Satellite tagging of fin whales off California and Washington in 2010 to identify movement patterns, habitat use, and possible stock boundaries

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Introduction

Though fin whales from the California/Oregon/Washington stock are listed as endangered under the ESA and 'depleted' under the MMPA, little is known about their movement patterns, habitat preferences, or stock structure within the region. A large number of fin whales were estimated to have been taken in the eastern north Pacific by whaling activities leading to a substantial decline in population estimates (Ohsumi and Wada 1974). The current population estimate for the California/Oregon/Washington stock is 3,454 whales (Carreta *et al.* 2007) and the population is thought to be increasing, but the observed trends are not significant (Barlow 1994, 1997). Possible threats to this species from anthropogenic sources include ship strikes (e.g. Douglas *et al.* 2008), fisheries interactions, and interactions with naval training exercises (i.e. sonar, ship strikes, and live fire exercises). A better understanding of fin whale movements, habitat use, and population structure is necessary to more accurately assess the status of this stock and develop management plans to encourage its recovery.

Cascadia Research Collective (CRC) has a long history of small boat-based photo-identification and biopsy sampling of numerous cetacean species, and maintains long term catalogs of blue, humpback, gray whales from the US west coast and Canada. Fin whales have been documented year-round along the US west coast both visually and acoustically (e.g. Moore *et al.* 1998, Carreta *et al.* 2007), and have been encountered by researchers at CRC sporadically in most months at points from Washington to northern Baja California, Mexico. While most CRC fin whale sightings were from California between July and October, fin whales have been encountered during surveys off the Washington coast in December and January, suggesting their seasonal movement patterns may not follow those typically seen in other large baleen whales (see Mizroch et al. 2009).

In 2008 three Andrews-style Low Impact Minimally Percutaneous External-electronic (LIMPET) tags were deployed on fin whales off San Clemente Island in conjunction with ongoing cetacean studies at the Southern California Offshore Range (Schorr *et al.*, unpublished data). While all three whales moved extensively throughout the Southern California Bight, with two individuals moving south into Mexico (one over 400km from tagging location) before returning to the southern Channel Islands area (Fig. 1), none of these individuals moved north of Point Conception, CA. Recent evidence from mitochondrial DNA analysis (Archer et al unpublished data) has also suggested a genetic boundary exists within this population near Point Conception.

Deployment of additional satellite tags on fin whales from the California/Oregon/Washington stock can provide baseline movement data for whales in this population to help define this and other boundaries which may exist. Satellite tags can also provide an indication of habitat preference, and will allow for analyses of percent time spent in shipping channels and naval training areas. Several recent fin whale ship strikes by both commercial and naval vessels have highlighted the potential risk these impacts may pose to their recovery.

Materials and Methods

Small boat surveys were undertaken from several ports north of Pt. Conception in 6 to 7 meter RHIBs specifically modified for tagging operations. Location, time, number of individuals and basic behavior state was recorded for each fin whale encounter. Photographs of fin whales encountered were collected for photo-identification studies currently underway at CRC. Biopsy samples collected were provided to SWFSC for analysis.

Satellite tags were deployed where possible, with a focal deployment area being north of Pt. Conception (funding provided by SWFSC and AFSC) to complement tag deployments from previous and concurrent studies within the SCORE training area. Tags deployed were the Andrews-style LIMPET dart tags (see Andrews *et al.* 2008, Schorr *et al.* 2009), in the location only configuration (Spot5 transmitters, from Wildlife Computers, Redmond, WA). The tags attached to the dorsal fin via two small darts, while the tag itself remained external to the body. These tags were designed to be as minimally invasive as possible while remaining attached long enough to collect pertinent movement data. Based on data from previous deployments, tags were duty cycled to transmit 15 hours out of each day, and transmit daily for 50 days, every second for 10 days (70 calendar days), every third day for 10 days (100 calendar days) and every 5th day thereafter to maximize high resolution movement data during the period of expected attachment duration, while still allowing for movements over longer periods if the tag remained attached.

Data obtained from the ARGOS system was processed with the Douglas Argos-Filter v. 7.06 (available at Alaska.usgs.gov/science/biology/spatial/douglas.html) using two independent methods: distance between consecutive locations, and rate and bearings among consecutive movement vectors. Location classes 3 and 2 were automatically retailed. Maximum rate of movement between consecutive points was set at 15 km/h. Depth, distance from shore, and closest land for all locations which passed the Douglas Argos-filter were determined in ArcGIS v. 9.2 (ESRI, Redlands, California).

