Table 3.2. A summary of at-sea data sets in the CDAS Central California data set (1980-2001) used in the marine bird analyses.

Data Set & Platform Type	Principal Investigator	Platform & Height	Ocean Habitat Covered	Years	Ocean Seasons/ Months Sampled	Total Transect Width	Total Sightings	Total Individuals
NMFS Midwater Trawl Juvenile Rockfish Assessment: Ship Surveys	Ainley	David Starr Jordan, 10 m	Surface survey of shelf and slope to 3,000 m	1985-2001	Mainly the upwelling season (March-August)	300 m	52,134	427,302
San Francisco Deep Ocean Disposal Site (SF-DODS) Ship Surveys	Ainley	Point Sur, 8 m	Surface survey of shelf and slope to 3,000 m	1996-2000	Year-round; all three ocean seasons	300 m	17,055	82,649
NMFS/SWFSC (Southwest Fisheries Science Center) ORCA WALE Ship Survey	Ballance	MacArthur, 11 m	Surface survey of the shelf, slope & deep ocean beyond	2001	Mainly the oceanic season (~August-November)	200-300 m, depending on species & conditions	823	1,917
EPOCS Shipboard Surveys	Ainley	Surveyor, 12 m, Discoverer, Oceanographer, 15 m	Surface survey of the deep ocean	1984-1994	Year-round; all three ocean seasons	300-600 m	450	843
MMS Low Altitude Aerial Surveys	Briggs	Pembroke, 62 m	Surface survey of the shelf, slope & deep ocean beyond	1980-1983	Year-round; all three ocean seasons	50 m	39,486	145,499
CA Dept. of Fish & Game, Office of Spill Prevention and Response (OSPR), Low Altitude Aerial Surveys	Bonnell, Tyler	Partenavia, 62 m	Surface survey of shelf and slope	1994-1998, 2001	Year-round; all three ocean seasons	50 m	17,368	289,159
CA Seabird Ecology Low-Altitude Aerial Surveys	Briggs	Partenavia, 62 m	Surface survey of shelf and slope	1985	Mainly the upwelling season (March and May)	50 m	2,439	9,307
MMS Santa Barbara Channel Low Altitude Aerial Surveys	Bonnell	Partenavia, 62 m	Surface survey of shelf and slope	1995-1997	Year-round; all three ocean seasons	50 m	1,830	8,310

Note: See chapter text for additional detail on the individual data sets in the CDAS central CA data set (1980-2001).

especially for herring and some demersal species, that occurred at a level perhaps inappropriate to the warm-water phase of the PDO. In response, the avifauna changed, showing major declines in key "cool-water" species such as Sooty Shearwaters (Ainley *et al.,* 1994; Veit *et al.,* 1997; Spear and Ainley, 1999), Common Murres and Cassin's Auklets (Ainley *et al.,* 1995b; Ainley and Divoky, 2001; Oedekoven *et al.,* 2001; Ainley and Lewis, 1974). Some warm-water species have appeared in small numbers during recent years, some only for brief periods (Ainley, 1976; Schwing *et al.,* 1997). Other species (e.g., Hawaiian Petrel, Black Skimmer) have shown signs of staying (Ainley and Divoky, 2001). Features of the coastal ocean environment off California (e.g., water temperature, winds, upwelling, fronts, food availability) are highly variable, and at different time and space scales. This makes it difficult to describe the relative distribution and abundance of marine avian species in the region, unless specific, shorter time periods are identified. It is likely the species' habitat usage did not change. However, we do know that certain species, such as murres and auklets, occupied the ocean progressively closer to shore as the warming period persisted (Oedekoven *et al.,* 2001).

In 1999, the ocean waters off central California appeared to be shifting to cooler sea surface temperatures and it was thought perhaps a cool PDO

phase had started (Bograd *et al.,* 2000; Schwing *et al.,* 2000). However, since 2003, ocean surface temperatures have returned to a relatively warm state, and the status of the PDO is not clear. Certainly, the results from this study indicate that some visiting species changed their occurrence patterns, if only for a few years, much like some did in response to warm events (Ainley *et al.,* 1994). For example, sightings of black-legged kittiwake appeared to expand from mostly slope waters in 1997/1998 to include shelf waters, as the waters cooled in 1999/2000 (see Figure 3.47).

