NOAA Technical Memorandum NMFS

APRIL 2008

ESTIMATES OF 2006 DOLPHIN ABUNDANCE IN THE EASTERN TROPICAL PACIFIC, WITH REVISED ESTIMATES FROM 1986-2003

Tim Gerrodette
George Watters
Wayne Perryman
Lisa Ballance

NOAA-TM-NMFS-SWFSC-422

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

The National Oceanic and Atmospheric Administration (NOAA), organized in 1970, has evolved into an agency that establishes national policies and manages and conserves our oceanic, coastal, and atmospheric resources. An organizational element within NOAA, the Office of Fisheries is responsible for fisheries policy and the direction of the National Marine Fisheries Service (NMFS).

In addition to its formal publications, the NMFS uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series, however, reflect sound professional work and may be referenced in the formal scientific and technical literature.

NOAA Technical Memorandum NMFS
This TM series is used for documentation and timely communication of preliminary results, interim reports, or special purpose information. The TMs have not received complete formal review, editorial control, or detailed editing.

APRIL 2008

ESTIMATES OF 2006 DOLPHIN ABUNDANCE IN THE EASTERN TROPICAL PACIFIC, WITH REVISED ESTIMATES FROM 1986-2003

Tim Gerrodette, George Watters, Wayne Perryman and Lisa Ballance

NOAA, National Marine Fisheries Service
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, California, USA 92037

NOAA-TM-NMFS-SWFSC-422

U.S. DEPARTMENT OF COMMERCE
Carlos M. Gutierrez, Secretary
National Oceanic and Atmospheric Administration
VADM Conrad C. Lautenbacher, Jr., Undersecretary for Oceans and Atmosphere
National Marine Fisheries Service
James W. Balsiger, Acting Assistant Administrator for Fisheries

ABSTRACT

As part of continuing research to monitor dolphin populations affected by the yellowfin tuna purse-seine fishery in the eastern tropical Pacific, a large-scale line-transect survey was carried out from August-December in 2006. Based on data collected on that cruise and using analyses similar to previous studies, estimates of abundance are reported for 10 dolphin stocks in the eastern tropical Pacific for 10 years between 1986 and 2006. Estimates of 2006 abundance and coefficients of variation are: northeastern offshore spotted (857,884, CV=0.23), western/southern offshore spotted (439,208, CV=0.29), coastal spotted (278,155, CV=0.59), eastern spinner (1,062,879, CV=0.26), whitebelly spinner (734,837, CV=0.61), striped (964,362, CV=0.21), rough-toothed (107,633, CV=0.22), short-beaked common (3,127,203, CV=0.26), bottlenose (335,834, CV=0.20) and Risso's (110,457, CV=0.35) dolphins. Revised estimates of abundance for previous years are based on new data on observer school size estimation bias and the addition of unidentified spinner and unidentified common dolphins. The 2006 estimates of abundance for northeastern offshore spotted dolphins are somewhat higher, and for eastern spinner dolphins substantially higher, than estimates from 1998-2000. Coefficients of variation and confidence intervals for the 2006 estimates are also larger than for other recent estimates. Estimates of population growth rate for these two depleted stocks, plus the depleted coastal spotted stock, may indicate that these populations are beginning to recover, but the western/southern offshore spotted stock may be declining. Population models which integrate all available information are needed to assess recovery.

INTRODUCTION

In 1997 the U.S. Congress directed the Secretary of Commerce to determine whether chasing dolphins and deployment of purse-seine nets around dolphins during tuna fishing operations in the eastern tropical Pacific (ETP) was having a significant adverse impact on depleted dolphin stocks (International Dolphin Program Conservation Act, Public Law 105-42). A portion of this law directed NOAA Fisheries to undertake three large-scale cruises between 1998 and 2000 to estimate the abundances of dolphin populations affected by the fishery.

Among other results, data from the 1998-2000 cruises indicated that northeastern offshore spotted and eastern spinner dolphin populations were not recovering as expected (Gerrodette and Forcada 2005, Reilly et al. 2005). Accordingly, the Southwest Fisheries Science Center conducted additional research cruises in 2003 and 2006 to monitor the dolphin populations. Preliminary estimates of abundance from the 2003 cruise were reported in Gerrodette et al. (2005).

This technical memorandum reports 2006 estimates of abundance of 10 dolphin stocks (management units) in the ETP, based on data collected during the 2006 *Stenella* Abundance Research (STAR06) cruise (Jackson et al. 2008). Estimates of abundance in earlier years back to 1986 are also reanalyzed with the latest estimates of group size estimation bias to produce a consistent time series of abundance estimates. A question of primary interest for northeastern offshore spotted and eastern spinner stocks is whether the populations are recovering now that reported fishery-related mortality has been reduced to a low level.

METHODS

Study area and stratification

The 2006 study area was the same as for the 1998-2000 and 2003 cruises. The study area extended from the US/Mexico border south to the territorial waters of Peru, bounded on the east by the continental shores of the Americas, and to the west by Hawaii, roughly from 32° N to 18° S latitude, and from the coastline of the Americas to 153° W longitude (Fig. 1).

Survey effort within the study area was stratified according to the geographic distribution of the two stocks which have been most affected by the fishery: the northeastern offshore stock of the pantropical spotted dolphin, *Stenella attenuata attenuata*, north of 5EN and east of 120EW (Perrin et al. 1994), and the eastern spinner dolphin, *Stenella longirostris orientalis* (Perrin 1990). Northeastern offshore spotted dolphins are found only in the Core stratum by definition, and eastern spinner dolphins are found primarily in the Core and Core2 strata (Fig. 1), so search effort per unit area was, by design, higher in these strata (Fig. 2). Within each stratum, transect lines were randomly but not uniformly spaced, given the logistical constraints of ship range and speed. Ships moved at night, which contributed to some independence among daily transects. The starting point of each day's transect effort was wherever the ship happened to be at dawn along the overall trackline.

The STAR06 survey was carried out with NOAA Ships *David Starr Jordan* and *McArthur II* between July 29 and Dec 7, 2006, the same time as previous surveys (Jackson et al. 2008). The *Jordan* has been used for ETP cetacean surveys for many years. It is 52.1m in length and has an observer eye height of 10.7m. The *McArthur II* was used on ETP surveys for the first time in 2003. It is a larger ship, with a length of 68.3m and an observer eye height of 15.2m.

Ships, study area and stratification in earlier years are described in Gerrodette and Forcada (2005). This report includes data from 10 ETP cruises carried out in 1986-1990, 1998-2000, 2003 and 2006.

Field methods

Methods of collecting data in all years followed standard protocols for line-transect surveys conducted by the Southwest Fisheries Science Center (Kinzey et al. 2000). In workable conditions, a visual search for cetaceans was conducted on the flying bridge of each vessel during all daylight hours as the ship moved along the trackline at a speed of 10 knots. The team of 3 observers rotated positions every 40 minutes; thus, each observer stood watch for 2 hours, then had 2 hours rest. Two observers, one on each side of the ship, searched with pedestal-mounted 25x150 binoculars. In 2003 and 2006, each 25X observer scanned from abeam (90E from the trackline) to the trackline. Together, the two 25X observers thus searched the 180E forward of the ship. This was a slight change from searching protocol prior to 2003. On cruises before 2003, each observer scanned from abeam to 10E past the trackline on the opposite side; thus, there was a 20E area of overlap near the trackline. The 25X binoculars were fitted with azimuth rings and reticles for angle and distance measurements. The third observer searched by eye and with hand-held 7X binoculars, covering areas closer to the ship over the whole 180E forward of the ship.

