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Blue whale (*Balaenoptera musculus*) behavior and group dynamics as observed from an aircraft off Southern California



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Abstract

We hypothesized that the response variables of blue whale sighting rate, group type and cohesion differed by explanatory variables behavior state, time of day, season, water depth and distance from shore. To address our hypotheses, we flew systematic line transect surveys in southern California and collected focal group data. Chi-square contingency table and G2 analyses were used to assess statistical relationships between response and explanatory variables. Observation effort totaled 87,555 km involving 18 (1-week-long) aerial surveys spanning Jan-Dec 2008-2013. Seventy blue whale groups (117 individuals) were seen, ranging in size from 1-6 whales (mean = 1.7, SD = 1.20). Results supported our hypotheses that blue whale group characteristics were influenced by behavior state and spatio-temporal variables. Sighting rates were significantly highest during summer followed by spring, fall and winter ($p < 0.001$). Group type differed significantly by season: groups were seen only during summer but singles and pairs were seen spring through fall ($X^2 = 31.18, p < 0.001$). Groups engaged predominantly in mill and slow travel/rest, while singles and pairs were only observed in medium/fast travel ($G^2 = 100.4, p < 0.001$). Behavior state differed significantly by time of day, group type, water depth and distance from shore. Mother/calf pairs and singles were found in deeper offshore waters than groups and pairs. Group cohesion and group size were positively correlated ($r^2 = 0.39, p < 0.05$): as group size increased whales became less cohesive and more spread out within groups. Our study suggests that group characteristics and behavior are sensitive to spatio-temporal factors. These parameters may serve as behavioral indices of anthropogenic disturbance to blue whales. Understanding influences on naturally occurring behavior is critical to differentiate potential impacts of growing human-related activities relative to concerns about blue whale population recovery.

