core Habitat

Laysan:

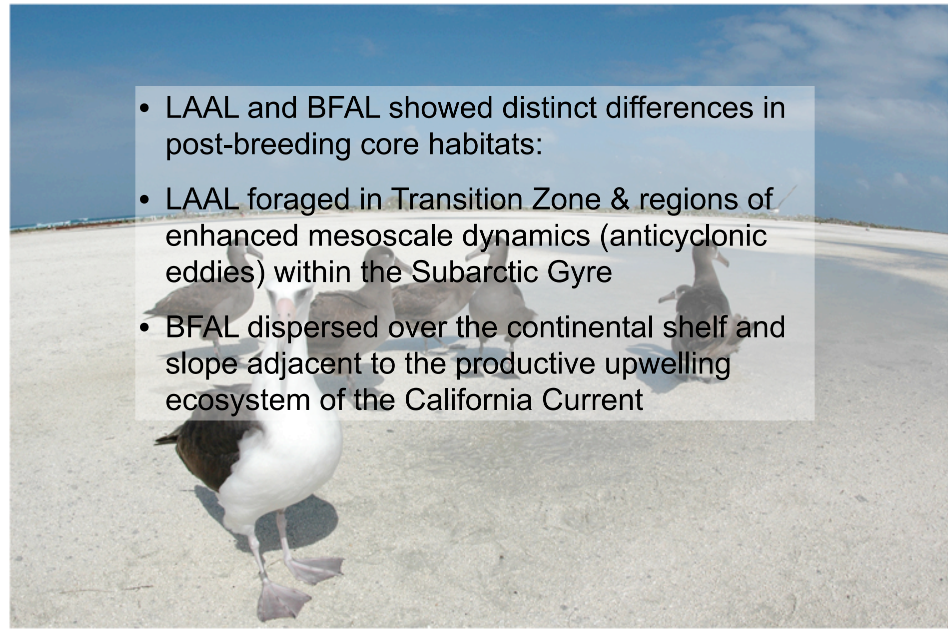
- Deep water (>5000 m)
- (+) SSH
- Low SST (<13°C)
- Low PP (<0.8 g C m^{-2} d^{-1})

Black-footed:

- Shallower water (<2000 m)
- (-) SSH
- Higher SST (~14°C)
- High PP (>1.6 g C m^{-2} d^{-1})

Interannual persistence of associations indicates that each species tracks particular oceanographic conditions during foraging

Conclusions



- LAAL and BFAL showed distinct differences in post-breeding core habitats:
- LAAL foraged in Transition Zone & regions of enhanced mesoscale dynamics (anticyclonic eddies) within the Subarctic Gyre
- BFAL dispersed over the continental shelf and slope adjacent to the productive upwelling ecosystem of the California Current