When a marine mammal was sighted, the horizontal and vertical angles to the sighting were measured, and the third observer entered the data in a computer using a customized data entry program, WinCruz. The program computed the radial and perpendicular distances to the sighting based on these angles (Kinzey and Gerrodette 2003). If the sighting was less than 5.6 km (3.0 nautical miles) from the trackline, the team went "off-effort" and directed the ship to leave the trackline and approach the sighted animal(s). The observers identified the sighting to species or subspecies (if possible) and made school-size estimates. Each observer team had at least one observer who was highly experienced in the field identification of marine mammals in the ETP. Observers discussed distinguishing field characteristics in order to obtain the best possible identification, but they estimated school sizes and, in the case of mixed-species schools, school composition, independently. The computer was connected to the ship's Global Positioning System to record the position of each sighting and all other data events.

Effort and sightings

Estimation of dolphin abundance was based on search effort and sightings that occurred during on-effort periods. We used sightings and effort in conditions of Beaufort sea state ≤ 5 and visibility ≥ 4km, discarding a small number of sightings and low amount of effort beyond these conditions. Sightings and effort within a day were summed; thus, one day of search effort was considered the sampling unit for purposes of variance estimation. If the ship crossed a stratum boundary during a day, separate transects were recorded for each stratum.

In this report, we consider sightings and estimate abundance for the following species and stocks: spotted (*Stenella attenuata*, northeastern offshore, western/southern offshore, and coastal stocks), spinner (*S. longirostris*, eastern and whitebelly stocks), striped (*S. coeruleoalba*), rough-toothed (*Steno bredanensis*), short-beaked common (*D. delphis*, northern, central, and southern stocks combined), bottlenose (*Tursiops truncatus*), and Risso's (*Grampus griseus*) dolphins.

School (group) size

In 2006, unlike previous ETP surveys, the *David Starr Jordan* did not carry a helicopter to photograph dolphin schools. Instead, aerial photogrammetry and photography for school size calibration were carried out with fixed-wing aircraft while the ships were relatively close to the coast. From October 26-November 4 for the *Jordan* (first part of Leg 5) and from November 9-18 for the *McArthur II* (first part of Leg 4), joint ship/aricraft operations were conducted with a NOAA Twin Otter aircraft using airports along the west coast of Mexico (mainly Acapulco). On days with excellent weather (Beaufort 2 and below), the aircraft flew to the vessel area to take vertical aerial photographs of schools detected from the ship. During days of joint ship/aircraft operations, no line-transect sampling took place.

By comparing each observer's estimates of the photographed schools to the counts from the color transparencies and black-and-white negatives, individual correction or calibration coefficients were estimated (Gerrodette et al. 2002). The calibration coefficients adjusted for each observer's tendency to over- or under-estimate dolphin school size. The application of these calibration coefficients to improve observers' estimates of school sizes had a strong effect on the estimates of abundance. The 2006 aerial photography data modified these coefficients for observers who worked in previous years, and thus affected past estimates of abundance. For uncalibrated observers, or for schools which fell outside the range of school sizes for which an observer had been calibrated, we used a group average correction factor (Gerrodette and Forcada 2005).

Abundance

Estimation of abundance was based on distance sampling (Buckland et al. 2001, Marques and Buckland 2003, Buckland et al. 2004) and followed methods described in Gerrodette and Forcada (2005). A multivariate extension of conventional line-transect analysis estimated abundance as

$$\hat{N} = \sum_j \frac{A_j}{2L_j} \sum_i \hat{f}_{ij}(0, c_{ij})\, \hat{s}_{ij} \;, \tag{1}$$

where A_j is the area and L_j the length of search effort in stratum j, $\hat{f}_{ij}(0, c_{ij})$ the estimated probability density evaluated at zero perpendicular distance of the sighting i in stratum j under conditions c_{ij}, and $\hat{s}_{ij}$ the estimated school size of the ith sighting in stratum j (or subschool size of the species of interest in the case of mixed-species schools). The vector of covariates c_{ij} included the continuous variables school size (total school size in the case of mixed-species schools), sea state, swell height and time of day, and the categorical variables ship (*Jordan* or *McArthur II*), sighting cue (the cue which led to the sighting, such as seabirds, splashes or the animals themselves), method of sighting (naked eye, 7X or 25X binocular), presence/absence of glare on the trackline, and presence/absence of seabirds associated with the school. Sea state measured on the Beaufort scale was actually a discrete variable, but the ordinal Beaufort scale could be modeled satisfactorily as a continuous variable (Barlow et al. 2001). All dolphin schools on or near the trackline were assumed to be detected.

As in previous analyses, we used the half-normal model to estimate $f_{ij}\ (0,c_{ij})$, with sightings truncated at 5.5 km. Each species was treated separately for estimation of $f_{ij}\ (0,c_{ij})$, but stocks within species were pooled, including sightings identified to species but not stock (*e.g.*, unidentifed spotted dolphins). Sightings of unidentified dolphins, unidentified small delphinids and unidentified medium delphinids were pooled together into a single category to estimate $f_{ij}\ (0,c_{ij})$. Covariates were tested singly and in combination, and a set of models was chosen on the basis of Akaike's Information Criterion corrected for sample size (AIC_c) (Hurvich and Tsai 1989). For computational efficiency, we retained all models with an AIC_c difference (ΔAIC) less than or equal to 2 from the model with the minimum AIC_c. Final values of $f_{ij}\ (0,c_{ij})$ were estimated by averaging across all the retained models, using the AIC_c scores as weights. The weight from the *j*th model was $\exp(-0.5\Delta AIC_j) / \sum_j \exp(-0.5\Delta AIC_j)$ (Burnham and Anderson 2002).

Pooled components of the abundance estimates were computed to provide additional summary and diagnostic statistics. Pooled components $\hat{f}(0)$, expected school size $\hat{E}(s)$, school encounter rate n/L, and percentage of the total abundance estimate due to the prorated abundance of unidentified sightings (see next section) were calculated across all sightings *i* and strata *j* as

$$\hat{f}(0) = \sum_j \sum_i \hat{f}_{ij}(0,c_{ij}) \Big/ \sum_j n_j \tag{2}$$

$$\hat{E}(s) = \sum_j \sum_i \hat{f}_{ij}(0,c_{ij})\ \hat{s}_{ij} \Big/ \sum_j \sum_i \hat{f}_{ij}(0,c_{ij}) \tag{3}$$

$$n/L = \sum_j n_j \Big/ \sum_j L_j \tag{4}$$

$$\%\ \text{pro} = 100 \sum_j \hat{N}_{unid,j} \Big/ \sum_j \left(\hat{N}_{unid,j} + \hat{N}_{id,j} \right) \tag{5}$$

for each stock and year. For stratum *j*, n_j is the number of sightings, $\hat{N}_{id,j}$ is the estimated abundance based on identified sightings, $\hat{N}_{unid,j}$ is the estimated abundance based on unidentified sightings.

Specific code in S-Plus was written to implement the analysis. The code included calls to FORTRAN routines for the maximum likelihood optimization of the covariate density models. These routines are modifications of Buckland's (1992) algorithm to fit maximum-likelihoods of density functions using the Newton-Raphson method.

