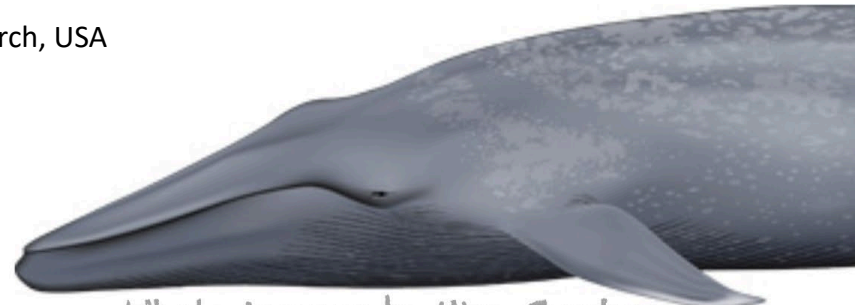
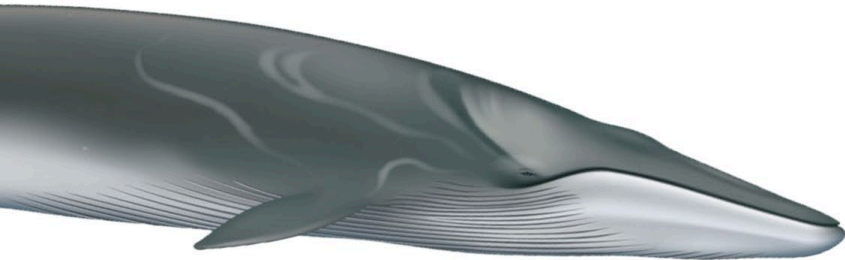


# Dispersal, site fidelity, and residency of satellite-tagged blue and fin whales in the California Current Ecosystem

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Whale images by Uko Gorter

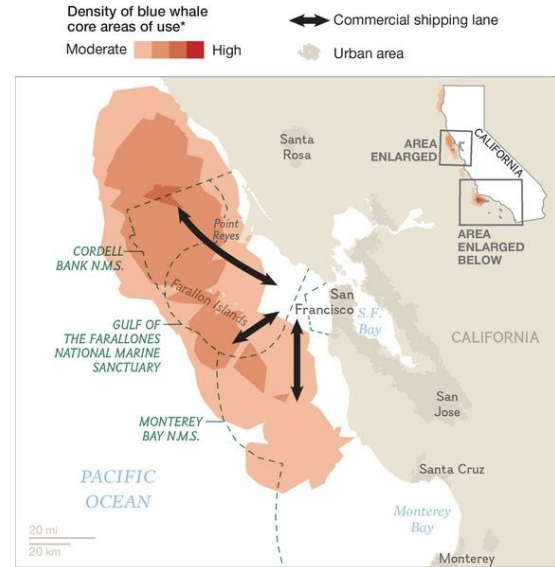
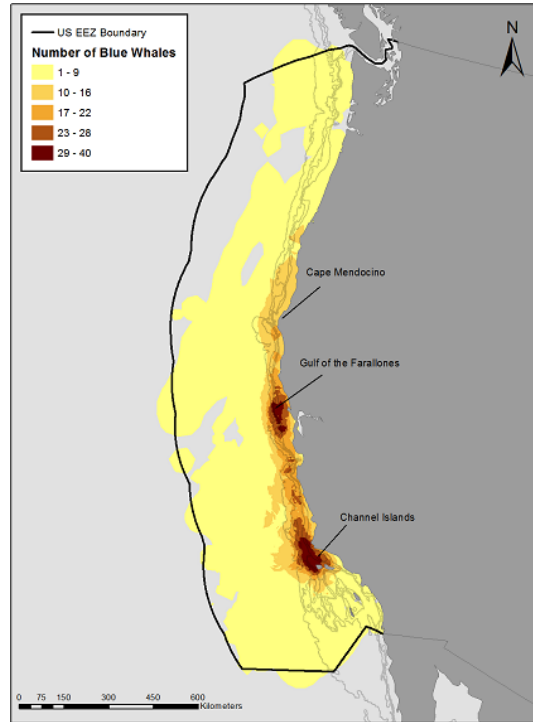


Studying large whales using satellite telemetry presents multifaceted challenges:

- Substantial size, streamlined morphology, elusive behavior, vast oceanic range, and ability to traverse great distances, **preclude direct capture for tag attachment.**
- Tag deployment at sea is costly and necessitates complex logistics.
- Data transmission limited to brief surface intervals coinciding with Argos satellite passes.

Progress in our understanding of whale ecology and behavior at the largest scales has been slow, **lagging other taxa.**

# Blue whale hotspots in the California Current Ecosystem



Irvine, L.M., et al.. 2014. Spatial and temporal occurrence of blue whales off the U.S. West Coast, with implications for management. *PLoS ONE* 9: e102959, doi: 10.1371/journal.pone.0102959.

Evaluation of biases inherent to the sampling approach:

1. **Tagging location bias** (Hays et al., 2020; O’Toole et al., 2020): device failure or premature detachment may result in shorter-duration tags overemphasizing the importance of the area near the tagging site.
2. **Representativeness of tagged individuals for population-level inferences** (Holdo and Roach, 2013; Street et al., 2021): multiple individuals tagged close in space/time result in tagged “cohorts” that may be more similar to each other as they disperse from the tagging area than the rest of the population.
3. **Site fidelity bias** (Morera-Pujol et al., 2022; Picardi et al., 2022): tagged animals may display multiple revisitations and longer residence times near tagging sites compared to other areas (especially if they provide enhanced/predictable feeding opportunities).