Survey Data. The rationale for collecting the data used in this summary was based on: 1) the interests of individual researchers to study spatial and temporal patterns of marine birds; 2) Federal government efforts to assess potential biological impacts of oil development; and 3) state government efforts to respond to oil spills, of which there had previously been several major ones in the study area. Nevertheless, these objectives broadly overlap the needs of sanctuary resource management.

Survey Methods at Sea. Both ship and air surveys used strip transects, with transect width depending on the platform used. Earlier aerial survey data were collected at sea using methods described by Briggs *et al.,* (1983, 1987b); more recent data were collected using updated technologies for determining the position of the survey trackline, including the use of Global Positioning System (GPS) and data logging software. Ship-based surveys were conducted using the flux-corrected techniques described in Spear *et al.,* (2004).

In Table 3.2 and below are descriptions of the at-sea surveys used in this assessment. The data sets were combined in a system called MMS-CDAS (The Marine Mammal and Seabird Computer Database Analysis System, MMS 2001, version 2.1), developed and maintained by the R.G. Ford Consulting Co. For the bird assessment, data from eight survey efforts were combined, and are now known as the CDAS central California data set (1980-2001). The results and products from this data set were published in 2003 in Phase I of this assessment, and updates are included in this chapter. Aggregating the individual data sets into one spatial framework provided more information over a larger area and time period. Figures 3.1, 3.2 and 3.3 show the spatial extent of the individual data sets and Table 3.2 provides a summary of survey effort in those data sets.

The ship and aerial strip-transect data used in CDAS were collected from 1980-2001 and occurred along the U.S. west coast from Washington through California. This study used data only from the study area, which extends from the coast between Point Arena and Point Sal, and offshore to the extent of data availability. Estuaries were not part of the survey area, although colony data from estuaries were included when available.

1. NMFS Rockfish Assessment Cruises. Seabird and marine mammal data were collected 1985-2001 (except 1995-1996) by D.G. Ainley, L.B. Spear and helpers (initially PRBO, and subsequently H.T. Harvey and Associates) from the flying bridge on the *NOAA research vessel David Starr Jordan* (8 m ASL). These cruises are conducted by the National Marine Fisheries Service (NMFS) -Tiburon (now Santa Cruz) Laboratories. Most cruises were done in May and June for purposes of assessing rockfish year-class strength, but included are a few cruises at other times of the year on this vessel. During the first few years, three sweeps of the study area (Bodega Bay to Cypress Point) occurred from late May into mid-June. The cruise dates were then advanced to be mostly in May, a change that led to bird observers participating only in the later sweep(s) in order to maintain consistency in timing within the data set relative to avian phenology. Cruises started and ended usually from a port in San Francisco Bay area. Except for ship costs, the seabird surveys were funded by participating individuals.

The ship followed a series of transects from shore to about the 2,000 m - 4,000 m isobaths, same tracks every cruise, spaced about 15' latitude apart. In the early years, when time was made available, bird observers directed the ship to transit waters farther offshore or well within the Gulf of the Farallones (sometimes avoided by NMFS owing to ship traffic that precluded fish sampling). At all times that the ship was underway during daylight, at least two (and sometimes three) observers counted all birds and pinnipeds seen within 300 m of one forequarter of the vessel (one with least glare) and all cetaceans within 800 m. Only when visibility was <300 m or winds >30 kts were counts not conducted.

Counts were continuous but broken into 15 minute bins. See Figure 3.1a.

2. The San Francisco Deep Ocean Disposal Site (SF-DODS) Cruises. These cruises were conducted by H.T. Harvey and Associates personnel (Ainley and Spear, 1996-2000) on board R/V *Pt. Sur*, beginning and ending at Moss Landing. The protocol was similar to that described for the Rockfish Assessment Cruises (see above), with extensive overlap in personnel, except that counts were made from within the wheelhouse (6 m ASL). Three cruises were done per year, one in each of the oceanographic seasons. After a transit to/from Moss Landing, a series of transects were conducted to cross the SF Deep Ocean Disposal Site, extending 15 nm in all directions. After this effort was completed a circuit of the Gulf of the Farallones was completed for comparison of inshore versus offshore avifauna. Included are a series of data collected from tug boats pulling barges from SF Bay to the SF-DODS. Protocols were the same, except that height above sea level was about 4 m and the survey strip width was 200 m for birds and pinnipeds and 400 m for cetaceans. The work was funded by the U.S. Army Corps of Engineers investigating the San Francisco Bay deep ocean (dredged materials) disposal site. See Figure 3.1b.