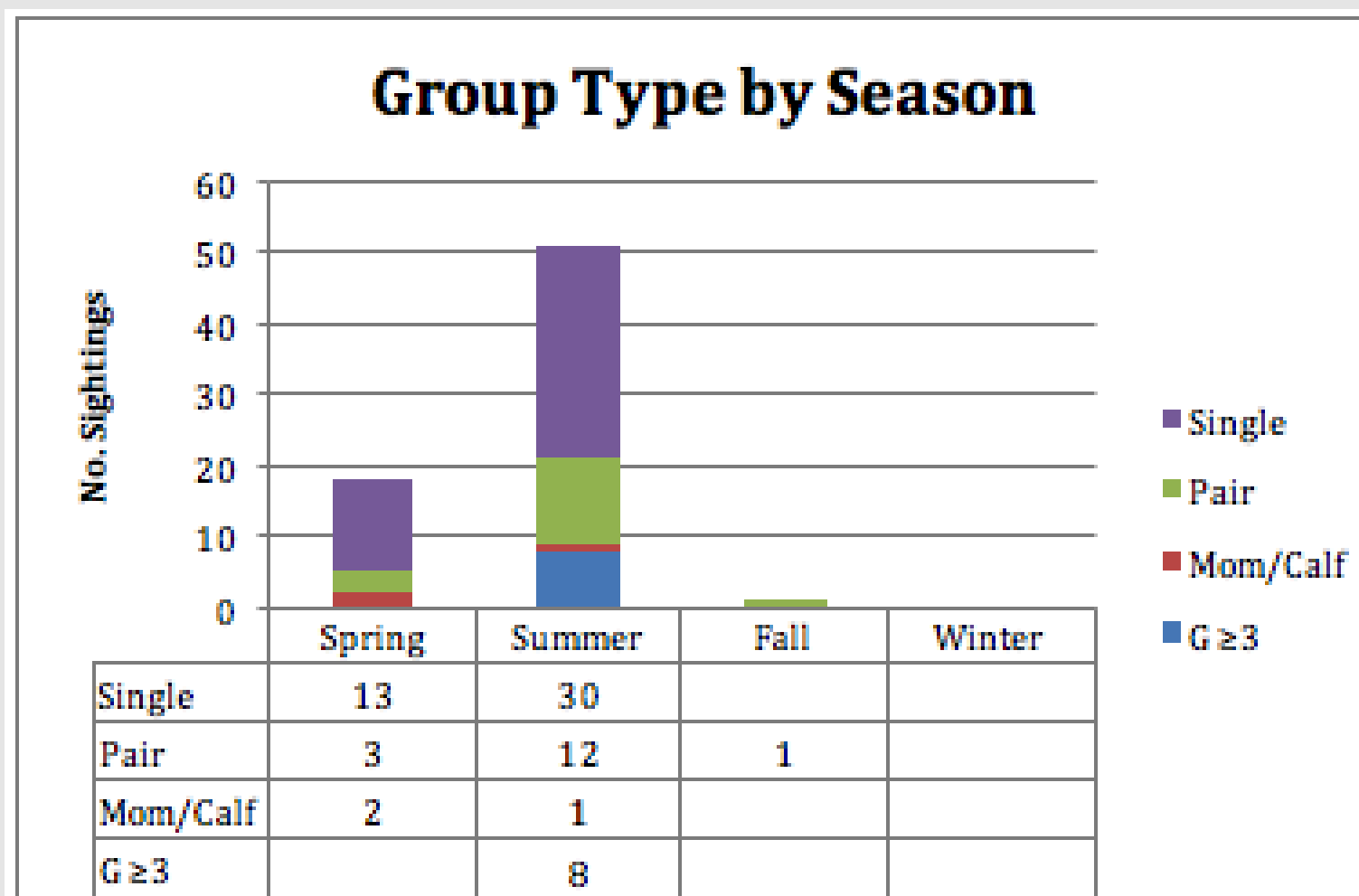


Figure 3. Group Type (number of sightings) by Season

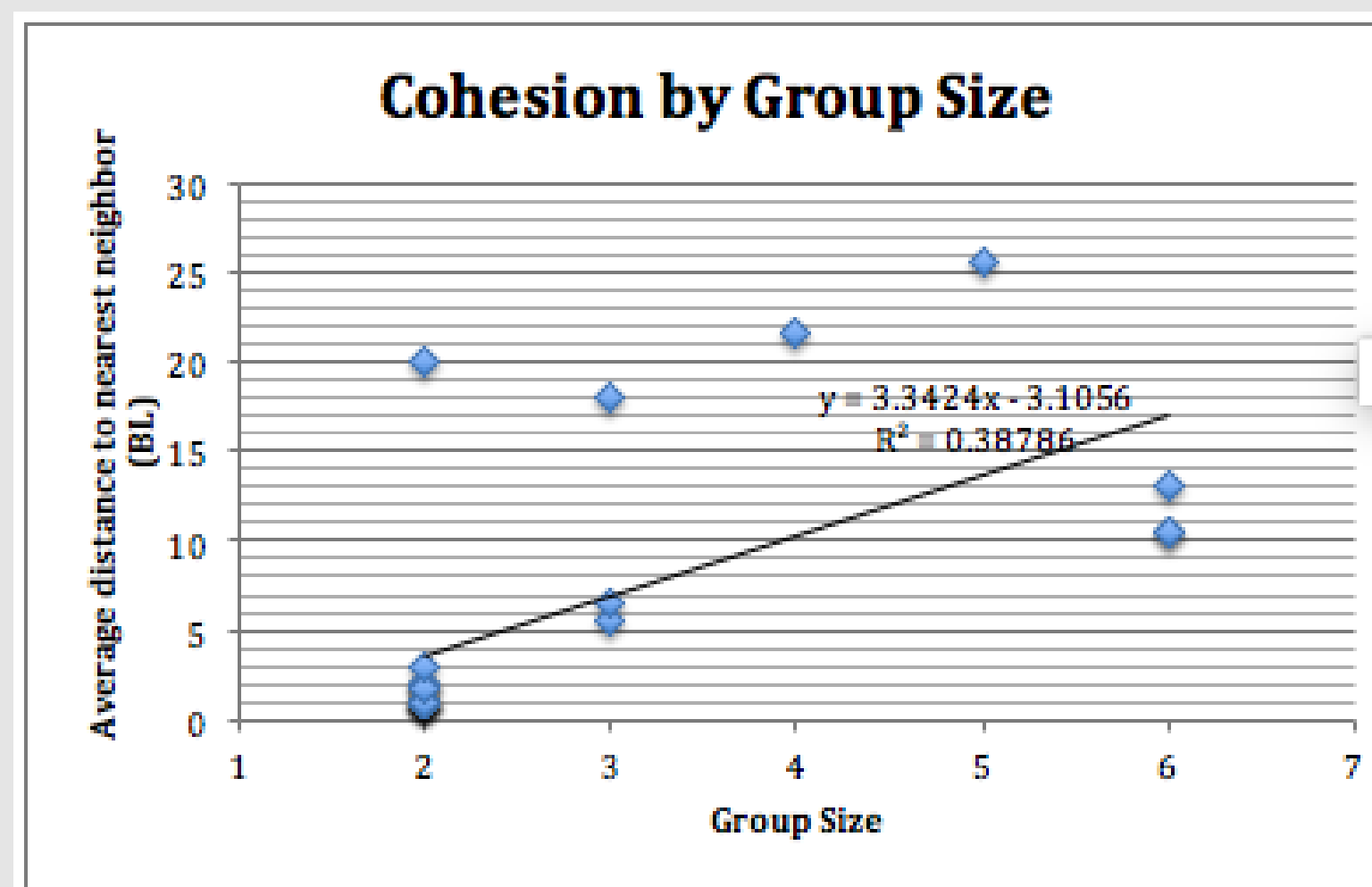


Figure 4. Blue Whale Cohesion by Group Size

Questions	Results
Does Group Type ¹ (GT) vary by...	Season? GT differed significantly between spring and summer among S, P, and G≥3 ($\chi^2 = 31.18, df = 2, n = 66, p < 0.001$), G≥3 only found during summer and not spring (Freeman-Tukey Deviate, $z = -1.96$), no blue whales seen during winter, P observed during spring, summer and fall.
	Time of Day (TOD)? GT differed significantly by TOD ($\chi^2 = 17.58, df = 2, n = 67, p < 0.001$)
	Distance? M/C ⁴ (18 km) and S (13 km) were found farther from shore than G≥3 (10 km) and P (9 km)
	Depth? M/C ⁴ (419 m) and S (478 m) were found in deeper water than G≥3 (286 m) and P (381)
Does Behavior State ² (BS) vary by...	GT? BS differed significantly by GT ($g^2 = 100.4, df = 4, n = 107, p < 0.001$), G≥3 engaged in MI and ST/R more than S animals and P only S and P were observed in TR, G≥3 were not
	Season? BS differed significantly between spring and summer $\chi^2 = 40.44, df = 2, n = 111, p < 0.001$, MI was observed more during spring (31%) than summer (24%) where ST/R was observed more during summer (23%) than spring (13%).
	Time of Day (TOD)? BS differed significantly by TOD ($\chi^2 = 20.19, df = 2, n = 113, p < 0.001$), MI decreased in “late afternoon” compared to “morning” and “early afternoon”, ST/R increased in “late afternoon” compared to “morning” and “early afternoon”