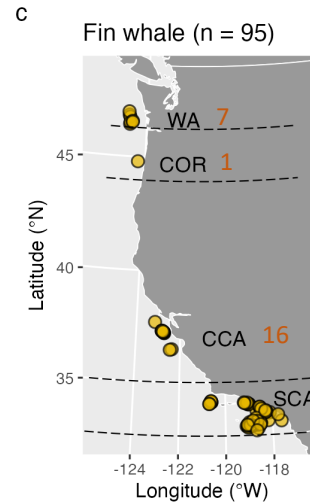
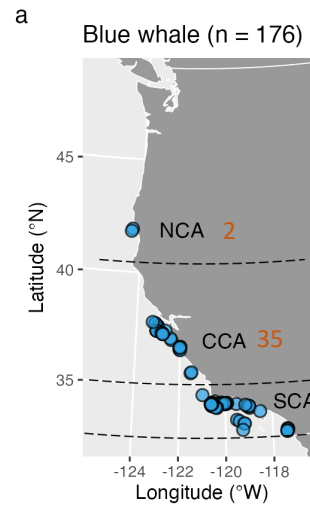
## Tag deployment locations (N = 271):

Blue whales (n = 176):

- SCA: n = 139
- CCA-NCA: n = 37

Fin whales (n = 95: 32 OSU, 63 MarEcoTel):

- SCA: n = 71
- CCA-PNW: n = 24



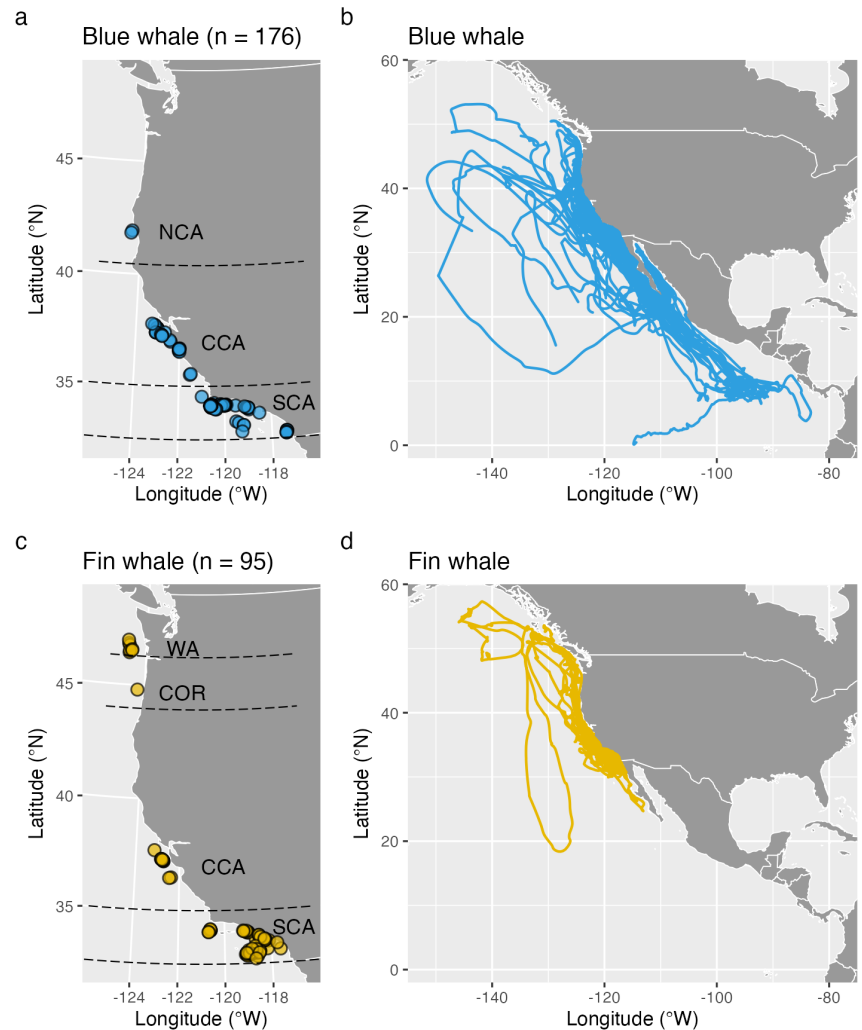
## Tag deployment locations and hSSSM tracks (3 locs/d):

Blue whales (n = 176):