3. The NOAA ORCAWALE Cruise. This cruise was conducted in 2001 on the NOAA/NMFS/SWFSC cruise to assess stock size of cetaceans. The vessel was the NOAA ship MacArthur. Data collection protocols used for birds were similar to those described for the NMFS Rockfish Assessment Cruises. See Figure 3.1c.

4. EPOCS Transit Cruises. These cruises were conducted 1984-1994 on NOAA vessels transiting from Seattle to the eastern tropical Pacific in order to service oceanographic buoys stationed along the Equator (Equatorial Pacific Ocean Climate Study). Protocol was largely the same as that described for the Rockfish Assessment Cruises (below), including extensive overlap in personnel. The exception was that the flying bridge was higher (12-15 m ASL) during EPOCS and, therefore, survey width was wider depending on vessel height (400-600 m for birds and pinnipeds; 800 m for cetaceans). These cruises were largely in waters well beyond the continental shelf. See Figure 3.1d.

5. Minerals Management Service (MMS) Effort: Marine Mammal and Seabird Surveys off Central and Northern California. These surveys included both high-altitude aerial surveys (for cetaceans) and low-altitude aerial surveys (for birds and mammals). The principal investigator for this study was Thomas P. Dohl of the Center for Marine Studies, University of California, Santa Cruz. Michael L. Bonnell headed the pinniped portion of the study and Kenneth T. Briggs headed the bird portion. Funding was provided by POCS-MMS, Contract Number: 14-12-0001-29090. The time period of this study was February 1980 through June 1983, and surveyed shelf, slope, and pelagic (offshore) waters to a distance of 60 nm from Point Conception to the California-Oregon boundary. Surveys were flown twice-monthly at two different altitudes (200 ft (60 m) and about 750-1,000 ft ASL) along approximately 40 east-west transect lines extending an average of 60 nm offshore. The transects sampled on a given survey were selected randomly from a set of 92 predetermined lines spaced at 5' latitude intervals. Sightings of seabirds were recorded only on low-altitude surveys, and only on the shaded side of the aircraft within a strip transect 50 m wide. Navigation was by Loran and VLF-Omega. See Figure 3.2a.

6 and 7. The OSPR Aerial Surveys and the MMS Santa Barbara Channel Aerial Surveys. These surveys were conducted as part of a program to maintain readiness for oil spill response. Aerial surveys were conducted frequently throughout the year to ensure that trained and experienced aerial observers were available in the event of an oil spill in California offshore waters. The principal investigators for this work were Michael L. Bonnell (from 1994 to 1998) and W. Breck Tyler (beginning in 2001), from the Institute of Marine Sciences, University