	Distance? BS varied by distance to shore where MI was observed in water closest to shore (8 km) followed by TR (13 km) and ST/R (16 km)
Does Cohesion ³ vary by...	Depth? BS varied by depth, MI behavior was observed in more shallow water (250.16 m) followed by ST/R (436.5 m) and TR (443.3 m).
	Group size? Cohesion by group size had a positive correlation ($R^2 = 0.39$), which was statistically significant ($p < 0.05, n = 24$), G≥3 were more spread out than pairs and thus exhibited less cohesive behavior, As group size increased so did average distance between nearest neighbor

¹Group Type: S = single, P = pair, M/C = mom/calf, G≥3 = group of three or more
²Behavior States: MI = mill, ST/R = slow travel/rest, TR = travel
³Cohesion = inter-individual spacing (in body lengths) of neighbors within a group
⁴Sample sizes were too small ($n = 4$ M/C groups) to do meaningful statistics

Methods/Analyses

- 18 one-week-long aerial surveys Oct 2008 -May 2013
- 87,555 km of observation effort (in the Southern California Bight)
- Flights conducted at 244-305 m altitude and 100 knots
- Baseline occurrence, distribution, density and behavior of marine mammals to address U.S. Navy marine species monitoring requirements.
- Two sets of data were separately analyzed using different sampling approaches: (1) point sample data associated with the first sighting of a blue whale(s), and (2) extended all-occurrence focal group behavioral sampling data (i.e., focal follows) collected on a subsample of all sightings while the aircraft circled at a radial distance of ~0.5-1 km and an altitude of 457 m for extended periods of 5-60 min.