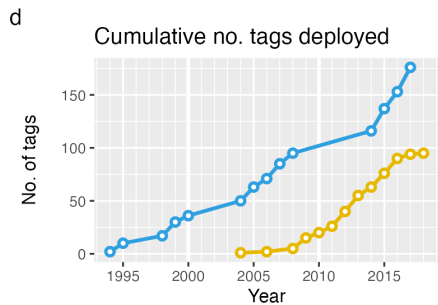
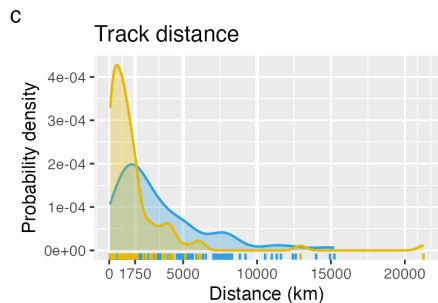
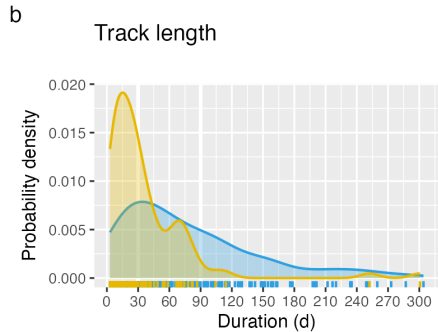
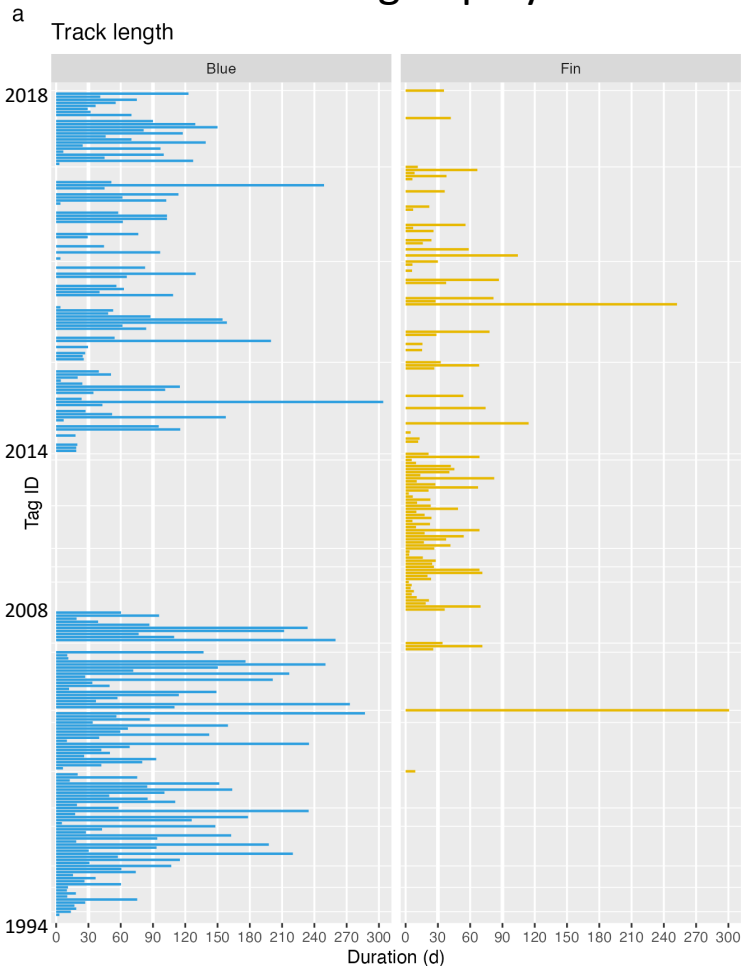
- SCA: n = 139
- CCA-NCA: n = 37

Fin whales (n = 95: 32 OSU, 63 MarEcoTel):