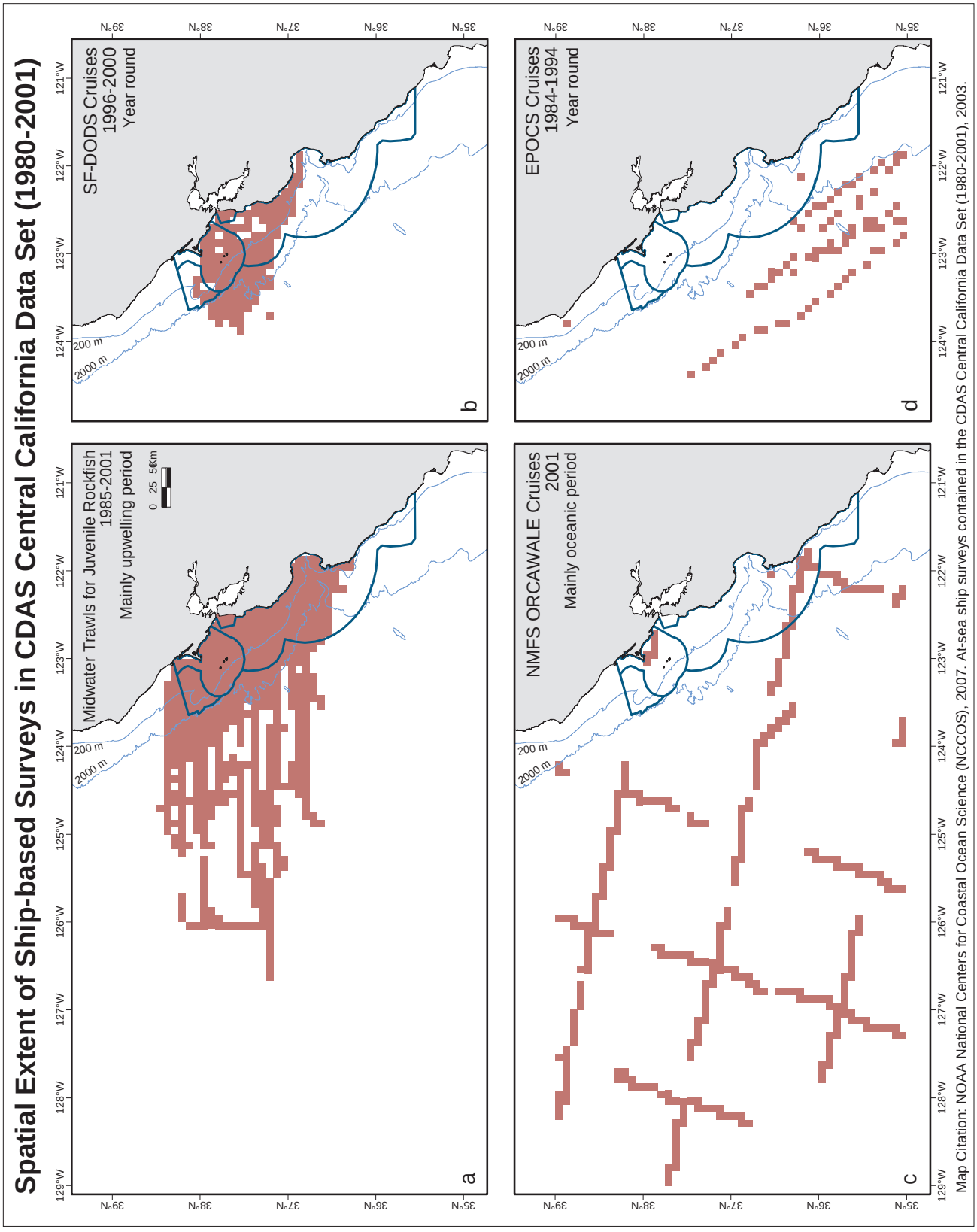

Figure 3.1. Spatial extent of ship-based surveys in the CDAS central California data set (1980-2001) used in the marine bird analysis.