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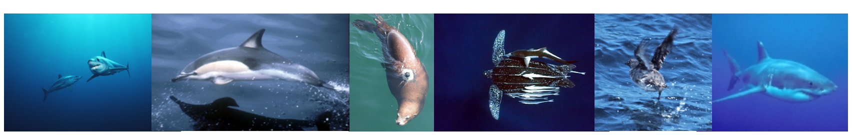
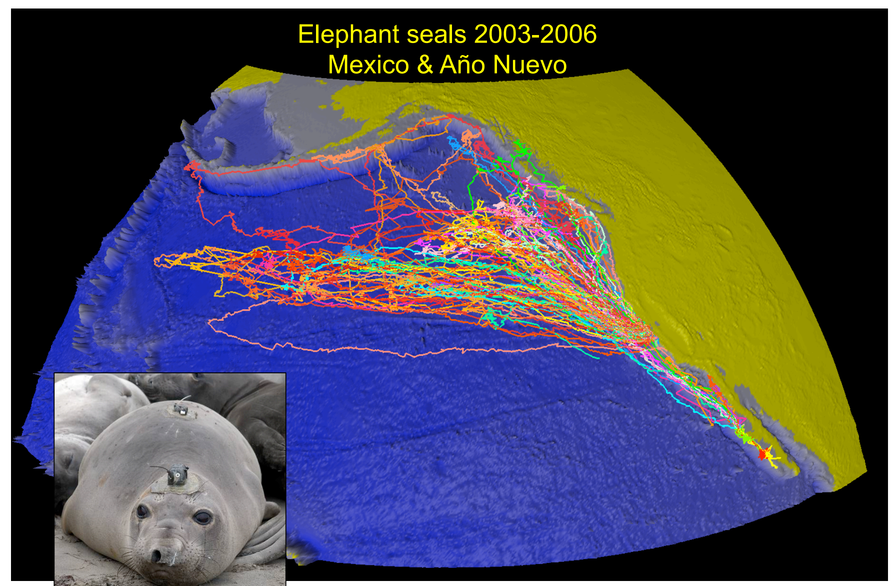
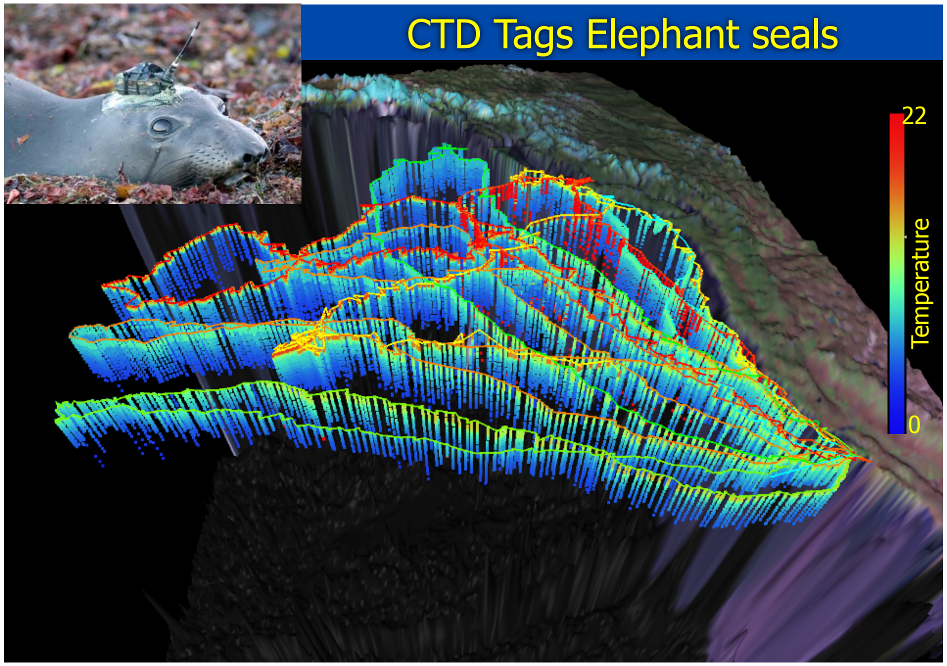
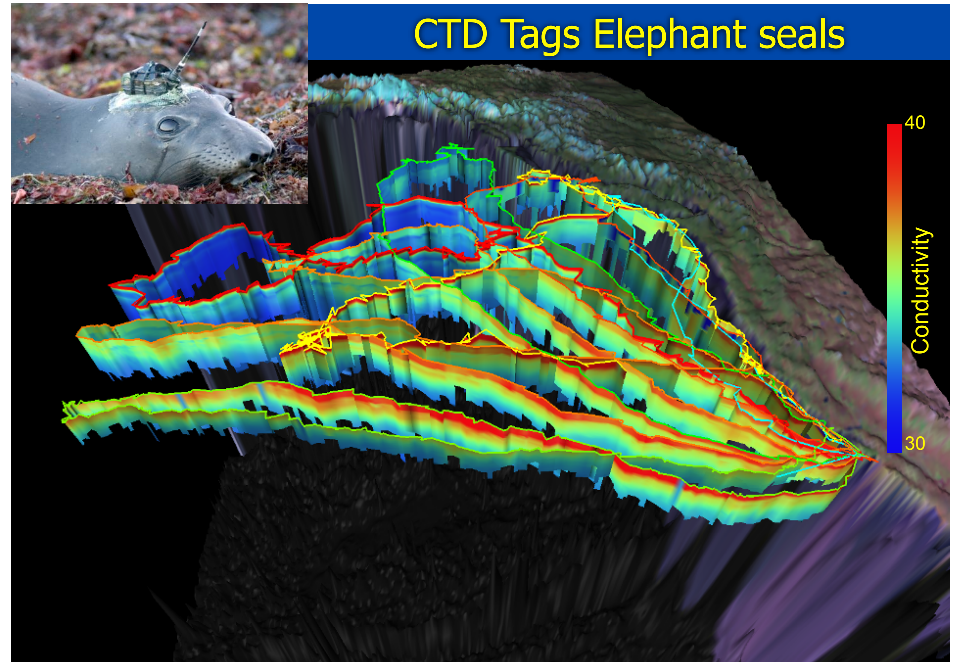