- SCA: n = 71
- CCA-PNW: n = 24



# Tag deployment metrics



Species



Species



## Blue whales:

Years: 1994-2017

N = 176

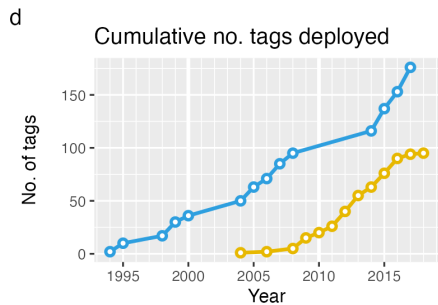
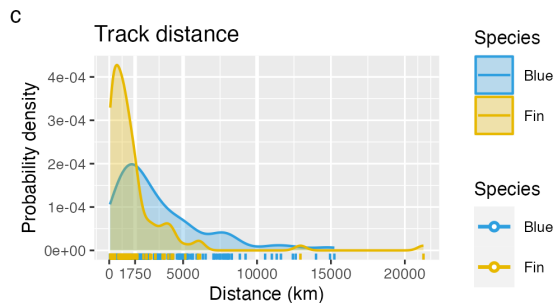
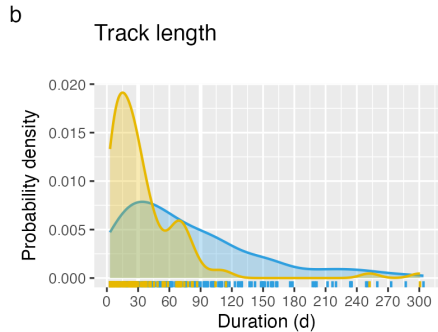
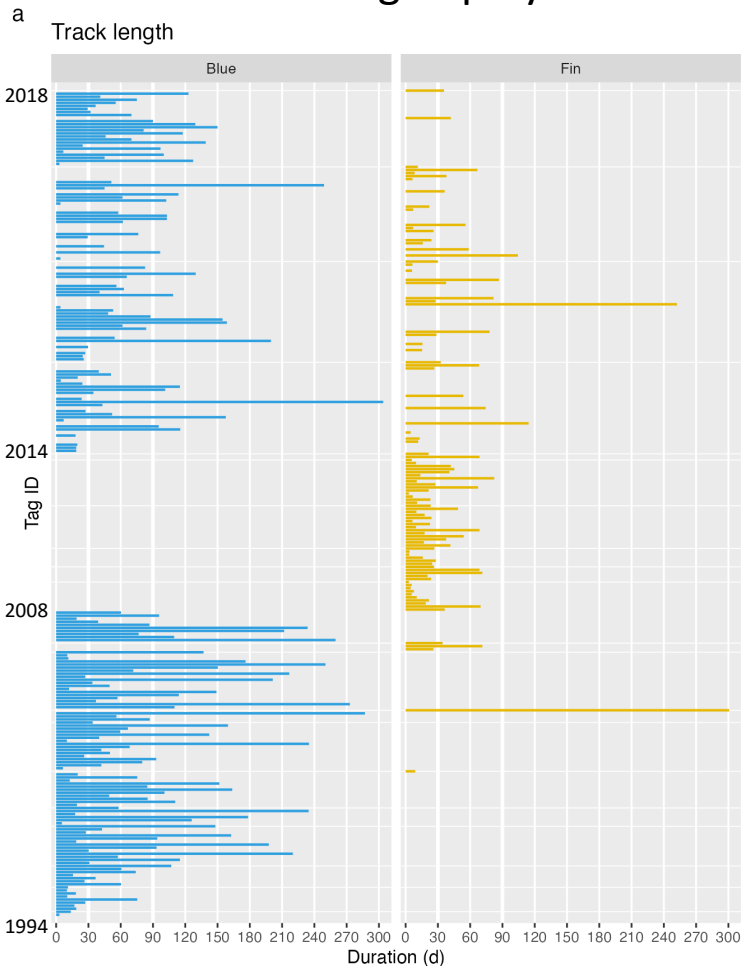
- Duration:

- Range: 3-304 d
- Mean = 79.1 d
- Median = 60.3 d
- SD = 65.8 d

- Distance:

- Range: 53.1-15,231 km
- Mean = 3,401 km
- Median = 2,355 km
- SD = 3,111 km

# Tag deployment metrics



## Fin whales:

Years: 2004-2018

N = 95 (32 OSU, 63 MarEcoTel)

- Duration:

- Range: 3-301 d
- Mean = 36.5 d
- Median = 24.0 d
- SD = 43.6 d

- Distance:

- Range: 70.6-21,260 km
- Mean = 1,688 km
- Median = 948 km
- SD = 2,706 km



# Individual dispersal from the tagging site

## Median distance

Blue whales:

- SCA: 99 km (n = 118)
- CCA-NCA: 159 km (n = 29)

Fin whales:

- SCA: 81 km (n = 55)
- CCA-PNW: 95.3 km (n = 15)

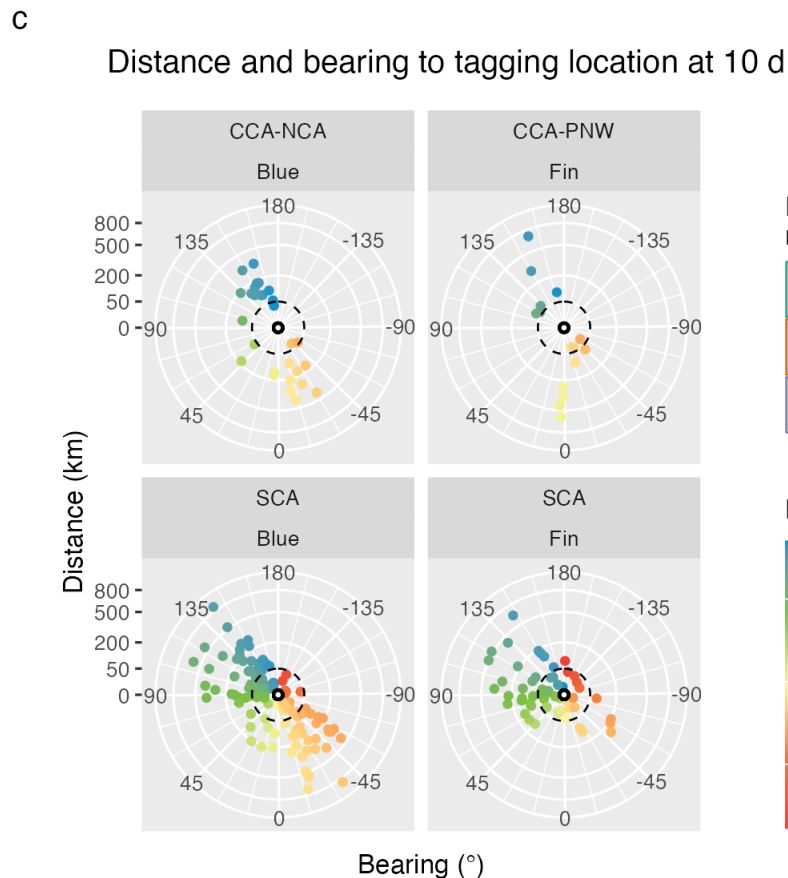
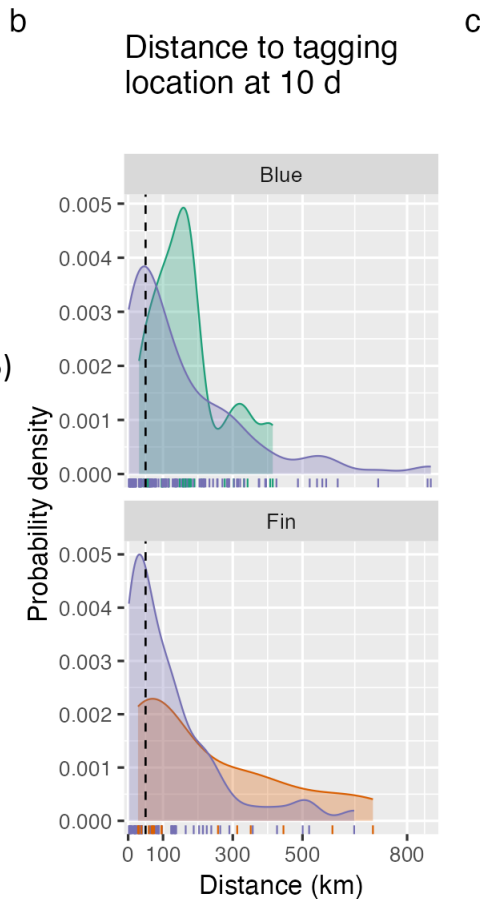
## Proportion within 50 km