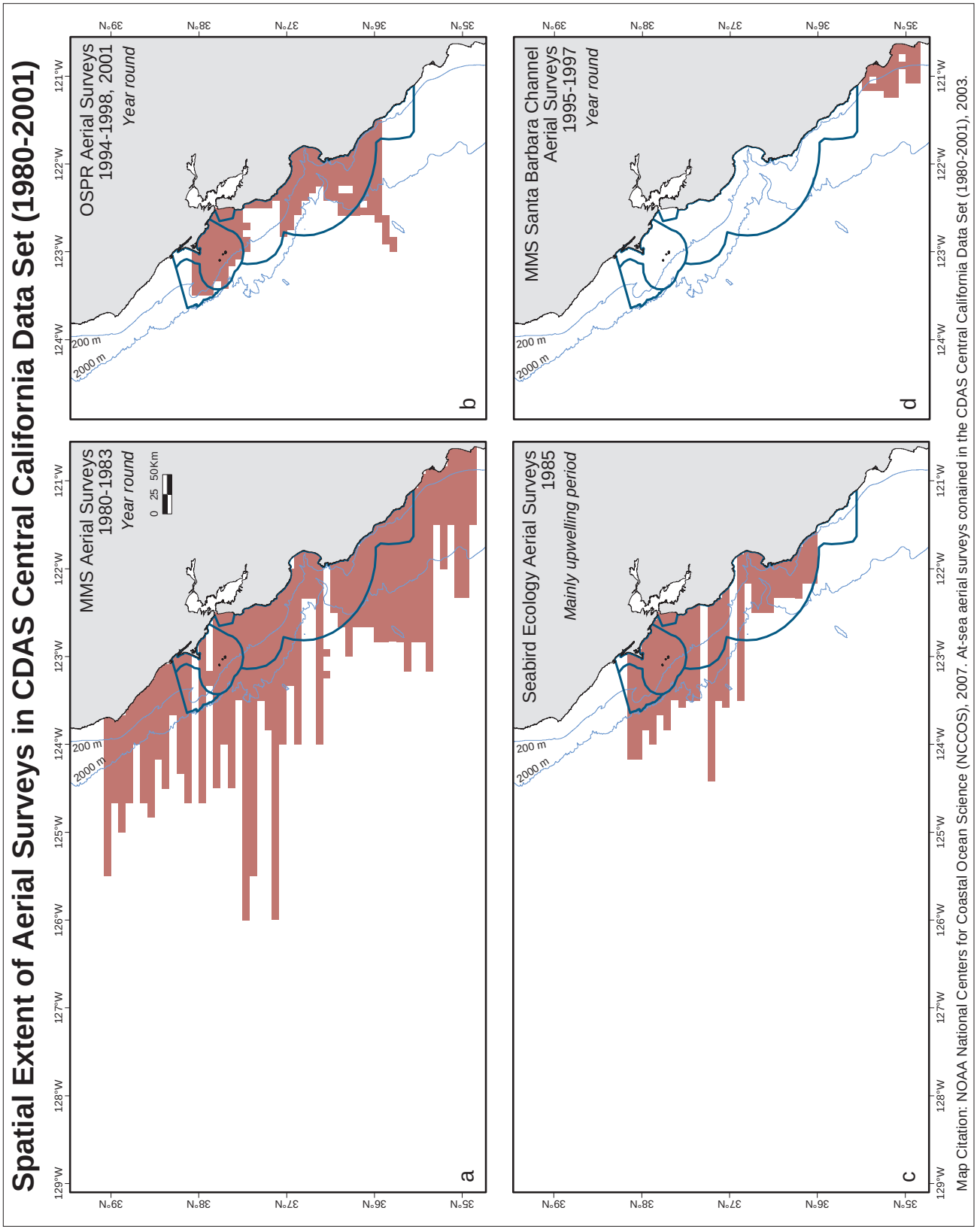

Figure 3.2. Spatial extent of aerial at-sea surveys in in the CDAS central California data set (1980-2001) used in the marine bird analysis.

of California, Santa Cruz. The funding agencies are the California Department of Fish and Game (CDFG), Office of Spill Prevention and Response (OSPR) (Contract Number: FG7407-OS). Credit for this study is shared with OSPR by the MMS, Pacific OCS Region. The areas of these studies pertinent to the present effort included offshore areas in the Gulf of the Farallones and Monterey Bay, San Francisco Bay.

The aircraft used was a Partenavia PN68 Observer provided by the Department of Air Services, CDFG, flown at an altitude of 200' (60 m) above ground level and at a typical air speed of 90 knots. Two observers searched a corridor of 50 m on each side of the aircraft. Species, numbers, behavior and other information was described on hand-held tape recorders for later transcription and computer entry. Date, time, and position of the aircraft were recorded directly into the data-logging computer with time, latitude and longitude provided by a GPS. Only data recorded by experienced observers are included in this data set. See Figures 3.2b and d.

8. The California Seabird Ecology Study Aerial Surveys. These aerial surveys were conducted as part of a smaller follow-on study to the above MMS effort. The principal investigator was Kenneth T. Briggs of the Institute of Marine Sciences, University of California, Santa Cruz. Portions of this work were done by D. G. Ainley and L. B. Spear at Point Reyes Bird Observatory, Stinson Beach, CA. The funding agency was POCS-MMS (Contract Number: 14-12-001-30183). The period of study was 1984 - 1987, and the area pertinent to the present synthesis focused on the Gulf of the Farallones. Field studies were conducted from Monterey Bay to about Bodega Head. Data collection protocols for aerial surveys were identical with those used for the MMS Surveys (above). Four aerial surveys were conducted in the spring and summer of 1985. See Figure 3.2c.

Data Synthesis

Summarizing Transect Data into Grid Cells. The above data sets required a significant amount of processing and correction in order to make them compatible for synthesis and analysis. Because wind speed affects detection of some marine bird and mammal species, data collected when wind speed exceeded 25 knots were excluded. From the digitized survey data, the distributions of effort and of species were allocated into 5' latitude by 5' longitude cells. All aerial data were continuous; each ship-based data set was converted separately into a continuous transect format to the extent possible. The continuous aerial data were binned into the appropriate cell. For the SF-DODS and EPOCS studies, and the Rockfish Assessment Cruises prior to 1997, the beginning position, ship heading, and speed were used to compute the end position of each 2-4 km continuous transect. From this, a midpoint of the transect was determined. As times of observations were not available, the position of

Table 3.3. Summary of combined data set effort by ocean season for the marine bird analysis.