Unidentified sightings

Not all sightings could be identified to stock with certainty. We dealt with unidentified sightings in the same way as previous analyses (Gerrodette and Forcada 2005). The number of sightings recorded as unidentified was first reduced by assigning sightings recorded as "probable" to that identified category. For the remaining unidentified sightings, we estimated abundance for the unidentified category and prorated abundance among appropriate stocks in proportion, by stratum, to the estimated abundance from identified sightings of those stocks that were included in the broader unidentified category. The general form of the proration was

$$\hat{N}_{ij} = \hat{N}^*_{ij} + \hat{N}_{uj}\left(\frac{\hat{N}^*_{ij}}{\hat{N}^*_{ij} + \sum_k \hat{N}^*_{kj}}\right), \tag{6}$$

where $\hat{N}_{ij}$ is the revised abundance estimate of stock *i* in stratum *j*, $\hat{N}^*_{ij}$ is the abundance of stock *i* in stratum *j* estimated from identified sightings of stock *i*, $\hat{N}_{uj}$ is the abundance of the unidentified category estimated from unidentified sightings in stratum *j*, and $\hat{N}^*_{kj}$ is the abundance of stock *k* in stratum *j* for stocks other than *i* included in the unidentified sighting category. The proration is based the assumption that all taxa within the unidentified category were equally likely to be unidentified. While probably unrealistic, no data were available to relax this assumption.

We estimated and prorated abundance of four unidentified sighting categories:

Unidentified sighting category	Prorated to dolphin stock or species
Unidentified spotted dolphin	Northeastern, western/southern, and coastal spotted
Unidentified spinner dolphin	Eastern and whitebelly spinner
Unidentified common dolphin	Short-beaked common
Unidentified dolphin	All of the above, plus striped, Risso's, rough-toothed, and bottlenose dolphins

The proration of unidentified dolphins did not include sightings of Fraser's (*Lagenodelphis hosei*), Pacific white-sided (*Lagenorhynchus obliquidens*), or dusky (*L. obscurus*) dolphins. These species are rare in the core of the study area, and we did not attempt to estimate their abundance for this report. The exclusion of these species from the proration of unidentified dolphin abundance had a negligible effect on the estimates of abundance of the other species.

Precision

Precision of the abundance estimates and pooled abundance components was estimated by bootstrap. Within each stratum, a bootstrap sample was constructed by sampling transects (days on effort) with replacement. To include variability due to school-size estimation and the bias correction procedure, for each school size estimate $\hat{s}$, the logarithm of a new school size for the bootstrap sample was chosen from a normal distribution with mean $\ln(\hat{s})$ and variance $\text{var}[\ln(\hat{s})]$, where the variance of the logarithm of the sighting's school-size estimate was obtained by from the calibration procedure (Gerrodette et al. 2002). The school size for the bootstrap sample was $\hat{s}_B = \exp(x - \text{var}(x)/2)$, where x was the random variate from the normal distribution. For each bootstrap sample, the full estimation procedure was carried out, including proration and model averaging. To include model selection uncertainty and to avoid overestimating precision, multiple models were used in each bootstrap. Models for $f_{ij}(0,c_{ij})$ estimation were restricted to the set of models with $\Delta AIC \leq 2$, based on the original data, plus the univariate half-normal model. We computed the standard errors (SE), coefficients of variation (CV) and 95% confidence intervals of the estimates of total abundance and pooled abundance components from the appropriate quantiles of 1,000 or more bootstrap samples.

Trend estimation

To examine trends in the 10 abundance estimates from 1986-2006 for each dolphin stock, we fitted the log-linear model $\log(N_t) = \log(N_0) + rt$, where t was time in years and the fit was weighted by the squared inverse of the coefficient of variation. The parameter r summarized the trend from 1986-2006. We also estimated r from 1998-2006 because after 1993, reported dolphin bycatch has been so low that such mortality should have negligible effects on population dynamics. Exponential population growth could reasonably be expected for stocks recovering from effects of the tuna fishery in previous years.

RESULTS

Effort and sightings

On STAR06 during conditions of Beaufort ≤ 5 and visibility ≥ 4km, there was a total of 21,229 km of transect effort on 194 transects, 8,639 km by the *Jordan* and 12,590 km by the *McArthur II*. Effort and number of transects by stratum are shown in Table 1 and Fig. 2. The amount of survey effort has fallen steadily over the last decade, and both the distance on effort and number of days on effort in 2006 were the lowest in the last 20 years (Fig. 3).

All 2006 on-effort sightings for species and stocks whose abundance is estimated in this report are shown in Figs. 4-11. The numbers of sightings used for abundance estimation (with perpendicular distance ≤ 5.5 km) are shown by stratum in Table 1. There were no sightings of long-beaked common dolphins (*Delphinus capensis*) in 2006; therefore, no estimate of abundance is reported here. Effort and number of sightings in previous years have been reported in Gerrodette and Forcada (2005) and Gerrodette et al. (2005).

Detection probabilities

Schools of dolphin species varied in the probability of being detected. Histograms of sighting frequency as a function of perpendicular distance from the trackline differed among species in 2006 (Fig. 12). Half-normal detection curves based on the estimated pooled $f(0)$ for each stock (eq. 2) are provided in Fig. 12 as visual summaries, but the actual detection probabilities used to estimate abundance (eq. 1) were usually functions of covariates such as school size in addition to perpendicular distance.

School size was the most common covariate selected among the 2006 detection models (Table 2). All eight categories for which a detection function was estimated had a model with school size within 2 AIC units, indicating that school size had an important effect on detection probability. A model with school size was the best model for spotted, spinner, rough-toothed and bottlenose dolphins, while a univariate model (perpendicular distance only) was the best for striped, short-beaked common, Risso's and unidentified dolphins (Table 2). Beaufort sea state and time of day were additional covariates selected for some stocks.

Values of pooled $\hat{f}(0)$ (eq. 2) for each dolphin stock in 2006 ranged from 0.25 km^{-1} for offshore spotted dolphins to 0.49 km^{-1} for rough-toothed dolphins (Table 3). These values imply a range of effective half-strip widths [$1/f(0)$] from 3.93 to 2.05 km. These values also imply that within the 11 km-wide strip transect (5.5 km on each side of the trackline), the probability of detecting a dolphin school ranged from 0.66 for offshore spotted dolphins to 0.37 for rough-toothed dolphins, pooled over all covariates (school size, Beaufort, etc). The probabilities of detecting other species fell between these values. Based on the bootstrap replicates for the two dolphin stocks which interact most frequently with the fishery, northeastern offshore spotted and eastern spinner dolphins, effective strip widths tended to be larger in 2003 and 2006 than in previous years, particularly for eastern spinners (Fig. 13).

School size

Approximately 75% of observers' best estimates in 2006 were below the the true size based on aerial photography, a result consistent with past years (Fig. 14). The median ratio of school size estimate to true school size was 0.68 in 2006, slightly less than the long-term median of 0.71. Thus, observers tended to underestimate true school size by about 30% overall, and adjustment for this estimation bias on an individual observer basis was an important part of estimating abundance of dolphins accurately. All values of school size discussed below and used in abundance estimation included this bias correction based on school-size calibration photographs, using the procedures described in Gerrodette et al. (2002) and Gerrodette and Forcada (2005). As already noted, the addition of 2006 aerial photography data affected school-size bias correction, and thus the estimates of abundance, for data prior to 2006.

