Effects of Wind, Tide, Time and Date on Aerial Counts of Gray Whales

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Introduction

California gray whales, Eschrichtius robustus (Lilljeborg), feed in the Bering and Chukchi seas in summer. In the fall many of these whales migrate to the lagoons and bays of Baja California, Mexico where they calve and mate (Figure 1). The most important of these wintering areas are Guerrero Negro, Scammon's and San Ignacio lagoons and Magdalena Bay. Concentration of whales in and near these shallow lagoons has permitted convenient enumeration by airplane since 1952 (Gilmore, 1960; Hubbs and Hubbs, 1967; Gard, 1974). During earlier aerial censuses, counts of whales for a given lagoon were found to be higher in calm weather than they were in windy weather (Hubbs and Hubbs, 1967). On the windy afternoon of 18 February 1962, Carl and Laura Hubbs (personal communication) counted only 387 whales in and near the mouth of Scammon's Lagoon whereas they counted 681 whales in the same area on the

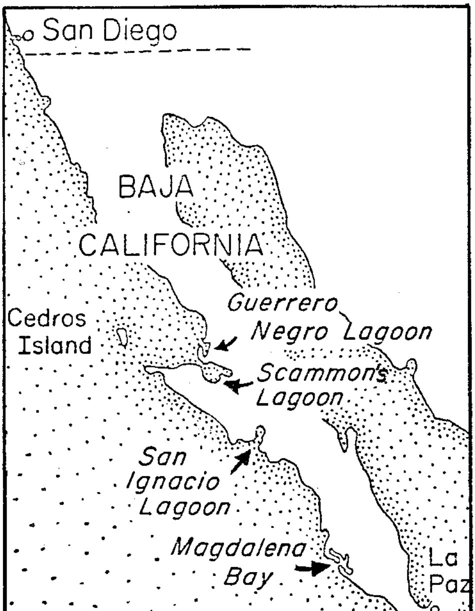

Figure 1. Map of the calving and mating lagoons of the California gray whale.

following calm morning. This observation stimulated initiation of the present investigation. Accordingly, our objectives were (1) to quantify the apparent effect of wind and the possible effects of tide, time of day and date on aerial counts of whales in Guerrero Negro Lagoon, and (2) to relate these findings to aerial censuses conducted in the Bering Sea and elsewhere.

Methods

We conducted eleven aerial censuses of whales in Guerrero Negro Lagoon between 14 and 22 February 1974. Censuses were carried out at moderately-sized Guerrero Negro Lagoon rather than at one of the larger lagoons because a relatively short period of time (about 45 minutes) was required for each census. Adults and calves were counted both inside the lagoon and in a small area just outside the mouth of the lagoon. We flew the same pattern over the lagoon during each census with an observer counting from each side of the airplane. Censuses were conducted from a Cessna 172 at an elevation of about 150 m and at a speed of 160 km per hour. Wind velocity was obtained with a hand-held anemometer.

We evaluated results using a multiple regression analysis, that is, we regressed number of whales on wind velocity, tidal height, time of day and day of the month in various combinations.

Results

Of the variables tested, wind was clearly most important in determining whale counts (R^2=0.73) and the regression was highly significant ($P<.001$)(Table 1 and Figure 2).

Table 1. Results of multiple regression analyses with different sets of independent variables to determine how factors affect gray whale counts at Guerrero Negro Lagoon, 1974.

Analysis	F	P	R^2
Whale count on wind	24.9	<.001	0.73
Whale count on wind and tide	16.6	<.01	0.81
Whale count on wind and time	17.2	<.01	0.81
Whale count on wind, time and date	10.3	<.01	0.82
Whale count on wind, tide, time and date	7.1	<.05	0.83
Whale count on wind and tide with one outlier removed	36.2	<.001	0.91

Inclusion of tide or time in the regresion increased R^2 somewhat to 0.81 (Table 1). As tide and time were highly correlated (r=-0.84), these variables were interchangeable. Addition of date to the regression gave negligible improvement (R^2=0.82) and inclusion of all variables in the regression gave little further improvement (R^2=0.83) while the significance of the overall regression decreased ($P<.05$). Elimination of one outlying observation gave marked improvement (R^2=0.91) and removed bias from the initial pattern of residuals; in the initial plot of residuals, seven of eleven observations were located below zero, but after the outlier was removed, equal numbers of observations were located above and below zero and the scatter was random. During the censuses, wind velocities ranged from 0 to 48 km/hr and tidal heights ranged from -0.2 to +5.9 ft.