Blue whales:

- SCA: 31.4%
- CCA-NCA: 10.3%

Fin whales:

- SCA: 43.6%
- CCA-PNW: 20%



# Group dispersal from the tagging site

Geodesic variance for the first 10 d of track

## Cohorts ( $\geq 2$ whales)

Blue whales (2-14 indiv):

- SCA: n = 19
- CCA-NCA: n = 7

Fin whales (2-12 indiv):

- SCA: n = 16
- CCA-PNW: n = 4

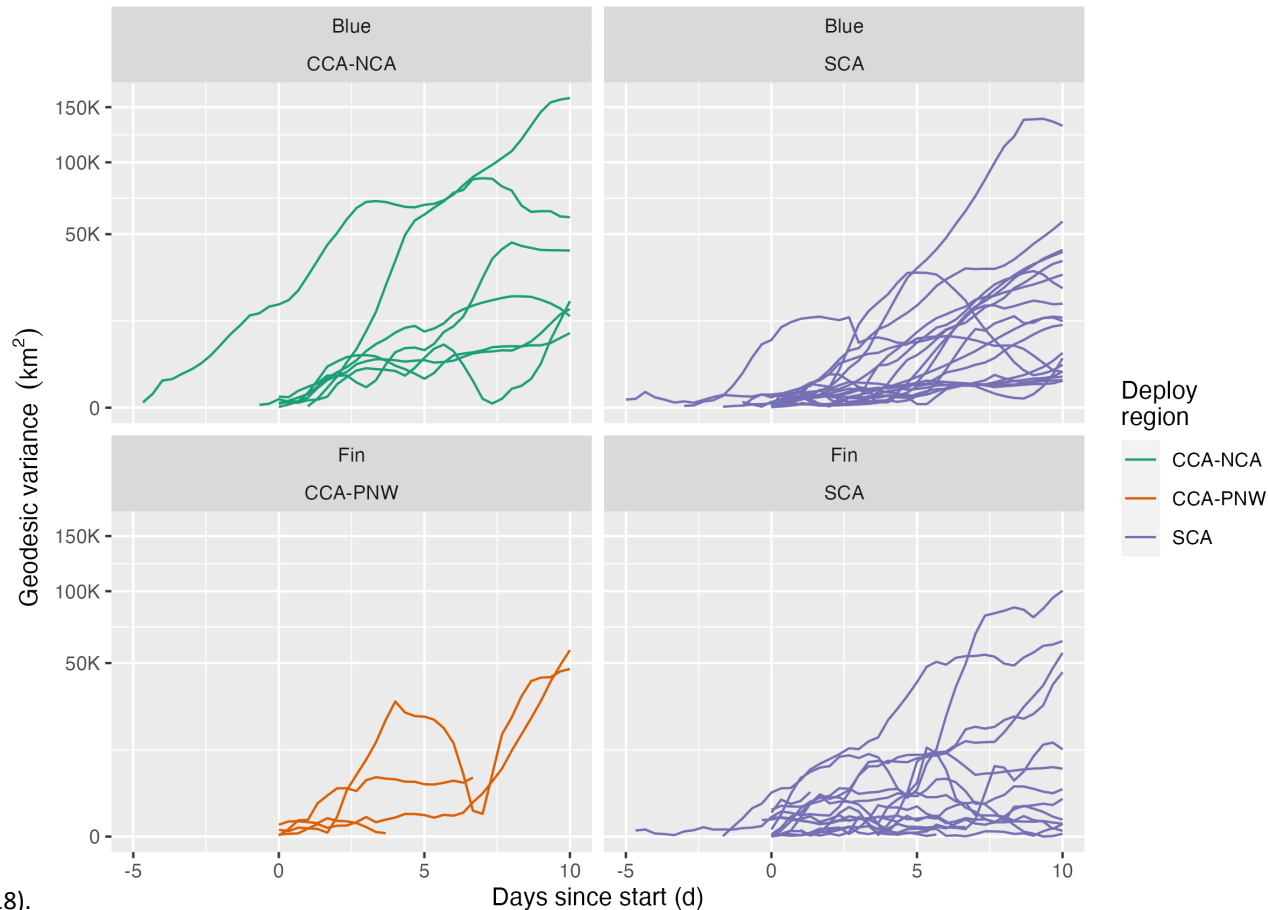
## Median geovar @ day 10

Blue whales:

