The following supplements accompany the article

Movement and home range of pink abalone *Haliotis corrugata*: implications for restoration and population recovery

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Supplement 1. Error estimation and data filtering

Both telemetry systems provide an estimate of accuracy with each tag position and these were used to filter the datasets prior to use. The VPS analysis software uses known positions of the synctags to provide the more sophisticated error evaluation. Each synctag triangulated position is associated with an error estimate that is the distance from the true position measured in the field (HPEm). An additional error estimate (HPE) is a theoretical value based on the receiver array geometry as well as expected error due to the influence of environmental conditions (depth, temperature, salinity) on acoustics. HPE values are provided for both synctag and animal tag positions; however, HPEm values are not known for animal tags because no 'true' position is known. If a relationship is found between HPEm and HPE for synctags, it can be used to filter both synctag and animal tag positions past a threshold level of HPE.

To determine the relationship between HPEm and HPE, HPE values were binned and plotted against the associated median, 90th and 95th percentiles of HPEm. These plots were created separately for the 2 different VPS deployments and combined HPE and HPEm values of all synctags into each analysis. The number of HPEm values within each bin exponentially declined with HPE, showing that the large majority of positions are associated with a very low error estimate. A threshold HPE value was chosen for both deployments and any synctag or animal tag positions with HPE values greater than those thresholds were deleted from the dataset. Median HPEm values for HPE bins at or below these thresholds were all below 10 m and most 90th percentiles were below 15 m. Various levels of HPE were used to filter the data for a set of the most frequently positioned animals to examine the change in apparent space use. More conservative HPE thresholds could dramatically change animal space use, even in regions where large numbers of positions were collected. Therefore, the chosen HPE thresholds were a compromise between loss of spatial information and increased confidence in individual positions. From a cumulative perspective, at these threshold levels, the median HPEm value of all synctag positions was 2.7 m and 0.6 m during Deployments 1 and 2 respectively and 90th

percentiles were 6.6 m and 2.1 m respectively. Since HPE is calculated by VPS software in the same way for synctags and animal tags, this degree of accuracy is expected to apply to animal tags as well.

The VRAP system also provides information with each position that can be used to determine accuracy. Each tag emission consists of several pulses. The deviation in arrival times of these pulses to the buoys is provided (dev) and higher deviations may indicate questionable transmissions. Known positions for synctags measured by GPS were used to produce a value comparable to HPEm that is provided by the VPS software. The relationship between dev and the manually calculated HPEm was analyzed similarly to the VPS analysis. A threshold dev level was chosen that corresponded to a median HPEm value of 5.1 m and all median HPEm values for dev values <10 were <5. The cumulative median HPEm for all synctag positions with dev values <10 was 3.4 m.

Since the spatial scale and speed of abalone movements are small, the telemetry resolution levels were closer to the scale of abalone movements than they would be to the movements of most animals. Thus, while the accuracy and precision of this dataset is remarkably good for a marine system with relatively high wave energy and depth, typical measurements like step length, path length, and speed were not useful because of increased influence from positioning frequency. For these reasons, most analyses were based on abalone home range size.

Supplement 2. Combination of telemetry systems

The average position for the central synctag was calculated from VRAP and VPS positions separately. These averages were separated by 0.47 m in the *x*-direction and 6.12 m in the *y*-direction. This difference was applied to all animal positions gathered by the VRAP to bring the systems into alignment. Only the spatial shift in positioning accuracy of the central synctag was used for this analysis because (1) during Deployment 1 when both VRAP and VPS positions were being collected, the majority of animal positions were closer to the central synctag than to any other synctag and (2) synctag placement during Deployment 1 was designed for the benefit of the VPS system and was outside the VRAP system's ideal positioning area. The VPS was chosen as the 'true' system because the VPS mean central synctag position was closer to the position measured by GPS in the field. Also, variance in the VPS positions was lower at 1.78 and 2.57 m in the *x*- and *y*-directions respectively, compared to 2.77 and 4.18 m for the VRAP. Prior to combining the 2 datasets, each individual dataset was filtered to the appropriate error threshold level.

Supplement 3. Confirmation of behavioral difference between abalone tags and synctags

Home ranges were calculated as areas within 90% isopleths for abalone with a meaningful number of positions looking across the entire study period, regardless of the time period of collection (range in days positioned 3 to 435). Home range areas that are greater for abalone tags than for synctags would indicate movements of abalone larger than the apparent movement of synctags due to limits in telemetry system resolution, and verify animal behavior. Synctags were positioned across the entire study period while most abalone tags were positioned for a smaller subset of the study period. Also, syntags were generally positioned with greater frequency. To

ensure that the frequency of positioning did not heavily influence the calculated synctag home range size and invalidate comparison with abalone tags, an analysis of synctag home range with reduced datasets was performed. Not all synctags were used in this analysis. The datasets used were the combined telemetry systems and deployments for synctag 1 (the central synctag) and Deployment 2 only for synctags 2, 4, and 5. The central synctag is best suited for this analysis because most animals remained closer to the central synctag than to any other, particularly during Deployment 1. The other synctags are not suited for this comparison during Deployment 1 because they were not meant for spatial reference at that time, but only for synchronizing the clocks of VPS receivers, and were placed outside of the VRAP triangle for this reason. Home ranges of other synctags during Deployment 2 are appropriate for comparison because of both spread in animal distributions away from the central synctag and because of the removal of the VRAP system. These datasets were reduced at random by proportions of 0.5, 0.25, 0.1, 0.01, and 0.001 and the resulting home ranges were calculated.