The cumulative distance covered during the signal contact period (period of time uplinks were received) and the straight-line distance from deployment were calculated using all locations that passed the filter. Rates of horizontal movement were calculated among consecutive locations with time intervals from 0.5 to 23 hours; rates calculated from shorter and longer intervals were excluded to decrease the potential of spuriously low or high rates of movements being included. We report the median values of our analyses to minimize the effect of outliers

Results

Fin whales were encountered on two occasions in May 2010 off the west coast of Washington, representing the fourth and fifth time they have been documented during five years of small boat surveys in that region (Cascadia Research, unpublished data). An estimated 27 whales were seen during these surveys, and 617 photographs of approximately 25 different individuals were collected (catalog reconciliation of these photos in progress), along with three biopsy samples. Additionally, 92 sightings of approximately 197 fin whales encountered opportunistically off the coast of California during other surveys were photographed, with an estimated 131 IDs and 23

biopsied collected since October 2009. All biopsy samples have been provided to Southwest Fisheries Science Center for analysis.

Four tags were deployed on two different survey days off the south-west coast of Washington during May 2010. One tag was lost due to a missed attempt in rough weather, and one tag failed to provide locations due to deployment below the base of the fin. An additional tag deployed in June 2010 from a concurrent project in Southern California is included in these results, as the animal crossed the Pt. Conception boundary (Table 1, Fig. 1). Median transmission duration was 24 days[1] (range = 3 to 80 days, n = 5). After filtering, 961 locations were received over 133 calendar days.

All tagged individuals remained near the continental slope, (grand mean distance to shore = 72 km), though Bp 21, tagged near San Clemente Island, spent time closer to shore while near the Channel Islands, but still in deep water (Fig. 2, Table 2). Median rates of horizontal movement were low overall, ranging from 2.2 – 3.5 km/hr (Table 1). Distance from tag deployment varied depending on transmission duration, but was higher overall for individuals tagged off the coast of Washington than for Bp 21 tagged off San Clemente Island, despite similar transmission durations between Bp 18 and Bp 21 (Table 1). Both Bp 18 and Bp 20 moved away from tagging location within 8 days of deployment, but Bp 18 traveled over 1900 km south in the first 23 days after tagging, compared to just over 600 km for Bp 18 (Figure 3).

Discussion

Overall movement patterns suggest a general association with the continental shelf, with the exception of several days of movement by Bp 18 up to 337 km offshore of the Southern California Bight (Fig. 1 and 2). Though Bp 18 and Bp 20 were tagged only 3 days and 25km apart, they quickly moved apart, with Bp 18 moving over 1200 km further down the coast and away from the tagging location (Fig. 1 and 3) during the same time period. While fin whales are often found in large loose aggregations, the divergent movements of individuals tagged concurrently in an area suggest that the associations are likely ephemeral in nature, though a larger sample size is needed to confirm this.

Behavioral states of individuals might be inferred by looking at movement vectors over time. For example, when looking at the distance from tagging location (Fig. 3), a clear pattern of slopes followed by plateaus is seen in both Bp 18 and Bp 20. The strong slopes associated with distance from tagging location may suggest that animals move more quickly between likely feeding areas, and then remain more localized while feeding for periods of time. Overall, rates of movement between points were low (below 4 km/hr) despite some large distances moved, and the known ability for fin whales to swim at speeds in excess of 30 km/hr (pers. obs.).

Two of the tagged individuals moved across the putative Pt. Conception stock boundary (Archer et al. unpublished data). Additionally, at least one of the individuals encountered off the coast of Washington in May 2010, is a previously identified (and satellite tagged) individual encountered several times in Southern California since 1995 (Falcone et al. unpublished). This suggests that

[1] One tag still transmitting (day 80) at time of reporting.

either the individuals tagged were not part of the Southern California stock, or that the genetic boundary may be an artifact of sampling bias

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Table 1. Details of fin whale satellite tag deployments, and information on movements of individuals using locatoins from after processing through the Douglas Argos-Filter. Cumulative Horizontal distance moved was calcualted using straight-line distances between all filtered locations. Rates of horizontal movement were calculated among consecutive pairs of locations with time intervals from 0.5 to 23 hours. These represent minimum rates, as movments between locations were likely not always in a straight-line, and do not take into account vertical movements (diving).

Animal ID	Area tagged	Date tagged	Trans. Duration (days)	Cumulative distance moved (km)	Distance from tagging location (km) Median (max)	Rate of Horizontal Movement (km/hr) Median (range) n
Bp 17	WA Coast	5/6/2010	3	114.7	11.6 (36.2)	2.8 (0.5 - 8.2) 19
Bp 18	WA Coast	5/6/2010	72	5388.3	1688.3 (1966.7)	3.5 (0.1 - 11.1) 151
Bp 19	WA Coast	5/6/2010	5	no locations received		
Bp 20	WA Coast	5/9/2010	24	1801.2	447.3 (646.6)	3.5 (0.1 - 14.1) 183
Bp 21	San Clemente Is.	6/28/2010	78	1868.4	352.4 (560.1)	2.2 (0.1 - 13.6) 390

Table 2. Details of habitat use by individual fin whales based on a bathymetry analysis of filtered satellite location data using ArcGIS.

