

# Modeling the dispersion and habitat associations of Black-footed Albatross in Central California National Marine Sanctuaries

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## Motivation

Black-footed Albatross (*Phoebastria nigripes*; BFAL) are endangered (according to IUCN criteria) due in part, to impacts from longline fisheries<sup>1</sup>



BFAL commute from Hawaiian breeding colonies to the West Coast of North America<sup>2</sup> and forage in National Marine Sanctuary (NMS) waters in spring & summer: Cordell Bank, Gulf of the Farallones, Monterey Bay<sup>3</sup>

Standardized monitoring species distribution and abundance data can be used to describe habitat use and characterize overlap with potential threats<sup>4</sup>

Protecting far-ranging species with basin-wide ranges (like BFAL) is inherently difficult<sup>5</sup>; further complicated by complex oceanography and seasonal dynamics of the California Current System (CCS)

We used at-sea monitoring data and concurrent environmental variables to model the influence of temporal, local (static and dynamic) and basin-wide habitat characteristics on BFAL distribution and abundance

## Albatross Surveys

Vessel-based sightings (BFAL observations) from PRBO Ecosystem Study Program cruises

Five years: 2004 – 08

Two seasons:

Chick-rearing (April, May, June)  
11 cruises and 65 lines

Post-breeding (July, Sept., Oct.)  
8 cruises and 50 lines

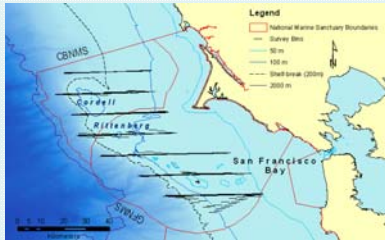


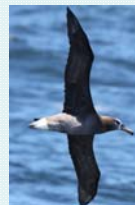
Figure 1: Map of the study area and survey lines. Dashes represent ~3km bins, along surveyed transects. GFNMS = Gulf of the Farallones NMS, CBNMS = Cordell Bank NMS.

## Environmental Data

Local survey vessel environmental data, integrated data from Pacific Fisheries Environmental Group (NOAA), basin-wide indices from literature

Table 1: Variables and their interpretation.

Variable	Interpretation
<b>Temporal</b>	
Year (cumulative Julian day)	Inter-annual scale
Breeding Season (Julian day)	Intra-annual scale
<b>Static</b>	
Average Depth	Bathymetric domain
CV of Depth	Bathymetric gradient
Distance to CB, RB, Shelf-Break	Proximity to feature
Latitude	North-South spatial gradient
Survey Line Length*	Survey biases
<b>Dynamic</b>	
Average SST	Water mass
CV of SST	Hydrographic fronts
Average SSS	Water mass
CV of SSS	Hydrographic fronts
Wind Modulus (Total Speed)	Use of wind
Meridional (NS) Wind Speed	Use of wind
Zonal (EW) Wind Speed	Use of wind
Atmospheric Pressure	Weather systems
Δ Atmospheric Pressure	Moving weather systems
6h Upwelling Index (36°N,39°N)	Advection
Monthly Upwelling Index (36°N,39°N)	Productivity
<b>Basin-Wide</b>	
Pacific Decadal Oscillation (PDO)	Broad-scale fluctuation in SST, SSH
North Pacific Gyre Oscillation (NPGO)	Broad-scale fluctuation in nutrients, salinity, SSH



\* Only used in analysis of spatial dispersion

\* Only used in models of occurrence / abundance

RB = Rittenberg Bank

CB = Cordell Bank

## Goals

- 1) Identify environmental factors relating to BFAL dispersion (patchiness)
- 2) Model habitat characteristics influencing BFAL occurrence & abundance in Cordell Bank NMS and Gulf of the Farallones NMS

## Analyses

### Environmental Factors Relating to BFAL Dispersion

Three Dispersion Metrics:

- 1) BFAL density (# birds / survey area); dependent & independent
- 2) Autocorrelation: Moran's Index (I)
- 3) Aggregation: Green's Index of Dispersion (Gx)

$$Gx = \frac{[(S^2/X) - 1]}{[\sum x - 1]}$$

Gx value	variance > mean	Aggregation
1	variance = mean	Maximum Random
0	variance = 0	Uniform
< 0	variance = 0	Uniform