Additionally, an analysis of differences in mean step length between abalone and synctags was used to verify differences in behavior of these tag types. The distributions of positions for 2 abalone (#611 & 658) during Deployment 1 were chosen because of their restricted space use and close proximity to the central synctag. The positions of these abalone appeared similar to those of the synctag, i.e. the abalone apparently were not moving. Step lengths for these positions were compared to those of the central synctag during the same time period. The number of positions for each comparison was made equal. Thus, the positioning frequency of the central synctag was reduced to match that of the animal tag by randomly deleting positions during the time period of interest. Mean step lengths were compared using a *t*-test. These 2 abalone were chosen because of their apparent lack of movement. A third abalone was chosen for comparison with a synctag because of obvious movement. Abalone #605 moved a greater distance from first to last position than any other. Visual examination of its positions revealed periods of directed movement and periods of relative stasis. Positions during these different behavioral modes were divided into separate datasets. Step lengths during apparent stasis and movement were compared to step lengths of the central synctag for the same time periods in 2 *t*-tests.

Reducing synctag positions at random did not affect home range area except at the 0.01 and 0.001 levels. Synctag 1 showed a slight increase in home range size at the 0.001 level (26 positions) (Fig. S1). Synctags 2 and 5 showed a slight increase in home range size at the 0.01 level and then decrease at the 0.001 level. Decreasing home range size with increasing positioning frequency for synctags could invalidate comparisons of home range size with abalone tags. This did not consistently occur across all synctags and the increase in home range area of synctag 1, when data was reduced to 26 positions, was minor.

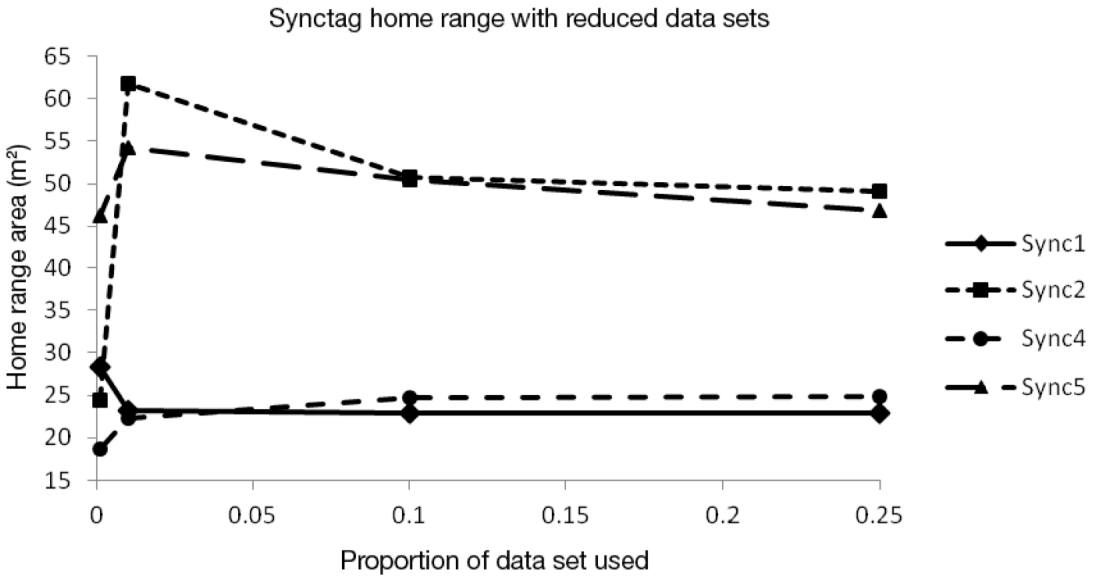

Fig. S1. Home range sizes for stationary synctags using position data sets reduced at random to produce smaller data sets that were proportions of 0.001, 0.01, 0.1, and 0.25 of the whole

Mean step length was higher for both abalone 611 (*t*-test: df = 816, $t = 9.61$, $p < 0.001$) and 658 (*t*-test: df = 320, $t = 9.11$, $p < 0.001$) than the mean step length of the central synctag during the same time periods. Mean step length was also higher for both the moving (*t*-test: df = 281, $t = 5.37$, $p < 0.001$) and stationary (*t*-test: df = 668, $t = 9.82$, $p < 0.001$) behavioral modes of abalone 605 than the mean step length of the synctag. In each of these comparisons of step length between abalone and the synctag, variance was higher for abalone, and could only be made equal through transformation for the abalone 658 and synctag comparison. This higher variance for abalone in itself confirms differences in behavior from a synctag. This indicates that abalone behavior is different than that of the stationary synctag, regardless of the visually interpreted abalone behavioral mode. Surprisingly, when the mean step lengths of abalone 605 during the 2 different behavioral modes were compared to each other, rather than to the synctag, they were not different (*t*-test: df = 498, $t = 1.66$, $p = 0.097$). While the mean and variance of step lengths during the moving behavioral mode were larger than during the stationary mode, the lack of significance confirms that step length is not an appropriate metric for examining variation in behavior within and among individual abalone.