Whale population estimates determined from the regression equations for whale count on wind and tide when all observations were included and when one outlier was deleted appear below:

$$Y = 73.5 - 1.69\ X_1 + 2.23\ X_2$$

$$= 73.5 - 1.69\ (0) + 2.23\ (5.9) = \underline{86.7}\ \text{(all observations)}$$

$$Y = 67.8 - 1.54\ X_1 + 3.06\ X_2$$

$$= 67.8 - 1.54\ (0) + 3.06\ (5.9) = \underline{85.8}\ \text{(outlier deleted)}$$

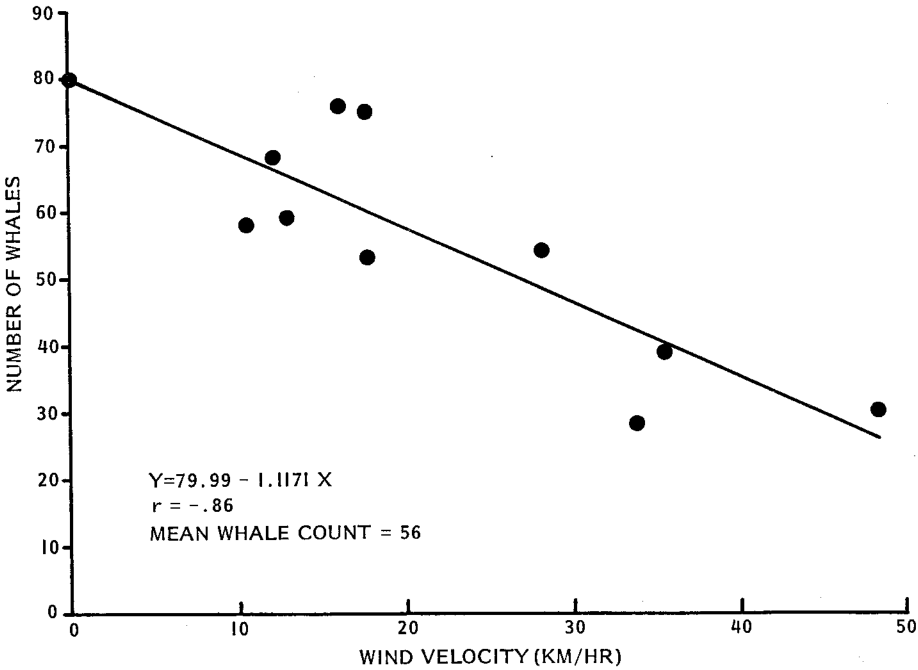

Figure 2. Regression of number of whales on wind velocity at Guerrero Negro Lagoon, 1974.

Discussion and Conclusions

Application of results to areas with strong tides

We selected the independent variables wind and tide for use in explaining variation in whale counts at Guerrero Negro Lagoon, an area with considerable fluctuation in these two environmental factors. Wind was selected because, with an R^2 of 0.73, it was the most important independent variable. Tide was chosen because White (1975) found that it influenced movement of whales into and out of nearby Scammon's Lagoon and it was equal to time of day as a predictor of whale count. High correlation between time and tide occurred because the censuses lasted only 9 days. Had the censuses extended over an entire tidal cycle, time and tide would have acted independently on whale count. Date was eliminated because its inclusion in the regression accounted for only an additional 1% of the variation in whale count. If the censuses had extended into March when many whales would have started on their northward migration, date would have been important.

Population estimates of whales based on regressions including wind and tide were 87 when all observations were included and 86 when the outlying observation was deleted. There may have been some turnover in the population during the census period as individual whales migrated into or out of the lagoon. However, the total number present during the period was nearly static because inclusion of date in the regression gave negligible improvement in R^2. Further, the estimated population was for whales on or near the surface where they could be observed from an airplane. Gard (1978) reported that at any given time about two-thirds of the whales present were beneath the murky water where they could not be seen.

Application of results to areas with weak tides

In the Bering Sea and other open ocean areas where tidal currents are relatively weak, wind velocity will probably be the most important environmental factor affecting aerial whale counts providing atmospheric visibility is good. A relationship better than the one between whale count and wind velocity for Guerrero Negro Lagoon (Figure 2) may exist because tidal effects would be nil. In such situations, variability in whale counts due to wind might be eliminated by use of a regression equation based on whale counts in a clearly defined area made at preselected wind velocities. Assuming a linear regression of whale count on wind velocity, an optimal allocation of observations would call for equal numbers of data points at the lowest and highest wind velocities ordinarily experienced in order to define the regression line accurately. Although accuracy in defining a regression line improves with increased observations, the actual number of censuses to be run in any particular situation would depend on the amount of money available for aircraft and observer expenses and the degree of accuracy required. Four counts may be sufficient to give useable data. In the present study, the estimate of number of whales (Y intercept) corrected for wind velocity using counts during the two extreme wind velocities and any two of the remaining wind conditions was in error by a maximum of 10% when compared to the estimate based on counts at all eleven wind velocities.

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Literature Cited

Gard, R. 1974. Aerial census of gray whales in Baja California lagoons, 1970 and 1973, with notes on behavior, mortality and conservation. California Fish and Game 60:132-144.

Gard, R. 1978. Aerial census and a population dynamics study of gray whales in Baja California during the 1976 calving and mating season. U.S. Marine Mammal Commission Report No. MMC-76/09. N.T.I.S., Springfield, VA. 20p.

Gilmore, R.M. 1960. A census of the California gray whales. U.S.F.W.S. Special Scientific Report: Fisheries No. 342. 30 p.

Hubbs, C.L., and L.C. Hubbs. 1967. Gray whale censuses by airplane in Mexico. California Fish and Game 53:23-27.

White, S.B. 1975. Population and behavioral patterns of gray whales wintering in Scammon's Lagoon. M.S. Thesis, Colorado State University, Fort Collins. 44 p.

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