Dolphin schools varied in size both among and within species (Fig. 15). In 2006, whitebelly spinner and short-beaked common dolphins had the largest observed mean school sizes (271 and 268, respectively), while rough-toothed dolphins had the smallest (13). Among the focal species, the mean observed school size for offshore spotted dolphins was 117 and for eastern spinner dolphins 193. Observed mean school sizes are biased estimates of true mean school sizes because they do not include factors which affect the probability that the schools are detected. For example, large schools are more easily detected than small schools, and more schools are detected in low than in high Beaufort conditions. Pooled estimated mean group sizes, $\hat{\mathrm{E}}(s)$ (eq. 3), which include the effects of the covariates, are given in Table 3 for each stock in 2006, together with estimates of their precision based on bootstrap replicates. For the two dolphin stocks most frequently set on, northeastern offshore spotted and eastern spinner dolphins, estimated mean school sizes were large in 2006 compared to previous years (Fig. 16). For eastern spinners, expected school size was approximately twice as large as in previous years.

Encounter rates

Because different dolphin stocks occur in different parts of the study area, the number of sightings and sightings per unit effort differed significantly by stratum (Table 1). Therefore, encounter rates pooled across strata, n/L (eq. 4), were less informative than effective strip width and school size. The mean number of schools detected per 100 km in 2006 varied from <0.1 for whitebelly spinner dolpins to >1.2 for western/southern offshore spotted dolphins (Table 3). Compared to previous years, encounter rates for northeastern offshore spotted and eastern spinner dolphins were high in 2003 and 2006 (Fig. 17).

Abundance

Estimates of abundance, $f(0)$, mean school size, encounter rate, and percentage of total abundance due to proration of unidentified sightings for the 10 dolphin species and stocks are given in Tables 3-12 for the 10 ETP-wide line-transect surveys carried out between 1986 and 2006. The abundance estimates and their 95% confidence intervals are shown graphically in Fig. 18. The populations of northeastern offshore spotted and eastern spinner dolphins, the two stocks of primary interest, were estimated to be 857,884 (CV = 22.5%) and 1,062,879 (CV = 25.7%), respectively, in 2006. The most abundant dolphins in the study area were short-beaked common dolphins (about 3.13 million in 2006) and the least abundant (among these 10) were rough-toothed and Risso's dolphins (about 108 and 110 thousand, respectively, in 2006). The estimates of abundance for short-beaked common dolphins included parts of the northern and southern stocks as well as all of the central stock.

Proportions of the abundance estimates due to the proration of unidentified sightings were all < 10% in 2006 (Table 3), a result consistent with previous years. As a fraction of the total estimate, unidentified sightings were most important for eastern spinner dolphins, and contributed 8.7% of the total abundance.

For northeastern offshore spotted and eastern spinner dolphins, estimates of abundance in 2003 and 2006 were higher than estimates from 1998-2000. The eastern spinner estimate in 2006 was especially large. The means of the estimates in 2003 and 2006 compared to the means of the estimates from 1998-2000 were 27% and 73% higher for northeastern offshore spotted and eastern spinner dolphins, respectively. The 95% confidence intervals in 2006 were larger than in previous surveys from 1998-2003 for these two stocks (Fig. 18).

ETP dolphin stocks showed varying patterns of change over the 20-year period from 1986 to 2006 (Fig. 18). The estimated rates of exponential changes ranged from

-0.023 for western/southern offshore spotted to 0.307 for coastal spotted dolphins (Table 13). Rates of change were 0.010 for northeastern offshore spotted and 0.019 for eastern spinner dolphins. The 95% confidence intervals on these estimates included zero for all stocks except bottlenose and rough-toothed dolphins. Over the 8-year period from 1998 to 2006, northeastern offshore spotted, coastal spotted, and eastern spinner dolphins were estimated to be increasing at rates 0.035, 0.077 and 0.092, respectively (Table 13). Western/southern offshore spotted dolphins were estimated to be declining at a rate of -0.080. All 95% confidence intervals on rates of change from 1998-2006 included zero, although just barely for northeastern offshore spotted dolphins.

DISCUSSION

The 2006 STAR cruise, like previous ETP cruises, was designed to estimate abundance of northeastern offshore spotted dolphins and eastern spinner dolphins. We also estimated abundance of other dolphin species or stocks in the study area, but the estimates of the non-target stocks tended to be less precise because the survey was not optimized for them.

School size was an important covariate affecting detection probability for most species in 2006 (Table 2). Despite the higher and more stable platform of the *McArthur II* compared to the *Jordan*, ship was not selected as an important factor for any of the best models based on the AIC criterion. We conclude that despite this obvious difference between the two ships, other factors, such as school size in particular, were more important predictors of detection probability. The use of the *McArthur II* since 2003 may be one reason that effective strip widths tended to be greater in 2003 and 2006 (Fig. 13), but most sightings of northeastern offshore spotted and eastern spinner dolphins were made by the *Jordan* in the Core area.

Heuristically, estimates of abundance can be viewed as a product of three factors: probability of detection, rate of detection, and the number of individuals in each detected group. In general terms, the higher estimates of northeastern offshore spotted and eastern spinner dolphins in 2003 and 2006 compared to 1998-2000 (Fig. 18) can be understood as a result of higher rates of detection (Fig. 17) and larger school sizes, particularly for eastern spinners in 2006 (Fig. 16), despite higher probabilities of detection (wider effective strip widths, Fig. 13).

For years prior to 2006, estimates given here differed from past estimates for several reasons. The first was that 2006 aerial photographic data affected both the individual school-size correction bias for individual observers who worked in previous years and the pooled school-size bias correction factor used for uncalibrated observers (Gerrodette et al. 2002). Observers as a group have generally been consistent in their tendency to underestimate schools (Fig. 14). However, the effects of using the latest bias correction data could be variable among years because bias correction was carried out on an individual observer-individual sighting basis; thus, it was possible for a few estimates of large schools by a particular observer or two to have had a larger effect. The second reason estimates in this report were different from past years was that sightings of unidentified common and unidentified spinner dolphins were included in the proration scheme. Previous analyses were supposed to include these unidentified sightings, but during the preparation of this report it was discovered that they had been left out. The inclusion of these additional unidentified sightings increased the estimates of eastern and whitebelly spinner dolphins in the case of unidentified spinner dolphins and of short-beaked common dolphins in the case of unidentified common dolphins. The amount of increase was variable among years and stocks depending on the relative proportion of identified and unidentified sightings. The third general reason estimates in this report were different from past years was a number of changes to the computer code to correct small bugs, make analyses more consistent across years, and enable the code to execute faster. Examples of such changes included: elimination of sightings of Fraser's, Pacific white-sided and dusky dolphins from unidentified dolphins, bootstrap sampling of school size from a lognormal rather than normal distribution, and, for 1986-1990, consistent pooling for $f(0)$ estimation across all spinner stocks and across rough-toothed and Risso's dolphin sightings.

Over the whole 20-year period from 1986-2006, most dolphin stocks had variable estimates of abundance (Fig. 18) with small, non-significant rates of change, either slightly positive or slightly negative (Table 13). Two exceptions to this pattern were coastal spotted dolphins and bottlenose dolphins, for both of which the second set of 5 estimates (1998-2006) were higher than the first set of estimates (1986-1990). The apparent growth of the coastal spotted dolphin stock may indicate that this depleted stock is recovering, pending a stock assessment (see below). For bottlenose dolphins, which are rarely taken in the fishery, the decadal difference in abundance might indicate some kind of habitat change, a previously proposed but only weakly supported hypothesis for the lack of recovery of the focal dolphin stocks (Gerrodette and Forcada 2005). Here we simply note that the other dolphin stocks do not show this pattern and that the subject merits further study.