Speed, being based on step length, is likely also not an appropriate metric in this dataset. Particularly during periods of relative stasis or small movements, speed will be influenced by 'wiggle' in the telemetry systems. However, to get an estimate of maximum possible speed, the moving behavioral mode of abalone 605 was examined. By looking at displacement from the beginning to the end of these modes, the maximum observed speed was 0.73 m hr^{-1}. This is a conservative estimate because the abalone is unlikely to have moved in a straight line between these points, but it represents a minimum speed a traveling abalone may exhibit.

The plots below display the frequency of movement bearings of 2 individuals relative to the center of their home range as described in the section titled 'long-term patterns' (Fig. S2). These plots illustrate that these individuals were homing by leaving and consistently returning to a single point in space.

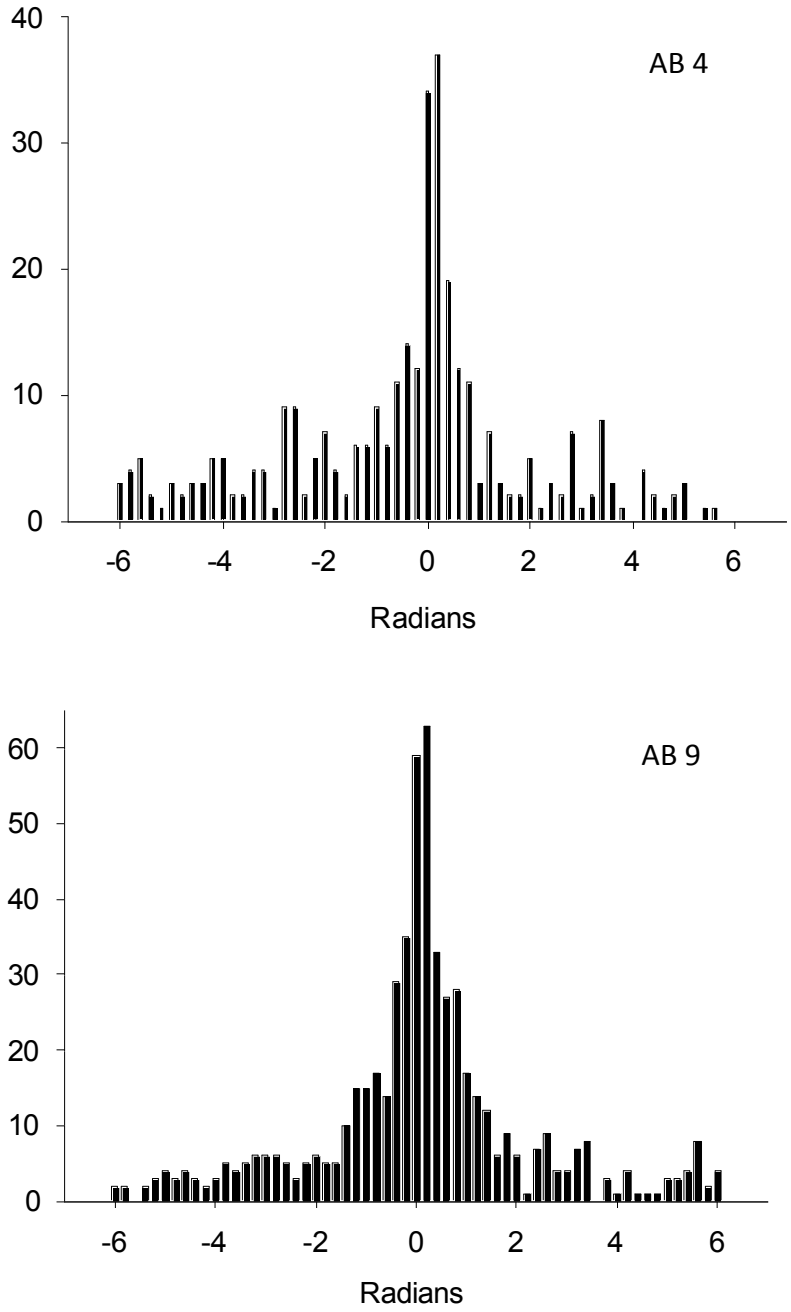

Fig. S2. Bearings relative to the home range center for 2 individual abalone, in addition to those illustrated in Fig. 6 of the main article