Animal ID	Number of locations	Depth (m) Median (range)	Distance to shore (km) Median (range)
Bp 17	28	779 (433 - 2048)	72.8 (65.6 - 103.3)
Bp 18	190	1898 (433 - 4673)	100.0 (29.8 - 336.9)
Bp 20	226	2709 (655 - 3151)	73.6 (34.9 - 138.2)
Bp 21	521	1307 (28 - 3635)	40.3 (0.3 - 89.4)

Figure 1. Map showing locations of tagged individuals. Bp 17 is represented by the red track (mostly obscured off the WA coast by movements of Bp 18 and Bp20), Bp 18 is represented by the white track, Bp 20 is the pink track, and Bp 21 is the green track.

Figure 2. Map showing Bp 18 (white track) and Bp 21 (green track) movements in the from Central California to the furthest extent south. While there is some overlap in habitat utilization between the two, Bp 18 spends more time in deeper waters and further offshore, while also covering a larger geographic region.

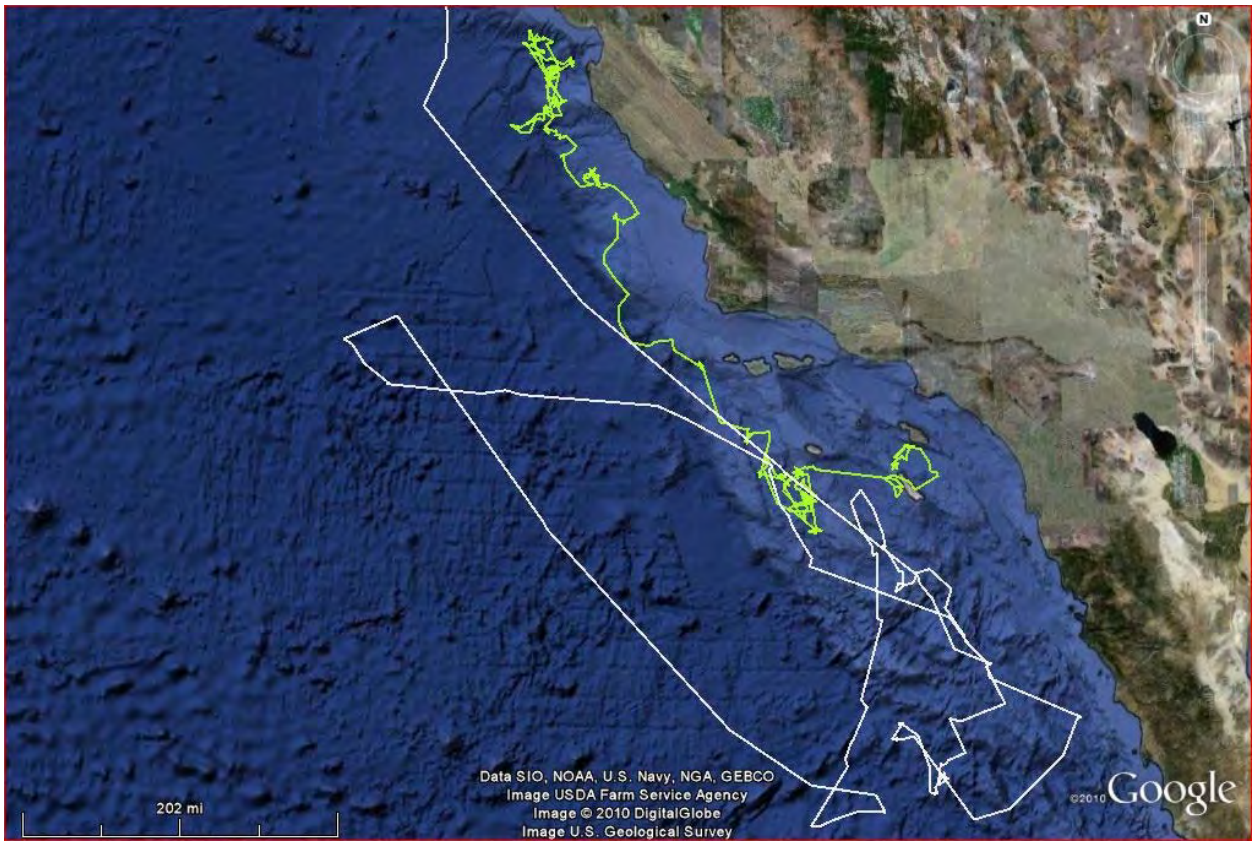

Figure 3. Graph showing distance from deployment location. Note the rapid movements away from tagging location by Bp 18 and Bp 20, followed by flatter plateaus which suggest the individual is moving around an area and no longer directly away from the tagging location. These plateaus may represent periods where the individual stops to forage.