Ocean Season	Ocean Season Time Period	Number of Months	Years of At-Sea Data	Kilometers of Trackline Surveyed	% of Total Trackline Surveyed	Number of Visits	Number of 5' Cells Sampled	% of Total Cells Sampled
Upwelling	15 Mar-14 Aug	5	1980-1982, 1985-2001	64,177	48%	11,050	1,335	58%
Oceanic	15 Aug-14 Nov	3	1980-1982, 1991, 1994-2001	29,263	22%	4,171	1,130	49%
Davidson Current	15 Nov-14 Mar	4	1980-1986, 1991-2001	40,265	30%	5,878	1,593	69%
TOTAL	1 Jan – 31 Dec	12	1980-2001	133,705	100%	21,099	2,294	100%

Note. The number of 5' cells sampled is not a straight sum; it refers to the number of unique cells surveyed.

the midpoint was used to select the cell to which the survey effort was assigned. If this midpoint fell on a cell boundary, it was assigned to the cell to the north or west. To maintain the correspondence between effort and bird observations, observations were also assigned to the transect midpoints. For the Rockfish Assessment Cruises from 1997 onward, effort was assigned to the cells through which the vessel passed based on the proportion of trackline that fell within each cell, and observations were

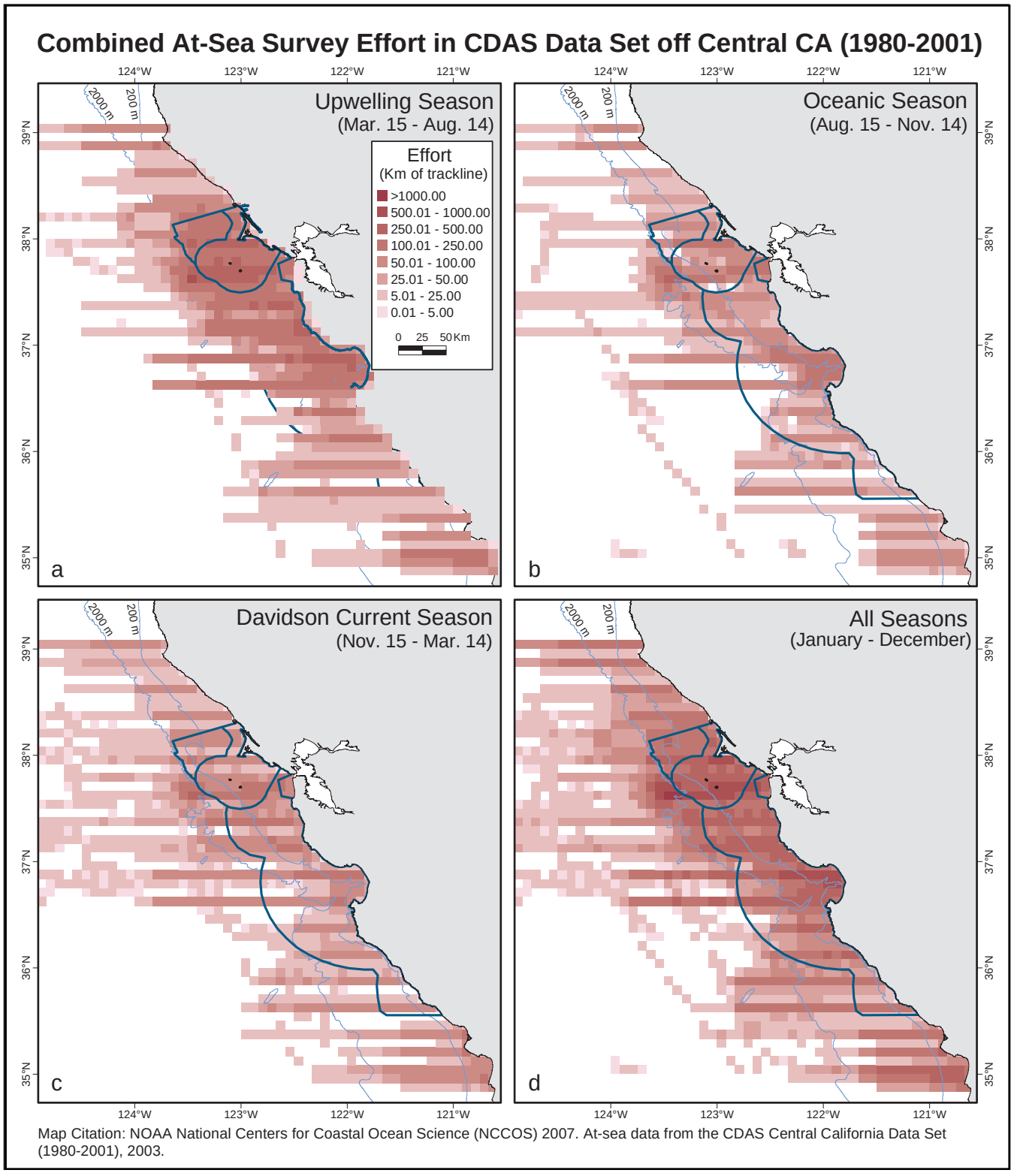

Figure 3.3. Total at-sea survey effort (shipboard and aerial) used for the marine bird analysis, CDAS data (1980-2001), 2003.

interpolated along the cruise track according to the time of each observation. The marine bird survey data from the ORCAWALE cruise were recorded continuously using automatic recording software and were processed like the aerial survey data.

Data Analysis

A variety of analytical methods were used to develop the analytical products for this study. Below are brief descriptions of the methods used in this assessment.

Effort. In these analyses it was important to know survey effort, whether or not birds were seen. Otherwise, true densities would be impossible to calculate, and it would not be possible to combine survey methods that used different survey strip widths or traveled at different speeds (thus covering different proportions of the ocean). The utility of aerial surveys is that they can provide a synoptic snapshot. However, owing to fast speed, species identifications were not as accurate (certain similar species were combined), very small species were sometimes missed, and no environmental data could be collected. Ship surveys could not provide a synoptic picture like aerial surveys.

The combined at-sea survey effort for birds included 133,705 km of trackline, involving 128,886 observations of 973,318 birds in the analyzed data set. Survey effort in CDAS is summarized by ocean season in Table 3.3 and Figure 3.3.