Stepwise generalized linear models (GLMs),  $p \leq 0.10$  cutoff

### Habitat Characteristics Influencing BFAL Occurrence & Abundance

Distributions: Binomial (Occurrence) or Poisson (Abundance)

Approach: Results ranked using AIC with 'leading' model(s) Akaike Weight  $\geq 0.90$ <sup>6</sup>

Note: If > 2 models selected, scaled average weight across all variables was calculated; scaled average weights > 1 identified as "Important Variables"

## Results

Table 2: Results of BFAL spatial distribution analysis (Gx, I, density). Std. coefficient = standardized slope. Step # = order of variable selection.

Spatial Distribution Metric	Adj. R <sup>2</sup>	Variable	Std. Coefficient	p Value	Step #
Gx	0.379	Zonal Wind	+0.451	0.001*	1
		Monthly upwelling at 39N	-0.306	0.02	2
		Latitude	-0.550	0.004	3
		Depth	-0.378	0.04	4
Moran's I	0.172	Albatross Density	+0.348	0.02	1
		Line Length	+0.314	0.04	2
Albatross Density	0.154	PDO	-0.410	0.009	1
		Atm. Pressure	-0.280	0.09	2

\*Significant using the Bonferroni correction

Table 3: Results of BFAL occurrence (presence / absence) and abundance (counts) models. NOTE: Grey and black font indicates negative and positive relationships, respectively.

Occurrence Best Models	Akaike wt.	Abundance Important Variables	Scaled Avg wt.
Distance to Shelf-Break + Northern (39N) Monthly Upwelling	0.810	NPGO	114.3
Distance to Shelf-Break + Southern (36N) Monthly Upwelling	0.190	Monthly upwelling at 39	3.2
-	-	Year	2.05
-	-	Breeding Season	1.9
-	-	SST*	1.5
-	-	Distance to Rittenberg Bank	1.4
-	-	SSS	1.05

\*Positive when modeled with the interaction of SST and SSS

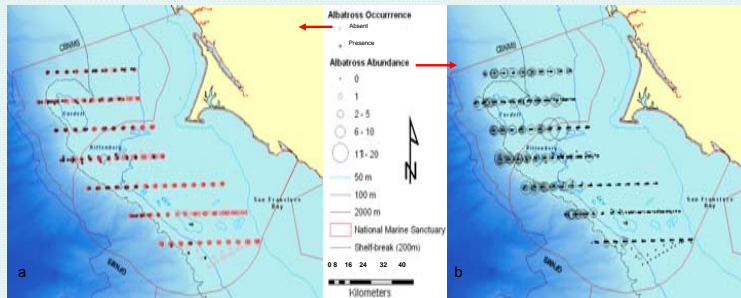


Figure 2: Composite map of BFAL (a) occurrence and (b) abundance from all surveys (April - Oct., 2004 -08).

## Interpretation

### Patterns of BFAL Dispersion

- Increased aggregation (larger Gx) related to stronger westerly wind
- Poor explanatory power; weak overall model fit (Adj. r<sup>2</sup>, Table 2)

### Variables Influencing BFAL Occurrence & Abundance

**Temporal:** Higher abundance during rearing season  
Abundance higher over time (with increasing NPGO)

**Static:** Higher occurrence near shelf-break  
Abundance higher close to Rittenberg Bank

**Dynamic:** Increased occurrence (abundance) with higher upwelling monthly index at 39 N, (lower SST and higher SSS)

**Basin-wide:** Abundance higher with positive NPGO (related to larger SSS and upwelling anomalies)



## Informing Management

- **Enhanced protection of habitats within existing sanctuaries**  
High BFAL use of shelf-break and Rittenberg Bank, potentially important fishing areas, especially during chick-rearing season
- **Importance of upwelling**  
Association with upwelling suggests BFAL habitat use results from integration of regional (SST) and broad scale (NPGO) variation

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