Over the 8-year period from 1998-2006 when reported dolphin bycatch was at low levels relative to population sizes, all 3 of the officially depleted dolphin stocks (coastal and northeastern offshore spotted and eastern spinner dolphins) were estimated to be growing at rates considered to be near the 4-8% maximum possible for dolphins (Reilly and Barlow 1986) (Table 13). Western/southern offshore spotted dolphins were estimated to be declining at 8% per year, however, and this may have implications for the interpretation of growth of the northeastern offshore spotted stock, as discussed further below.

Previous studies considering data through 2000 (Lennert-Cody et al. 2001, Gerrodette and Forcada 2005, Wade et al. 2007) have concluded that neither of the two focal dolphin stocks was recovering at a rate consistent with its depleted status and low reported bycatch. The new, higher estimates for 2003 and 2006 reported here, however, may indicate that the stocks are beginning to recover. Such an interpretation must be tempered by several caveats. First, despite the substantial ship time, the estimates of abundance have moderate amounts of uncertainty for surveys of this type because the study area is so large. The 95% confidence intervals on the estimates of growth rate include zero for both stocks (Table 13). The 2006 coefficients of variation and confidence intervals for the estimates of abundance for these two stocks are larger than other recent estimates (Table 3, Fig. 18), which is at least partly due to the reduced survey effort in 2006 (Fig. 3). Second, the decline in abundance since 2000 of the western/southern stock of offshore spotted dolpins (Fig. 18) may indicate that the increase in the northeastern offshore stock is due to dolphins moving across the geographic boundaries at 120ºW and 5ºN that define the two stocks but which do not correspond to any obvious hiatus in distribution (Fig. 4). This has been a persistent issue for any changes, either increases or decreases, in the northeastern offshore spotted stock, and future assessment models will shed light on that question by including oceanographic habitat variables (Forney 2000). Third, the rates at which the two populations are currently growing should be estimated by assessment models, which can condition on realistic population dynamics. Further, assessment models can include additional information on fishery mortality (Wade et al. 2007) including cryptic kill (Archer et al. 2001), reproduction (Kellar et al. 2006, Kellar 2008, Cramer et al. in press), behavior (Lennert-Cody and Scott 2005, Archer et al. submitted 2008), age structure (Hoyle and Maunder 2004), prey abundance (Fiedler et al. 1998), and habitat (Reilly and Fiedler 1994, Watters et al. 2003). Such models are the subject of current work.

ACKNOWLEDGEMENTS

Annette Henry was the cruise coordinator of the STAR06 cruise. We thank the observers for collecting the data, the cruise leaders for supervising the work, Al Jackson for editing the data, and the officers and crews of the vessels for their support. Jay Barlow and Megan Ferguson provided constructive criticism of the draft report. The S-Plus code used in the analysis was adapted from code originally written by Jaume Forcada.

LITERATURE CITED

Archer, F., T. Gerrodette, A. Dizon, K. Abella, and Š. Southern. 2001. Unobserved kill of nursing dolphin calves in a tuna purse-seine fishery. Marine Mammal Science **17**:540-554.

Archer, F. I., S. L. Mesnick, and A. C. Allen. submitted 2008. Variation and predictors of vessel response behaviour in a tropical dolphin community. Animal Behavior **00**:0.

Barlow, J., T. Gerrodette, and J. Forcada. 2001. Factors affecting perpendicular sighting distances on shipboard line-transect surveys for cetaceans. Journal of Cetacean Research and Management **3**:201-212.

Buckland, S. T. 1992. Maximum likelihood fitting of hermite and simple polynomial densities. Applied Statistics **41**:241-266.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, New York.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2004. Advanced Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press, Oxford.

Burnham, K. P., and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2 edition. Springer, New York.

Cramer, K., W. Perryman, and T. Gerrodette. in press. Declines in reproductive output in two dolphin populations depleted by the yellowfin tuna purse-seine fishery. Marine Ecology Progress Series.

Fiedler, P. C., J. Barlow, and T. Gerrodette. 1998. Dolphin prey abundance determined from acoustic backscatter data in eastern Pacific surveys. Fishery Bulletin **96**:237-247.

Forney, K. A. 2000. Environmental models of cetacean abundance: reducing uncertainty in population trends. Conservation Biology **14**:1271-1286.

Gerrodette, T., and J. Forcada. 2005. Non-recovery of two spotted and spinner dolphin populations in the eastern tropical Pacific Ocean. Marine Ecology Progress Series **291**:1-21.

Gerrodette, T., W. Perryman, and J. Barlow. 2002. Calibrating group size estimates of dolphins in the eastern tropical Pacific Ocean. Southwest Fisheries Science Center, Administrative Report LJ-02-08, 20 p.

Gerrodette, T., G. M. Watters, and J. Forcada. 2005. Preliminary estimates of 2003 dolphin abundance in the eastern tropical Pacific. Southwest Fisheries Science Center, Administrative Report LJ-05-05, 26 p.

Hoyle, S. D., and M. N. Maunder. 2004. A Bayesian integrated population dynamics model to analyze data for protected species. Animal Biodiversity and Conservation **27.1**:247-266.

Hurvich, C. M., and C.-L. Tsai. 1989. Regression and time series model selection in small samples. Biometrika **76**:297-307.

Jackson, A., T. Gerrodette, S. Chivers, M. Lynn, S. Rankin, and S. Mesnick. 2008. Marine mammal data collected during a survey in the eastern tropical Pacific Ocean aboard the NOAA ships *David Starr Jordan* and *McArthur II*, July 28-

December 7, 2006. NOAA Technical Memorandum NMFS NOAA-TM-NMFS-SWFSC-421, 45 p.

Kellar, N. M. 2008. Pregnancy patterns of pantropical spotted dolphins (*Stenella attenuata*) in the eastern tropical Pacific determined from hormonal analysis of biopsies and correlations of the patterns with the purse-seine tuna fishery. PhD thesis. University of California, San Diego

Kellar, N. M., M. L. Trego, C. I. Marks, and A. E. Dizon. 2006. Determining pregnancy from blubber in three species of delphinids. Marine Mammal Science **22**:1-16.

Kinzey, D., and T. Gerrodette. 2003. Distance measurements using binoculars from ships at sea: accuracy, precision and effects of refraction. Journal of Cetacean Research and Management **5**:159-171.

Kinzey, D., P. Olson, and T. Gerrodette. 2000. Marine mammal data collection procedures on research ship line-transect surveys by the Southwest Fisheries Science Center. Southwest Fisheries Science Center, Administrative Report LJ-00-08, 32 p.

Lennert-Cody, C. E., S. T. Buckland, and F. F. C. Marques. 2001. Trends in dolphin abundance estimated from fisheries data: a cautionary note. Journal of Cetacean Research and Management **3**:305-319.

Lennert-Cody, C. E., and M. D. Scott. 2005. Spotted dolphin evasive response in relation to fishing effort. Marine Mammal Science **21**:13-28.

Marques, F. F. C., and S. T. Buckland. 2003. Incorporating covariates into standard line transect analyses. Biometrics **59**:924-935.

Perrin, W. F. 1990. Subspecies of *Stenella longirostris* (Mammalia: Cetacea: Delphinidae). Proceedings of the Biological Society of Washington **103**:453-463.

Perrin, W. F., G. D. Schnell, D. J. Hough, J. W. Gilpatrick, Jr., and J. V. Kashiwada. 1994. Reexamination of geographic variation in cranial morphology of the pantropical spotted dolphin, *Stenella attenuata*, in the eastern Pacific. Fishery Bulletin **92**:324-346.

Reilly, S. B., and J. Barlow. 1986. Rates of increase in dolphin population size. Fishery Bulletin **84**:527-533.