Organizing Data into Ocean Seasons. The effort and species data were organized and mapped into three distinct ocean seasons (Bolin and Abott, 1963): Upwelling, Oceanic, and Davidson Current, because ocean conditions differ distinctly among them and these seasons significantly influence the distribution and abundance of marine biotic patterns of the California Current (Ainley, 1976; Briggs *et al.,* 1987). As there is significant interannual variation in the actual initiation and termination of these ocean seasons, the following dates were used to define each season, for purposes of analysis: Upwelling Season is 15 March-14 August; Oceanic Season is 15 August-14 November; and Davidson Current Season is 15 November-14 March.

These ocean seasons were used to organize the data by the broad-scale oceanographic conditions that influence the distribution and abundance of marine species in the study area. Because the time periods used for the ocean seasons are of different lengths and because survey effort also varies geographically and by season, the bird density estimates of the various cells in the seasonal maps do not have identical variances. Density values are unbiased estimates, but the degree of certainty varies from cell to cell and from season to season. Combining data in this way allows the broad seasonal geographic patterns to be displayed.

Although the total at-sea data span the years from 1980 to 2001, data are not available for all seasons and all cells in all years. For the Upwelling Season, data were from 1980-1982 and 1985-2001. For the Oceanic Season, data were from 1980-1982, 1991, and 1994-2001. For the Davidson Current Season, data were from 1991-2001.

Estimating Density. To provide occurrence patterns of marine birds in the study area, density maps were developed using the CDAS central California data set (1980-2001), 2003. Densities (animals per square kilometer) were calculated by dividing the number of animals seen by the amount of area surveyed. The area surveyed was calculated by multiplying the length of the trackline of the vessel or aircraft by the width of the survey strip, which varied from 50 m for most aerial surveys to 300 m for most ship-based surveys; see Tables 3.2 and 3.3. Density estimates were calculated using the formula described below, for each species observed during each study and for each season in each geographic cell. Multiple density estimates in a given cell were averaged, using survey area as a weighting factor.

Bird density was estimated using the standard formula:

$$D = n / (l \times w)$$