Elephant Seals: Premier Oceanographers of the North Pacific



Costa Lab, UCSC





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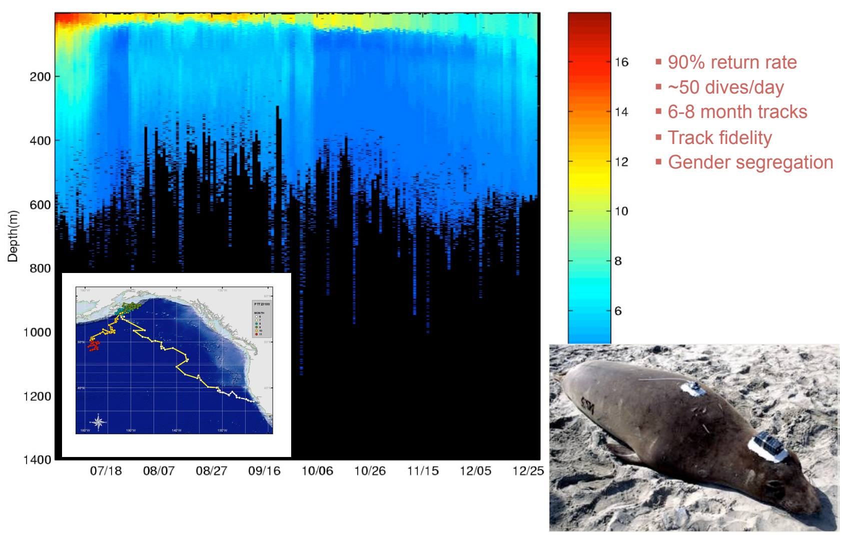
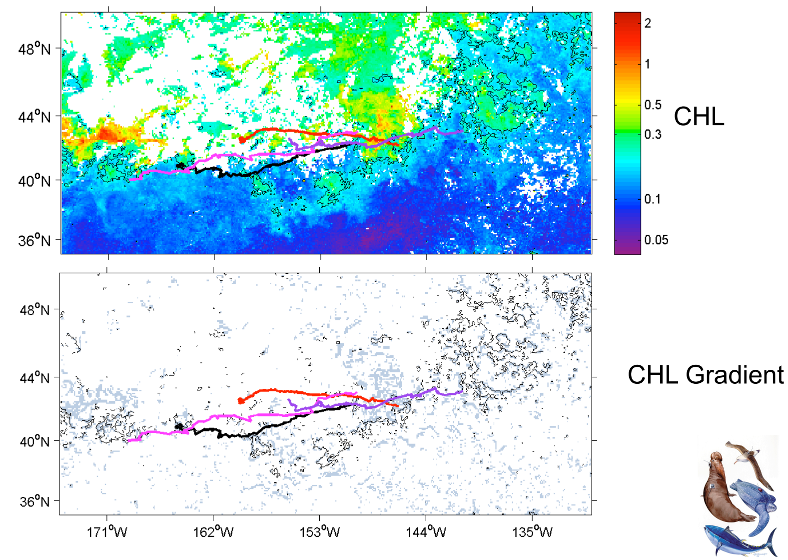