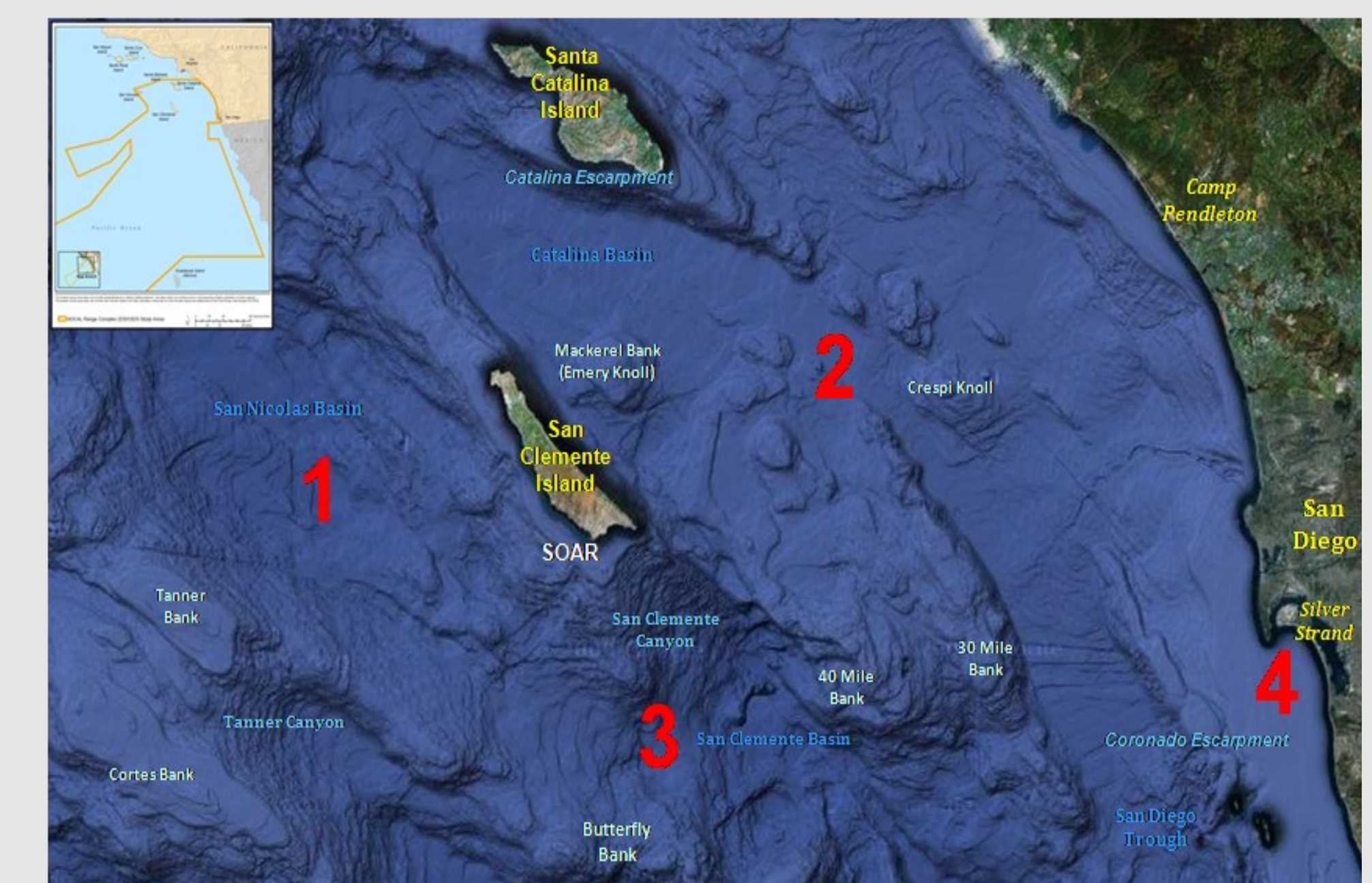


Figure 1. 2008–2013 SCB Aerial Survey Area

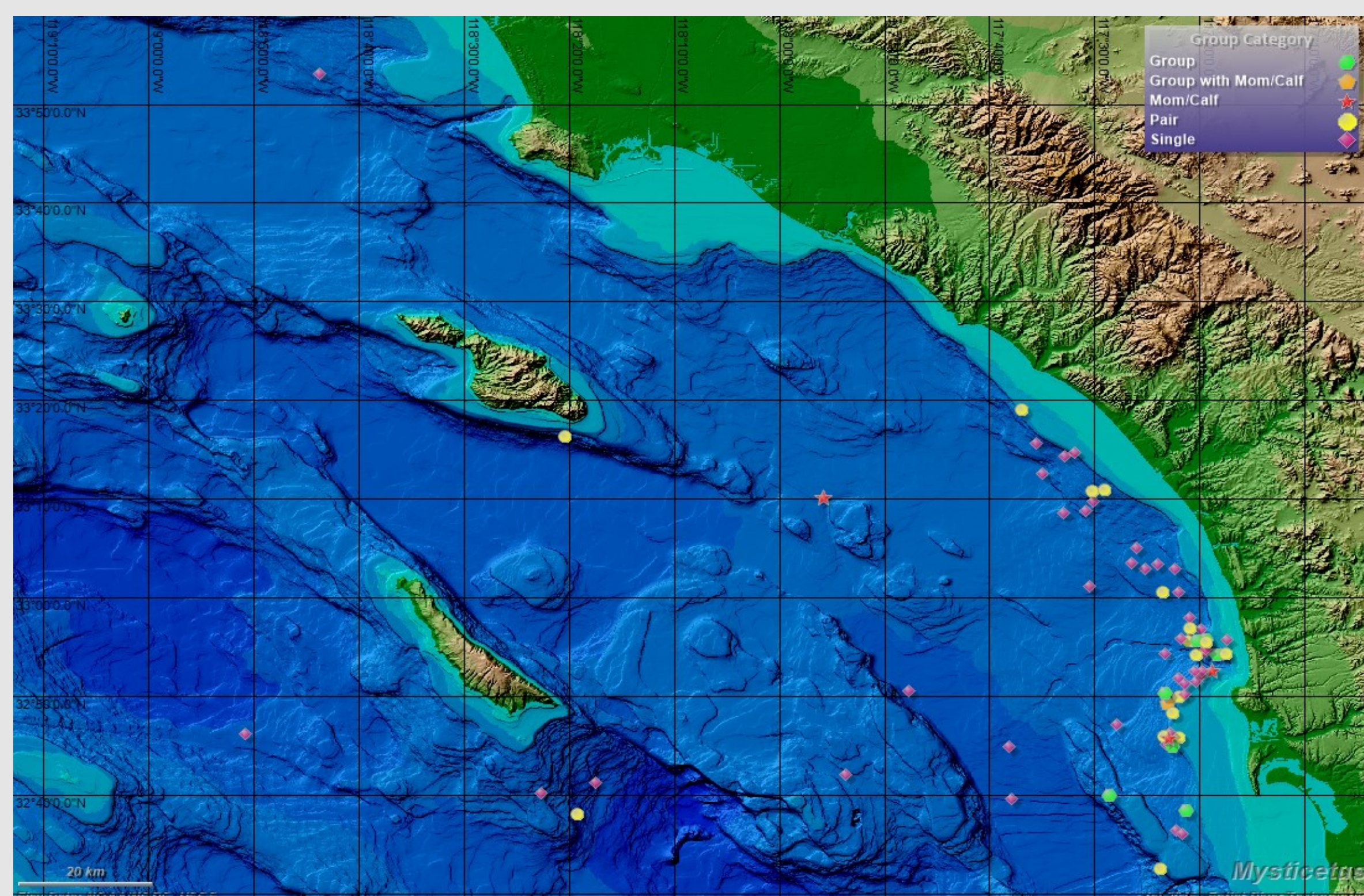


Figure 2. All blue whale sightings 2008–2013

Conclusions

- Behavior State differed by Group Type.
- Group Type and Behavior State were influenced by spatio-temporal variables (i.e. time of day, season, distance from shore, depth).
- Groups were only observed during summer, pairs during spring summer and fall
- Inter-whale associations from focal follows of two different blue whale groups demonstrate pair-association behaviors among groups (i.e. synchronicity in surfacing and movements).
- Pairs were recorded during spring through fall, providing additional evidence form at least short-term (< 1 hr) social associations involving synchronized behavior and close cohesion spacing associated with the migration/feeding season - this would be a good thing to further investigate in the future.
- As group size increased so did average distance between nearest neighbor Groups (G≥3) were more spread out or less cohesive than pairs (P).



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