Reilly, S. B., M. A. Donahue, T. Gerrodette, K. Forney, P. Wade, L. Ballance, J. Forcada, P. Fiedler, A. Dizon, W. Perryman, F. A. Archer, and E. F. Edwards. 2005. Report of the scientific research program under the International Dolphin Conservation Program Act. NOAA Technical Memorandum, National Marine Fisheries Service, Southwest Fisheries Science Center 372, 100 p, La Jolla.

Reilly, S. B., and P. C. Fiedler. 1994. Interannual variability of dolphin habitats in the eastern tropical Pacific. I: Research vessel surveys, 1986-1990. Fishery Bulletin **92**:434-450.

Wade, P. R., G. M. Watters, T. Gerrodette, and S. B. Reilly. 2007. Depletion of spotted and spinner dolphins in the eastern tropical Pacific: modeling hypotheses for their lack of recovery. Marine Ecology Progress Series **343**:1-14.

Watters, G. M., R. J. Olson, R. C. Francis, P. C. Fiedler, J. J. Polovina, S. B. Reilly, K. Y. Aydin, C. H. Boggs, T. E. Essington, C. J. Walters, and J. F. Kitchell. 2003. Physical forcing and the dynamics of the pelagic ecosystem in the eastern tropical Pacific: simulations with ENSO-scale and global-warming climate drivers. Canadian Journal of Fisheries and Aquatic Sciences **60**:1161-1175.

Table 1. Area, effort, number of transects, and number of dolphin sightings in 2006 used to estimate abundance, by stratum. Strata are shown in Fig. 1.

	Stratum				
	Core	Core2	Outer	N. coastal	S. coastal
Area (10^6 km^2)	5.869	0.592	14.186	0.535	0.171
Effort (km)	10,268	768	9,131	1,027	35
Number of transects	98	5	68	22	1
Number of sightings					
Offshore spotted	102	7	21	4	0
Coastal spotted	4	0	0	12	0
Eastern spinner	63	4	0	1	0
Whitebelly spinner	6	1	9	0	0
Striped	98	5	37	1	0
Rough-toothed	37	0	7	9	0
Short-beaked common	64	0	37	16	0
Bottlenose	54	4	24	42	0
Risso’s	26	0	5	13	0
Unid. spotted	0	0	0	1	0
Unid. spinner	6	0	2	8	0
Unid. small dolphin	67	0	23	3	0
Unid. medium dolphin	10	0	2	4	0
Unid. large dolphin	2	0	3	0	0
Unid. dolphin	26	0	8	18	0

Table 2. Models for estimation of detection probability in 2006. All models included perpendicular distance (pd), plus covariates indicated. For each species, Model 1 is the model with lowest AIC. Additional models are shown if the AIC difference from Model 1 is less than 2.0. School size = total size of dolphin school, Beaufort = Beaufort sea state, time = local time of day. “pd only” indicates a model with perpendicular distance only (no covariates). Models for striped dolphins included a fourth model with swell height, and models for unidentified dolphins included two additional models with swell height and Beaufort, not shown here.

	Model 1	Model 2		Model 3	
Dolphin species	covariate(s)	covariate(s)	ΔAIC	covariate(s)	ΔAIC
Spotted	school size	pd only	1.01		
Spinner	school size	pd only	0.94		
Striped	pd only	school size	0.72	time	1.88
Rough-toothed	school size				
Short-beaked common	pd only	school size	0.99	time	1.77
Bottlenose	school size	school size + Beaufort	1.38		
Risso’s	pd only	school size	0.55		
Unidentified	pd only	time	0.23	school size	0.96

Table 3. 2006 estimates of abundance, pooled components of abundance, and measures of their precision. *N* = abundance, *f* (0) = value of probability density function of detection at zero perpendicular distance in km^{-1}, E (*s*) = expected school size, 100*n/L = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	*N*	857884	197176	22.5	551852	1274019
	f (0)	0.255	0.016	6.2	0.237	0.300
	E (*s*)	118.2	20.0	17.3	85.8	149.9
	100*n/L	0.861	0.128	14.9	0.621	1.115
	% pro	2.49	2.92	103.0	0.04	10.29
W/S offshore spotted	*N*	439208	129197	28.8	227055	724675
	f (0)	0.254	0.016	6.2	0.237	0.298
	E (*s*)	114.9	16.4	14.6	87.0	141.7
	100*n/L	1.258	0.162	12.9	0.960	1.582
	% pro	0.13	0.19	146.3	0.02	0.50
Coastal spotted	*N*	278155	162886	59.0	31150	656534
	f (0)	0.262	0.039	13.8	0.244	0.396
	E (*s*)	223.4	130.2	61.1	24.9	539.9
	100*n/L	0.080	0.023	29.1	0.037	0.128
	% pro	7.37	9.35	107.7	0.40	32.78
Eastern spinner	*N*	1062879	280277	25.7	607428	1727235
	f (0)	0.255	0.019	7.3	0.228	0.299
	E (*s*)	196.3	29.1	14.9	138.9	253.3
	100*n/L	0.305	0.056	18.1	0.202	0.416
	% pro	8.73	7.29	80.0	0.35	26.16
Whitebelly spinner	*N*	734837	447764	60.8	154246	1802469
	f (0)	0.257	0.019	7.3	0.228	0.300
	E (*s*)	264.2	128.6	49.3	92.7	591.1
	100*n/L	0.075	0.021	28.7	0.037	0.121
	% pro	3.13	4.60	98.8	0.22	17.64
Striped	*N*	964362	201255	20.7	616898	1404055
	f (0)	0.282	0.021	7.4	0.251	0.331
	E (*s*)	54.8	6.3	11.8	42.1	66.8
	100*n/L	0.633	0.097	15.2	0.464	0.843
	% pro	0.90	1.32	119.4	0.05	4.68
Rough-toothed	*N*	107633	22908	21.6	66891	153970
	f (0)	0.487	0.055	11.4	0.384	0.601
	E (*s*)	12.2	1.6	13.4	9.3	15.6
	100*n/L	0.249	0.043	17.1	0.174	0.335
	% pro	1.47	1.92	110.7	0.12	6.96
Short-beaked common	*N*	3127203	835650	26.4	1620370	4876096
	f (0)	0.275	0.019	6.7	0.245	0.314
	E (*s*)	258.5	34.7	13.8	185.7	320.9
	100*n/L	0.521	0.099	18.9	0.337	0.731
	% pro	1.14	1.47	108.8	0.12	5.36
Bottlenose	*N*	335834	68709	19.7	231636	495304
	f (0)	0.330	0.025	7.5	0.289	0.390
	E (*s*)	23.0	3.5	14.9	17.6	31.0
	100*n/L	0.577	0.079	13.6	0.434	0.735
	% pro	1.15	1.29	95.5	0.16	5.10
Risso's	*N*	110457	41355	34.8	52510	209008
	f (0)	0.364	0.052	13.9	0.284	0.482
	E (*s*)	22.3	6.1	25.8	13.5	37.8
	100*n/L	0.202	0.057	28.0	0.104	0.321
	% pro	1.46	1.70	99.2	0.11	6.06