- SCA: 12,462 km<sup>2</sup>
- CCA-NCA: 18,849 km<sup>2</sup>

Fin whales:

- SCA: 3,373 km<sup>2</sup>
- CCA-PNW: 52,196 km<sup>2</sup>



# Fidelity to tagging site

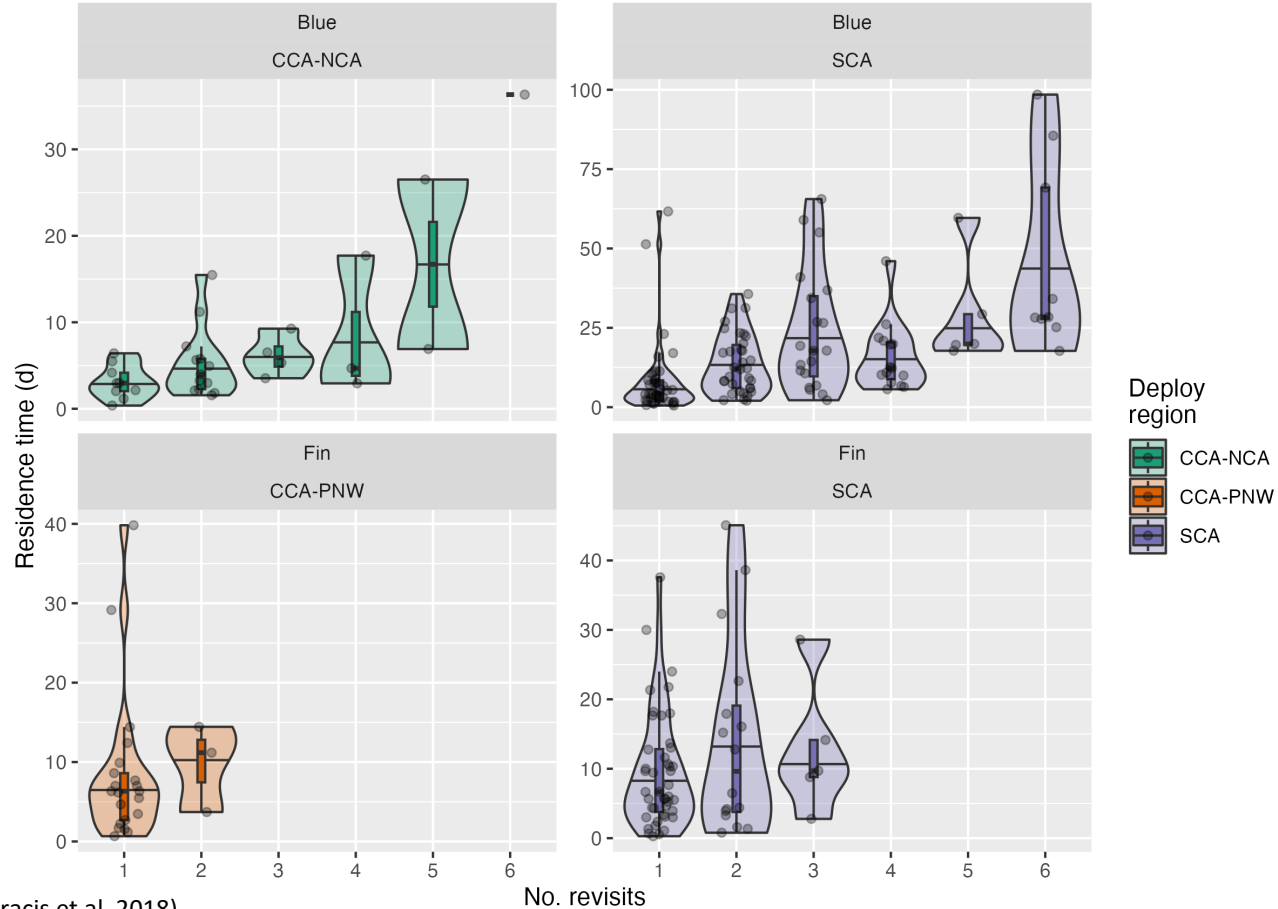
Revisits to the tagging site by deployment region

Blue whales:

- No. revisits:
  - SCA and CCA-NCA: 1-6
- Median cumulative residence time:
  - SCA: 4.3-28.4 d
  - CCA-NCA: 4.0-36.3 d

Fin whales:

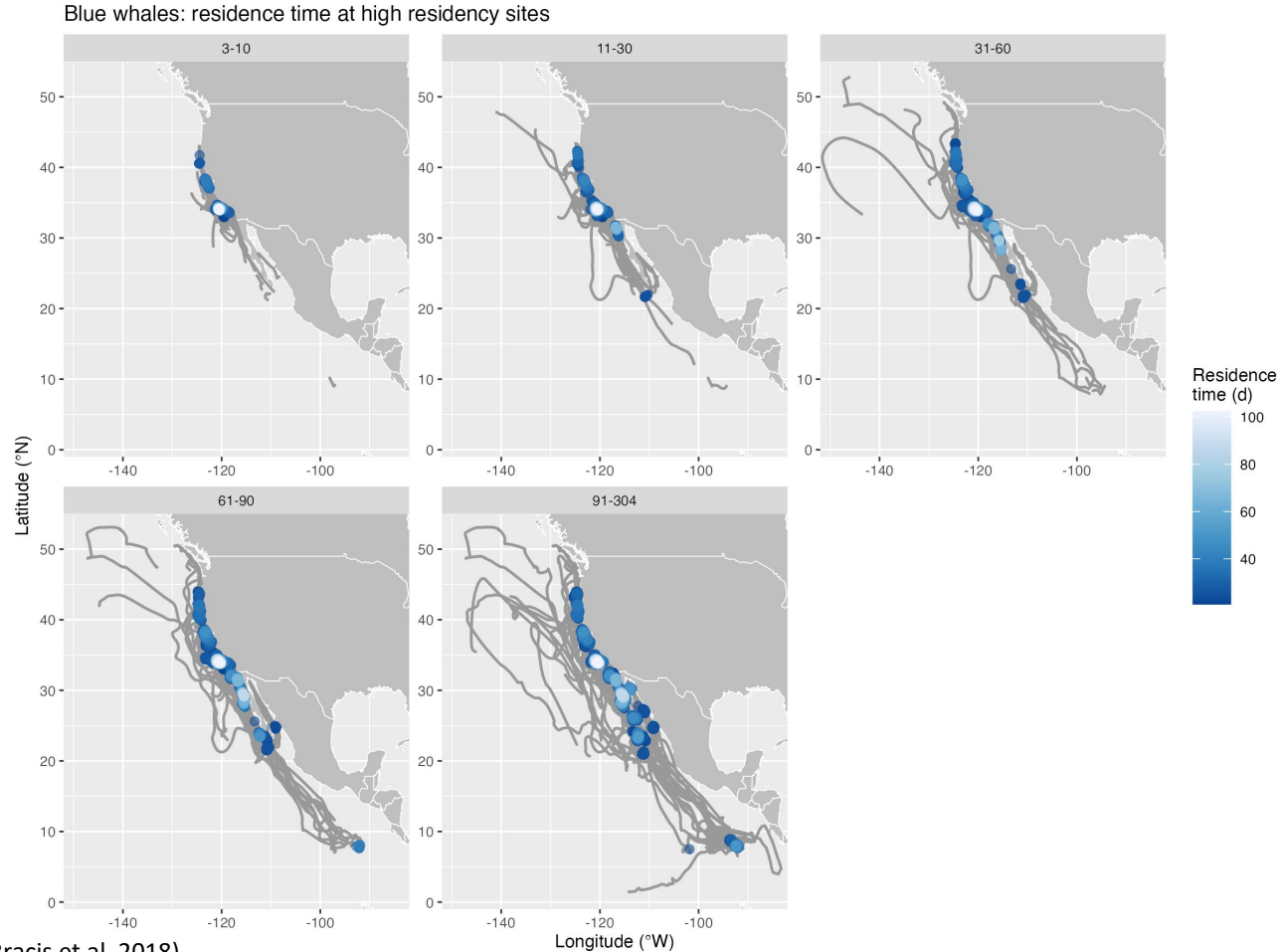
- No. revisits:
  - SCA: 1-3
  - CCA-PNW: 1-2
- Median cumulative residence time:
  - SCA: 6.7-9.7 d
  - CCA-PNW: 6.3-11.2 d



