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

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Technical Approach: Use Multiple Tag Platforms

CTD Tag

GPS Tag

Geolocation Tag (6 g)

Pop Up Tag

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

Tracking apex marine predator movements in a dynamic ocean

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

Thunnus albacares

Caretta caretta

Lamna ditropis

Prionace glauca

Thresher shark

Leatherback turtle

Humpback whale

Loggerhead turtle

Pacific bluefin tuna

Albacore tuna

Blue shark

Mako shark

White shark

Fur seal

Northern elephant seal

North American sea lion

Blue whale

Northern fur seal

Equatorial current

Subtropical gyre

Equatorial convergence zone

Humboldt currents

Kuroshio

Kuroshio extension

SST

Laminar flow

Sulu

Equatorial water

Marine Life, deployed 4,306 tags on 23 species in the North Pacific Ocean, resulting in a tracking data set of unprecedented scale and scope. The data were used to study the migration patterns of large marine predators, including bluefin and yellowfin tunas, mako, white and blue sharks, and leatherback sea turtles. The study aimed to understand migration pathways, link ocean features to multispecies hotspots, and illustrate niche partitioning among the species. A total of 4,306 tags were deployed on 23 species from 2000 to 2009, tracking 265,386 days. The study highlighted the importance of large marine predators as top consumers in marine ecosystems and the need to understand their movements in relation to ocean processes across a range of ecological scales.
as the ocean warms, subsurface hypoxia 

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

CCLME = California Current Large Marine Ecosystem

Pelagic Predators return to CCLME after seasonal migrations

Pelagic Predators attracted to CCLME

Relative density models showed a strong positive relationship between

Seasonal Migration across latitudes

Seasonal Migration in relation to SST and CHL-a

Latitude north

Year

Pacific bluefin tunas

Yellowfin tunas

Shortfin mako sharks

Salmon sharks

White sharks

Blue whales

Month of year

1.0

0.5

0

-0.5

-1.0

20 25 30 35 40

SST (ºC)

0 5 10 15 20 25 30 35

2001 2002 2003 2004 2005 2006 2007 2008 2009

Tunas

Sharks

Blue whales

Paci

n tuna

Humpback whale

Fin whale

Sperm whale

Sooty shearwater

California sea lion

Northern fur seal

Blue whale

Northern elephant seal

Thresher shark

Yellowfin tuna

Alopias vul

shortfin mako sharks

Salmon sharks

White shark

Longerhead turtle

Mola mola

Pacific bluefin tuna

Leatherback turtle

Salmon shark

Laysan albatross

Black-footed albatross

Humboldt squid
Pelagic marine predators face unprecedented challenges and uncertain futures. Overexploitation and climate variability impact the abundance and distribution of top predators in ocean ecosystems. 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.

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

Pacific Ocean
1980: ~ 91,000 adult females
1995: ~ 6,500 adult females
2000: ~ 3,490 adult females

Status: Critically Endangered

Eastern Pacific
1995: ~ 4638
2000: ~ 1690
2005: <1000
The 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.

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

**Zoom View of Playa Grande**

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

**Is this accurate?**

March Average Surface Chlorophyll-a

**The model simulation captures very well the ocean eddies “highways”**

**Modeling the life cycle of Leatherback Turtles**

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

**Jan. Mean Surface Ocean Currents [cm/s]**

Regional Ocean Modeling System (ROMS)

1) The higher resolution ROMS model is nested within the global model.
2) Use ROMS to study the details of passive dispersion of particles and water masses from Playa Grande.
3) Introduce active behavior to the dispersed particle to mimic the turtles.
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.

NOTE: tracer is efficiently transported away from the coast by large-scale eddies

Dispersion from Playa Grande

Tracer is released between January-March when turtle leaves the beach
red arrow denote mean ocean eddies “highways”

Dispersion from Nicaragua Beach

Tracer is released between January-March when turtle leaves the beach
NOTE: tracer’s residence time along the coast is higher
red arrow denote mean ocean eddies “highways”

Regions of high variance in sea level denote ocean eddies “highways”
**Dispersion Statistics**

Statistics are compiled using release experiment from 2000-2008

Probability Density Function of Passive Tracer

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**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**

<table>
<thead>
<tr>
<th>Species</th>
<th>Body Size</th>
<th>Pop Center</th>
<th>Est. Pop.</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laysan</td>
<td>2.5 to 3.0 kg</td>
<td>NWHI</td>
<td>590,000 pairs</td>
<td>Vulnerable</td>
</tr>
<tr>
<td>Black-footed</td>
<td>3.0 to 3.5 kg</td>
<td>NWHI</td>
<td>61,000 pairs</td>
<td>Threatened</td>
</tr>
</tbody>
</table>
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. This contrasts with parapatric forms, which have adjacent but nonoverlapping ranges, and allopatric forms, which have separated ranges. 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.

Fieldwork

- Tern Island, French Frigate Shoals (NWHI)
- 5 seasons (2002-2007)
- Breeding season: Dec-Jun
- Post-breeding: Jun-Dec
- Tagged over 200 individuals

Tagging

- Microwave Telemetry
- Pico-100
- 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)

Core Habitat (2005)

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

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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

Elephant Seals: Premier Oceanographers of the North Pacific
Elephant Seals: Premier Oceanographers of the North Pacific

- 90% return rate
- ~50 dives/day
- 6-8 month tracks
- Track fidelity
- Gender segregation

Data from TOPP - Costa Lab, UCSC
D. Palacios, NOAA/JIMAR
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Blue Whale Hot Spots

ARS = area-restricted search

Seasonal Movements

Autumn  Winter  Spring  Summer

Whales tagged in September

Interannual Variability

1999

N = 15
Average = 98 days duration

2005

N = 14
Average = 87 days duration

2007

N = 14
Average = 114 days duration

New Species Discovered in Marine Life Census