Table 4. 2003 estimates of abundance, pooled components of abundance, and measures of their precision. N = abundance, $f(0)$ = value of probability density function of detection at zero perpendicular distance in km^{-1}, E (s) = expected school size, 100*n/L = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	N	822157	127087	15.7	579926	1075088
	$f(0)$	0.278	0.040	13.9	0.248	0.405
	E (s)	91.8	12.1	13.5	59.0	108.8
	100*n/L	0.909	0.106	11.8	0.697	1.100
	% pro	4.49	2.71	52.8	1.19	12.06
W/S offshore spotted	N	758985	201434	26.5	408918	1162696
	$f(0)$	0.277	0.039	13.5	0.248	0.397
	E (s)	92.1	10.1	11.2	67.6	107.8
	100*n/L	1.438	0.163	11.4	1.147	1.782
	% pro	2.35	1.02	39.6	1.14	5.21
Coastal spotted	N	161596	46943	30.8	65979	257914
	$f(0)$	0.329	0.052	16.1	0.261	0.449
	E (s)	53.2	15.5	27.3	32.5	91.8
	100*n/L	0.343	0.103	32.6	0.097	0.497
	% pro	12.41	6.96	51.9	2.64	31.20
Eastern spinner	N	673943	147914	22.1	408922	977001
	$f(0)$	0.251	0.039	15.4	0.189	0.359
	E (s)	123.5	18.0	14.5	93.1	163.7
	100*n/L	0.306	0.053	17.9	0.195	0.406
	% pro	2.68	8.31	158.2	0.70	33.32
Whitebelly spinner	N	531496	229556	43.2	170363	1022845
	$f(0)$	0.259	0.040	15.4	0.190	0.358
	E (s)	86.2	17.6	19.6	61.5	132.4
	100*n/L	0.136	0.049	39.3	0.030	0.212
	% pro	5.90	15.46	145.3	1.55	63.81
Striped	N	1617012	283949	19.7	924869	2025765
	$f(0)$	0.357	0.036	10.7	0.280	0.422
	E (s)	54.0	5.9	11.1	39.3	63.3
	100*n/L	0.682	0.108	16.3	0.454	0.874
	% pro	1.93	0.82	38.7	1.03	4.30
Rough-toothed	N	47593	16484	31.0	27218	92670
	$f(0)$	0.432	0.103	21.4	0.365	0.764
	E (s)	8.9	0.9	10.2	7.4	10.9
	100*n/L	0.157	0.030	19.8	0.099	0.215
	% pro	1.43	0.75	46.1	0.72	3.46
Short-beaked common	N	1197168	472773	35.5	709369	2669497
	$f(0)$	0.319	0.036	11.6	0.249	0.382
	E (s)	129.6	27.8	19.1	107.7	222.4
	100*n/L	0.331	0.058	17.4	0.233	0.451
	% pro	1.66	1.84	82.8	0.90	8.13
Bottlenose	N	312225	87168	26.8	188168	509506
	$f(0)$	0.324	0.038	11.3	0.293	0.435
	E (s)	40.6	16.8	43.2	17.9	80.7
	100*n/L	0.583	0.083	14.0	0.440	0.765
	% pro	0.94	0.65	55.0	0.43	3.06
Risso’s	N	81474	20304	24.8	48140	122422
	$f(0)$	0.365	0.044	11.8	0.287	0.459
	E (s)	18.6	3.9	20.9	11.8	26.6
	100*n/L	0.203	0.044	21.6	0.131	0.295
	% pro	1.37	0.62	40.0	0.72	3.18

Table 5. 2000 estimates of abundance, pooled components of abundance, and measures of their precision. N = abundance, $f(0)$ = value of probability density function of detection at zero perpendicular distance in km^{-1}, E (s) = expected school size, $100*n/L$ = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	N	636780	137380	20.1	438643	974029
	$f(0)$	0.302	0.025	7.9	0.273	0.368
	E (s)	96.9	14.3	14.4	72.7	129.9
	$100*n/L$	0.615	0.091	14.7	0.456	0.804
	% pro	5.87	3.17	52.8	1.50	13.07
W/S offshore spotted	N	1026321	368195	32.6	515081	1958317
	$f(0)$	0.296	0.024	7.8	0.269	0.359
	E (s)	114.7	15.5	13.1	90.0	150.5
	$100*n/L$	1.219	0.162	13.2	0.928	1.562
	% pro	1.27	0.82	63.3	0.24	3.21
Coastal spotted	N	220227	85635	36.2	106169	429443
	$f(0)$	0.350	0.045	12.6	0.289	0.459
	E (s)	93.6	34.0	34.4	48.0	174.5
	$100*n/L$	0.147	0.042	28.5	0.073	0.234
	% pro	39.29	13.57	34.5	14.44	65.27
Eastern spinner	N	418760	94212	22.1	256018	628997
	$f(0)$	0.303	0.025	8.2	0.265	0.363
	E (s)	119.2	25.7	21.7	78.3	175.7
	$100*n/L$	0.235	0.04	17.0	0.164	0.323
	% pro	1.59	0.66	42.4	0.69	3.12
Whitebelly spinner	N	958065	376139	37.8	407724	1808417
	$f(0)$	0.304	0.026	8.4	0.266	0.364
	E (s)	218.1	57.9	25.9	122.0	348.7
	$100*n/L$	0.084	0.022	25.9	0.045	0.129
	% pro	1.28	0.76	59.1	0.27	3.10
Striped	N	1030323	179380	17.2	715504	1425796
	$f(0)$	0.369	0.027	7.1	0.325	0.432
	E (s)	49.1	5.5	11.2	39.3	60.8
	$100*n/L$	0.565	0.064	11.2	0.448	0.699
	% pro	1.25	0.53	42.8	0.51	2.56
Rough-toothed	N	56450	19473	40.1	19255	95777
	$f(0)$	0.405	0.063	17.4	0.260	0.506
	E (s)	14.3	2.9	20.7	9.0	20.5
	$100*n/L$	0.119	0.023	19.2	0.077	0.168
	% pro	1.19	0.49	41.7	0.49	2.48
Short-beaked common	N	2466718	822537	31.3	1244501	4427817
	$f(0)$	0.238	0.017	7.0	0.203	0.275
	E (s)	313.7	46.8	14.7	233.5	418.5
	$100*n/L$	0.295	0.049	16.7	0.210	0.397
	% pro	1.17	0.55	46.9	0.41	2.43
Bottlenose	N	362096	78667	21.6	219409	527871
	$f(0)$	0.373	0.031	8.3	0.314	0.435
	E (s)	29.0	4.9	17.0	20.4	39.3
	$100*n/L$	0.499	0.067	13.4	0.373	0.644
	% pro	1.11	0.43	38.7	0.51	2.14
Risso’s	N	139055	67734	42.1	55111	332843
	$f(0)$	0.424	0.062	15.3	0.294	0.544
	E (s)	19.4	6.9	29.6	12.9	39.5
	$100*n/L$	0.158	0.030	19.0	0.106	0.222
	% pro	1.24	0.57	46.5	0.42	2.63

