ABOUT THIS MAP

Figure 4.26 is a map of observed species richness for cetaceans (whales, dolphins and porpoises) off north/central California, based on the CDAS central California data set (1980-2003). Richness refers to the number of species that are in a geographic region, and is an indicator of community structure and composition. Richness is not a measure of community diversity, which combines both number of species and relative density into a single index. Richness is an explicit measure of the number of species present in a community and is independent of their relative abundances.

The color and mapping intervals were selected to emphasize spatial structure and to highlight significant areas. Areas not surveyed appear white; no information is available for these areas. Dark blue lines indicate the boundaries of the National Marine Sanctuaries in the study area: Cordell Bank, Gulf of the Farallones and Monterey Bay. Bathymetric contours for the 200 meter and 2,000 meter isobaths are shown in blue.

DATA SOURCES AND METHODS

Observations of marine mammals at sea in this assessment are based on the CDAS central California data set (2003), developed using the Marine Mammal and Seabird Computer Data Analysis System (CDAS), developed by the R.G. Ford Consulting Co. This data set contains data from eight major survey programs (five aerial surveys, three ship surveys) conducted between 1980 and 2003; the data extends from Pt. Arena to Pt. Sal in the study area, and offshore to the extent of data availability. See the Data and Analyses section of this chapter for more information on the data and methods.

The number of species in a community or geographic region is a basic descriptive parameter that has been widely studied and utilized (Ludwig and Reynolds, 1998). In practice, however, estimating the number of species is difficult because there is a strong relationship between sampling intensity and the number of different species detected, a situation exactly analogous to the species-area curve described by MacArthur and Wilson, 1967. In general, the number of species detected increases as the intensity of sampling increases. The relationship is typically asymptotic, and eventually additional sampling effort within the same geographic region yields no new species. The estimates of species richness presented here are based on approximations of the asymptotic limit of the species-sampling relationship. Although measures of richness are designed to be independent of effort, Figures 4.1 and 4.2 in this chapter show summary maps of CDAS sampling effort for pinnipeds and cetaceans for comparison.

Estimation of species richness for cetaceans was more complex than for pinnipeds because the level of effort was different for each species. Variation in sampling effort occurred because detectability of cetacean species was extremely variable. Variability in the detectability of different species meant that the area sampled also varied among species. We know of no method for estimating richness that is robust to this situation, and therefore estimated cetacean species richness as simply the number of different species observed in each 20' cell. This method entails sampling bias since it underestimates species richness in poorly sampled cells. We only used cells in which a minimum number of observations of groups, *Nmin*, were made. The value of *Nmin* was determined by regressing the number of species detected in each sampled cell on the total number of groups observed in that cell (*N*), excluding cells with fewer than a specified minimum number of observations. In general, richness is highly correlated with number of observations when the number of observations is low, and ceases to be correlated when the total number of observations becomes large. *Nmin* was therefore defined as the minimum number of observations for which the regression of richness on *N* ceased to be significant at $p=0.05$. For the cetacean data, we found that *Nmin*=25. In other words, if only cells with 25 observations or more are used, there is no correlation between richness and the number of observations within a cell. Therefore the number of species observed in the cell provides an unbiased estimate of species richness in that cell. This approach reduces the number of 20' cells for which richness can be estimated, since cells that were sparsely sampled or had few observations fell below *Nmin*. Hence, offshore data were aggregated into larger blocks (60' x 60') because sampling effort there was less intense. In several cases irregularly-shaped blocks were used (seven 20' blocks rather than nine 20' blocks) because one of the 20' blocks was sufficiently well sampled to satisfy *Nmin*. The

resultant coverage was reasonably complete within the study area, especially over the continental shelf.

RESULTS AND DISCUSSION

The CDAS survey database (1980-2003) for north/central California includes sightings of 19 cetacean species in the study area; this includes over 65% of the cetacean species occurring in the study area. Three uncommon or rare cetacean species that were not observed on any of the surveys in the CDAS database were the pygmy sperm whale, the dwarf sperm whale, and the striped dolphin.

The cetacean species richness map showed two 20' cells of highest species richness (13 species) that were similar geographically to those of the pinnipeds: 1) the northwestern area of the Gulf of the Farallones, which includes the Farallon Islands and extends east to Pt. Reyes; and 2) a 20' cell south and east of Pt. Año Nuevo and its upwelling center, encompassing the shelf off Santa Cruz and the north rim and slope of the Monterey Canyon.

These two cells coincide with important upwelling and retention regions. The 20' cell off Point Reyes is associated with the strong persistent upwelling center to the north at Point Arena that transports cold nutrient rich water south to Point Reyes and the Gulf of the Farallones (Kaplan and Largier 2006; see also Largier *et al.*, 2006). The 20' cell south and east of Point Año Nuevo coincides with upwelling that occurs between Point Año Nuevo and Davenport (Rosenfeld *et al.,* 1994; Pennington and Chavez, 2000). The spatial and temporal structure of upwelling is very complex and results in complex physical (and biological) oceanography around Point Reyes and Point Año Nuevo that likely play an important role in retention and transport of marine mammal prey. The two cells of highest cetacean richness noted above were also cells of highest richness for the pinnipeds.

Over the lower slope off Monterey Bay, 12 cetacean species (dark orange) were recorded in a large 1° cell between 36º and 37º north latitude; although the richness in this cell is likely influenced by cell size, it is significantly higher in richness than adjacent large cells to the northwest and southeast. The entire area of Cordell Bank NMS had ten species, Gulf of the Farallones NMS had 10-13 species, and the Monterey Bay NMS had richness values ranging from 4-13 species, with most of the MBNMS area having a cetacean richness of 10 or more species.

Because of the method used to estimate cetacean richness, these values reflect minimum richness values; the actual cetacean richness of these cells is likely higher for most, if not all cells.

The following eight species were found in all three of the highest (12-13) richness areas: blue whale, humpback whale, minke whale, killer whale, Pacific white-sided dolphin, northern right whale dolphin, Risso's dolphin, and Dall's porpoise. Both red areas also included gray whale, common dolphin, bottlenose dolphin, and harbor porpoise. Also, Baird's beaked whale was recorded near the Farallon Islands and fin whale was recorded in Monterey Bay. In addition to the eight common species noted above, the large offshore block included sightings of fin whale, sperm whale, Baird's beaked whale, and Cuvier's beaked whale.

Estimates of cetacean richness throughout the study area probably reflect the variability in coastal, shelf and shelf-slope habitats where there are multiple microhabitats defined by factors such as depth, currents, fronts, upwelling etc. This variability is evident in both the pinniped and cetacean maps, and shows general similarities to the results for marine bird diversity (see Figure 3.42). A number of smaller, discrete areas attract marine mammals because more food is available owing to the complex oceanographic factors. Higher numbers of cetacean species are likely found in these areas because of their unique bathymetric features, coupled with the complex physical and biological oceanography that affect food web development and the availability and abundance of prey.