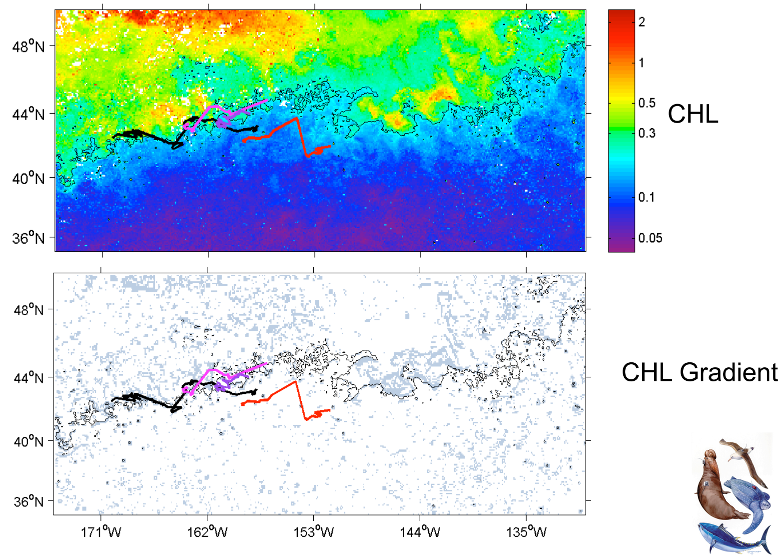
TRACKS of 4 ELEPHANT SEALS; July 2004

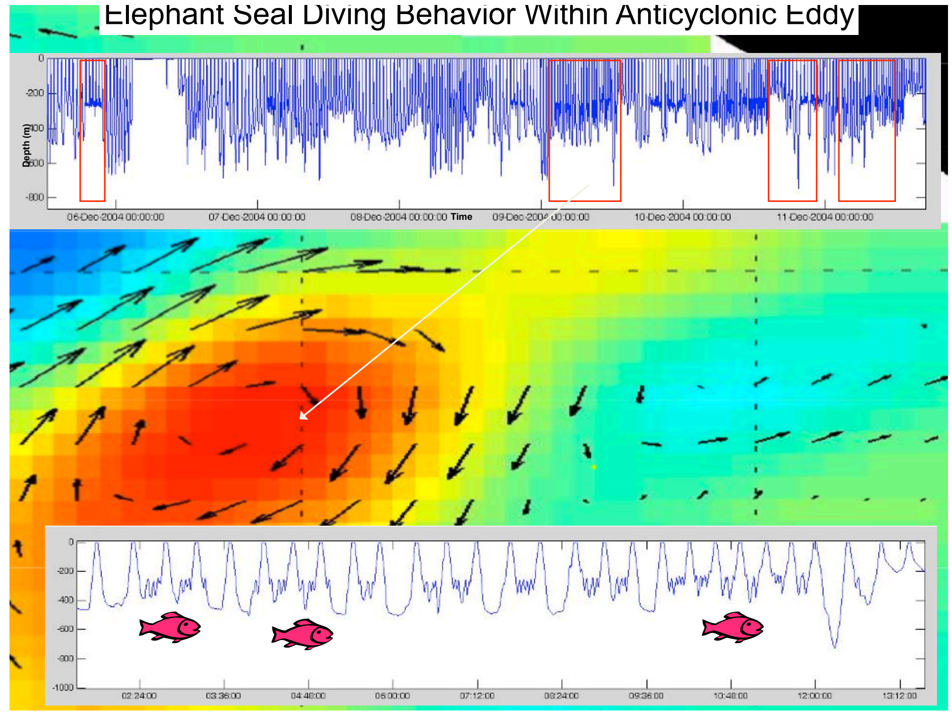


Data from TOPP - Costa Lab, UCSC

D. Palacios, NOAA/JIMAR

TRACKS of 4 ELEPHANT SEALS; September 2004





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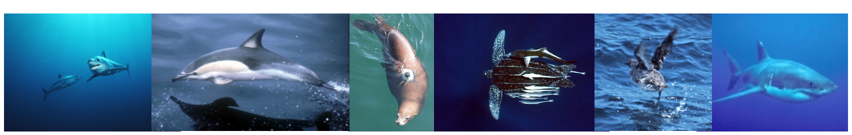
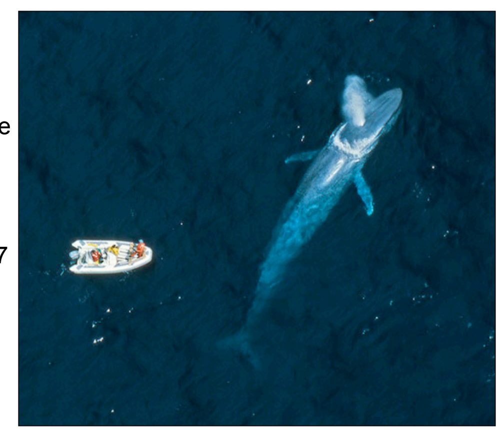
- ❖ **<u>Elephant seal</u> foraging in fronts and eddies**
- ❖ **California upwelling and <u>blue whale</u> migration**