# Blue whale hotspots of high residency

## Blue whales:

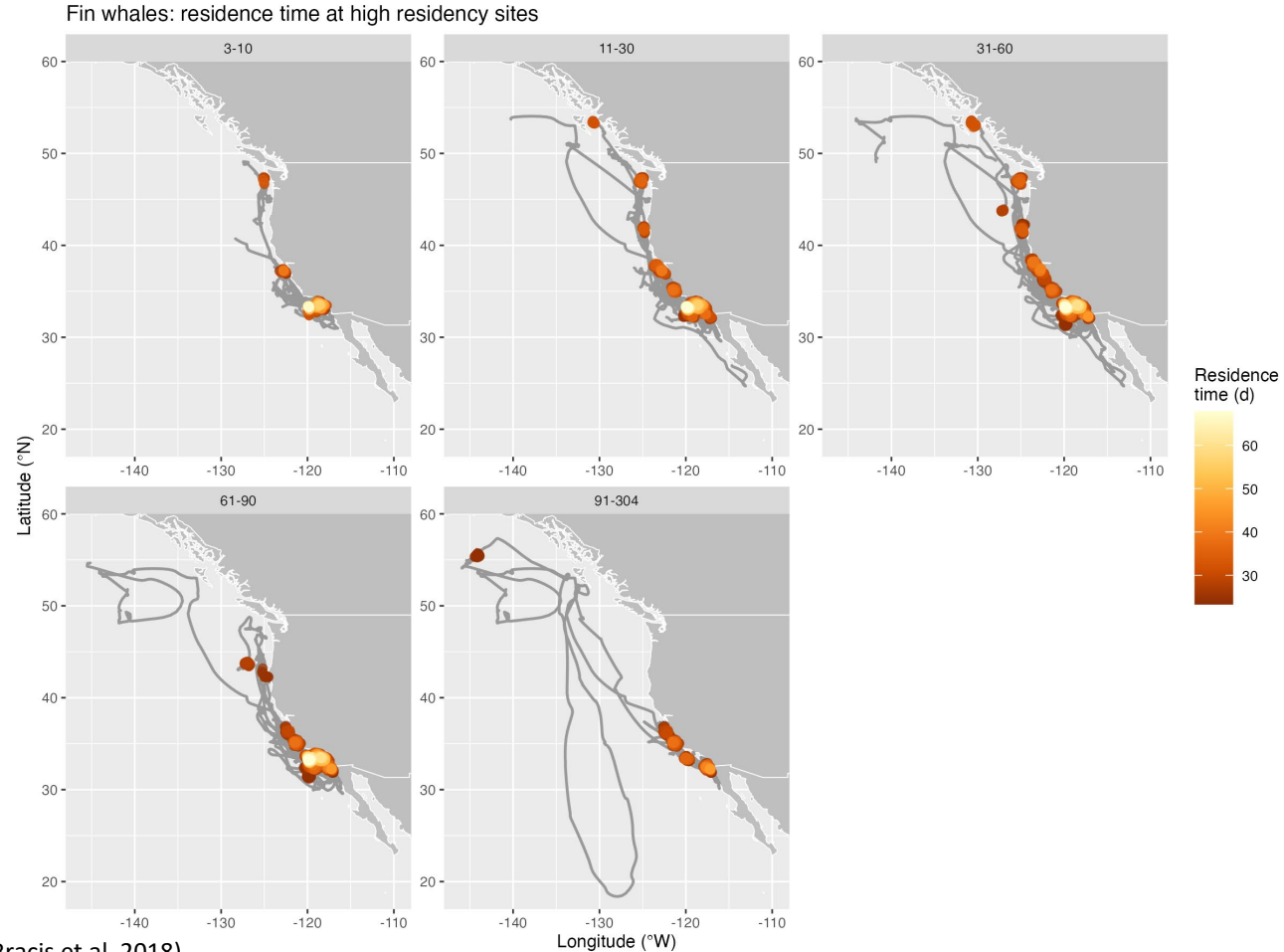
- $\leq 10$  d and 11-60 d: reflect tagging location
- 31-60 d and 61-90 d: sites along the coast, both north and south. Continuous.
- $\geq 91$  d: sites emerge at opposite end of migration
- SCA remains hotspot of highest residence
- N Baja California Peninsula also important, but less recognized



# Fin whale hotspots of high residency

## Fin whales:

- $\leq 10$  d and 11-60 d: reflect tagging location
- 31-60 d and 61-90 d: sites along the coast, mostly north. More disjunct.
- $\geq 91$  d: sites emerge offshore to NW (migration mostly within CCE)
- SCA remains hotspot of highest residence
- Complex (sub)population structure confounds interpretation



## Conclusions

### Overall movements:

- Blue whales exhibited a well-defined, long-range seasonal migration pattern (53-deg in lat x 69-deg in long), traveling from their summering grounds in the CCE to subtropical and tropical wintering areas in the Gulf of California and the Costa Rica Dome
- Fin whales demonstrated less distinct migratory behavior (39-deg in lat x 33-deg in long), with indications of migration to offshore NW waters

### Individual dispersal from the tagging site:

- Regional differences: both blue and fin whales tended to remain closer to tagging site in SCA than in CCA-NCA/CCA-PNW
- Blue whales exhibited greater dispersal distances from the tagging site compared to fin whales

### **Group dispersal from the tagging site:**

- Blue whale cohorts had larger median geodesic variance than fin whales, suggesting greater dispersal distances by blue whale groups
- Overall trend for cohorts to disperse, but some cohorts had consistently low values of geodesic variance, suggesting cohesive movement

### **Fidelity to tagging site:**

- More prevalent for blue than for fin whales (more revisits and longer residence times)
- Higher in SCA for both blue and fin whales (more revisits)
- Blue whales exhibited higher revisitation rates, whereas fin whales displayed more transient behavior and shorter residency times, possibly reflecting differences in foraging strategies, prey preferences, and social dynamics

## **Other sites of high residency:**

- SCA remains hotspot of highest residence for both species
- More continuous along the coast for blue whales and more disjunct for fin whales
- Differences between blue and fin whales in terms of individual dispersal, cohort dispersal, sites of high revisitation, and migration patterns in the CCE can be attributed to variations in their ecological requirements and life history strategies



## **Recommendations:**

- Increase sample size in more northern regions
- Tag in other regions of the range
- Tags should routinely last for at least 60-90 d to capture more areas of high residence and mitigate high residence near tagging site
- The observed regional and species differences on the magnitude and effect of tagging bias should be more routinely considered in studies that rely on these data

# Acknowledgements

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