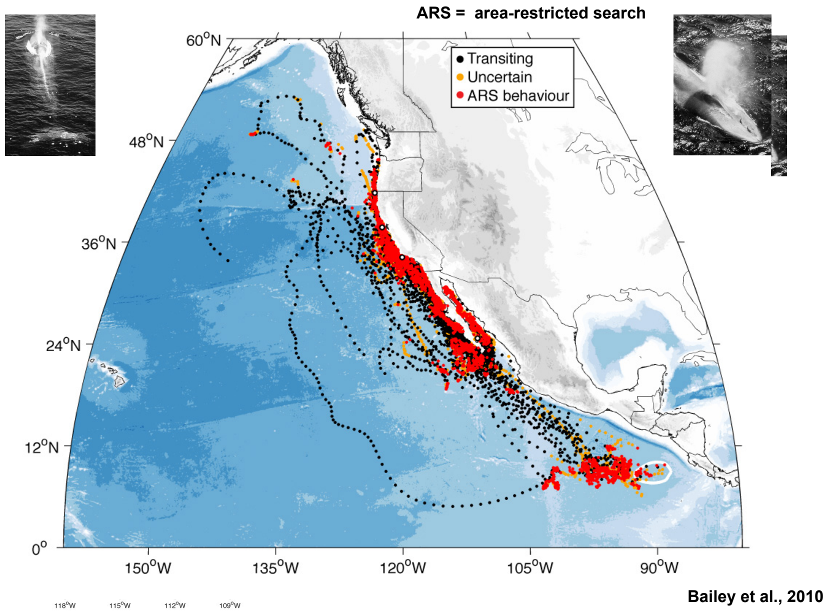


Blue Whales

- 128 tags deployed during 1993-2007
- Mean track duration 81 days (range 0-504 days)
- Mean number of satellite positions per day = 2
- SSM on all tracks with duration of 7 days or more
- 92 SSM tracks

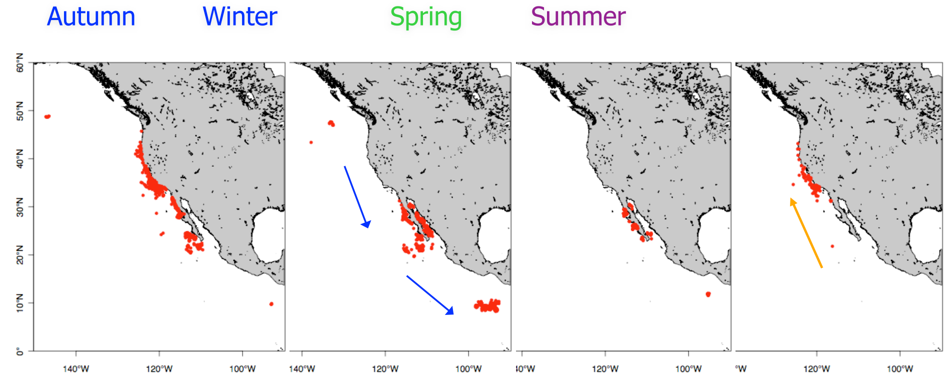


Blue Whale Hot Spots



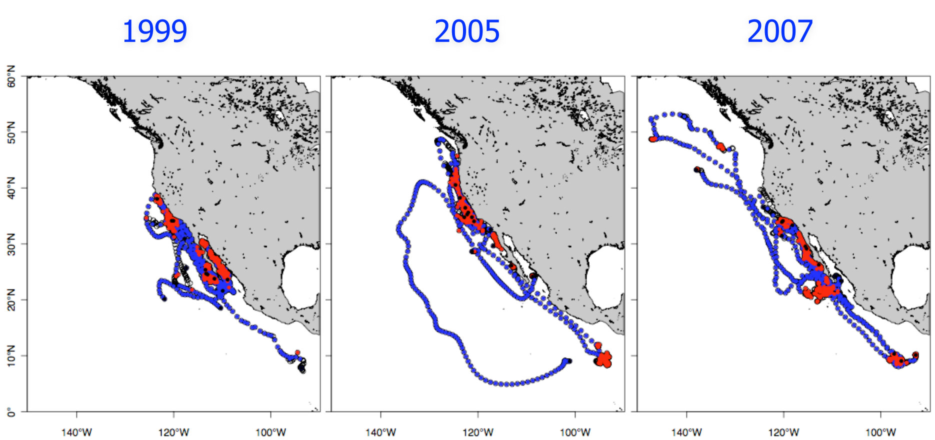
Bailey et al., 2010

Seasonal Movements



Whales tagged in September

Interannual Variability



1999	2005	2007
N = 15	N = 14	N = 14
Average duration = 98 days	Average duration = 87 days	Average duration = 114 days

CENSUS OF MARINE LIFE PROJECT AREAS