Table 6. 1999 estimates of abundance, pooled components of abundance, and measures of their precision. N = abundance, $f(0)$ = value of probability density function of detection at zero perpendicular distance in km^{-1}, E (s) = expected school size, $100*n/L$ = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	N	660452	106141	17.0	430566	840421
	$f(0)$	0.293	0.021	7.0	0.262	0.344
	E (s)	104.8	10.9	11.3	76.5	118.8
	$100*n/L$	0.611	0.084	13.6	0.448	0.782
	% pro	7.89	3.39	40.0	3.36	16.68
W/S offshore spotted	N	960704	274017	31.7	401067	1475159
	$f(0)$	0.293	0.019	6.5	0.260	0.337
	E (s)	116.2	11.4	10.6	86.4	131.0
	$100*n/L$	1.178	0.153	12.9	0.898	1.497
	% pro	1.75	0.90	50.2	0.60	4.03
Coastal spotted	N	107477	41828	39.1	36572	205324
	$f(0)$	0.296	0.047	13.4	0.274	0.437
	E (s)	78.8	35.3	49.8	27.2	156.9
	$100*n/L$	0.075	0.028	37.0	0.027	0.131
	% pro	28.71	13.38	47.9	6.12	56.34
Eastern spinner	N	543242	183604	33.3	265486	949940
	$f(0)$	0.278	0.026	9.1	0.245	0.342
	E (s)	169.5	63.2	37.2	80.9	311.6
	$100*n/L$	0.230	0.042	18.2	0.154	0.316
	% pro	2.18	0.88	37.7	1.05	4.45
Whitebelly spinner	N	941984	390782	42.5	251793	1785547
	$f(0)$	0.277	0.023	8.2	0.244	0.331
	E (s)	219.3	56.9	27.0	113.0	332.7
	$100*n/L$	0.096	0.025	26.6	0.050	0.146
	% pro	2.01	0.93	43.6	0.87	4.59
Striped	N	1047717	193881	18.3	705344	1468348
	$f(0)$	0.343	0.019	5.6	0.310	0.388
	E (s)	39.0	4.3	10.9	31.4	47.8
	$100*n/L$	0.662	0.079	11.9	0.515	0.826
	% pro	2.01	0.71	34.5	1.03	3.88
Rough-toothed	N	40322	12256	30.5	19921	67038
	$f(0)$	0.482	0.070	14.5	0.359	0.627
	E (s)	9.9	2.0	20.4	6.8	14.6
	$100*n/L$	0.134	0.025	18.9	0.088	0.186
	% pro	2.23	0.65	27.9	1.33	3.82
Short-beaked common	N	4046272	1201369	27.8	2268054	6926043
	$f(0)$	0.303	0.030	9.5	0.267	0.386
	E (s)	256.1	36.2	14.2	187.8	328.9
	$100*n/L$	0.391	0.061	15.7	0.276	0.521
	% pro	2.11	0.72	33.0	1.11	3.84
Bottlenose	N	354103	112788	30.8	181048	612953
	$f(0)$	0.419	0.040	9.2	0.367	0.519
	E (s)	24.7	5.5	22.6	14.9	36.3
	$100*n/L$	0.377	0.049	12.9	0.287	0.474
	% pro	1.80	0.60	32.0	0.97	3.28
Risso’s	N	108397	30197	29.8	51690	165385
	$f(0)$	0.484	0.052	11.9	0.349	0.548
	E (s)	17.4	3.5	19.0	12.1	25.2
	$100*n/L$	0.168	0.042	24.9	0.097	0.259
	% pro	1.83	0.60	33.5	0.89	3.15

Table 7. 1998 estimates of abundance, pooled components of abundance, and measures of their precision. N = abundance, $f(0)$ = value of probability density function of detection at zero perpendicular distance in km^{-1}, E (s) = expected school size, 100*n/L = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	N	689410	95005	13.5	525396	902631
	$f(0)$	0.378	0.020	5.3	0.339	0.419
	E (s)	63.9	6.1	9.3	53.7	77.9
	100*n/L	0.787	0.092	11.8	0.607	0.967
	% pro	9.72	3.50	37.0	4.14	17.47
W/S offshore spotted	N	765437	229771	29.6	390996	1277560
	$f(0)$	0.373	0.020	5.2	0.338	0.415
	E (s)	72.9	6.7	9.0	61.7	87.9
	100*n/L	1.315	0.140	10.7	1.050	1.600
	% pro	3.33	1.67	51.1	1.07	7.31
Coastal spotted	N	125248	38629	32.9	52678	199845
	$f(0)$	0.454	0.049	11.7	0.343	0.503
	E (s)	57.5	19.4	31.5	31.8	111.0
	100*n/L	0.122	0.029	23.8	0.071	0.188
	% pro	25.05	12.32	51.1	4.34	50.49
Eastern spinner	N	545213	132873	23.6	341864	854979
	$f(0)$	0.338	0.024	7.2	0.294	0.389
	E (s)	111.7	14.5	12.6	89.8	147.4
	100*n/L	0.230	0.037	16.1	0.163	0.309
	% pro	4.63	1.97	43.8	2.13	9.56
Whitebelly spinner	N	271442	103317	36.5	102823	509931
	$f(0)$	0.338	0.024	7.2	0.295	0.388
	E (s)	103.3	26.2	24.3	59.5	160.7
	100*n/L	0.039	0.011	27.1	0.020	0.061
	% pro	12.62	9.07	74.3	1.47	32.61
Striped	N	1066521	151115	14.1	796923	1379690
	$f(0)$	0.408	0.024	5.8	0.367	0.460
	E (s)	41.8	3.1	7.4	36.5	48.6
	100*n/L	0.490	0.047	9.5	0.402	0.578
	% pro	3.11	1.33	43.6	1.31	6.36
Rough-toothed	N	68274	19300	28.1	35618	110086
	$f(0)$	0.698	0.069	9.7	0.585	0.893
	E (s)	9.4	1.2	13.2	7.1	12.0
	100*n/L	0.115	0.018	15.5	0.082	0.152
	% pro	2.71	0.93	34.9	1.43	5.06
Short-beaked common	N	2277456	580256	25.5	1258256	3543480
	$f(0)$	0.352	0.025	7.2	0.303	0.402
	E (s)	194.8	39.2	19.9	128.9	280.0
	100*n/L	0.319	0.043	13.6	0.240	0.408
	% pro	5.93	2.75	46.9	2.05	12.78
Bottlenose	N	327166	76444	23.2	202889	495622
	$f(0)$	0.417	0.023	5.5	0.379	0.467
	E (s)	20.1	2.6	13.2	15.2	25.3
	100*n/L	0.657	0.075	11.4	0.524	0.816
	% pro	2.27	0.67	30.4	1.30	3.81
Risso’s	N	64962	14567	20.8	44235	101914
	$f(0)$	0.372	0.051	12.4	0.331	0.523
	E (s)	17.1	4.2	25.2	10.3	26.1
	100*n/L	0.199	0.035	17.6	0.133	0.271
	% pro	2.34	0.63	26.7	1.43	4.04

Table 8. 1990 estimates of abundance, pooled components of abundance, and measures of their precision. N = abundance, $f(0)$ = value of probability density function of detection at zero perpendicular distance in km^{-1}, $\mathrm{E}(s)$ = expected school size, $100*n/L$ = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	N	755112	294936	39.1	321828	1459104
	$f(0)$	0.254	0.020	8.0	0.218	0.303
	$\mathrm{E}(s)$	112.0	36.4	33.2	55.6	192.3
	$100*n/L$	0.660	0.106	16.1	0.458	0.874
	% pro	11.44	7.76	67.7	2.40	29.25
W/S offshore spotted	N	533076	123379	23.1	314099	797611
	$f(0)$	0.252	0.020	7.7	0.217	0.299
	$\mathrm{E}(s)$	136.8	27.4	20.6	86.7	193.9
	$100*n/L$	0.622	0.075	12.0	0.480	0.781
	% pro	35.32	10.35	28.0	17.32	58.03
Coastal spotted	N	3350	3424	107.2	0	11098
	$f(0)$	0.262	0.041	14.9	0.223	0.397
	$\mathrm{E}(s)$	17.9	6.0	33.2	9.0	31.5
	$100*n/L$	0.006	0.005	95.0	0.000	0.016
	% pro	11.89	9.16	60.8	2.22	35.22
Eastern spinner	N	460952	158402	33.6	218201	852120
	$f(0)$	0.300	0.032	10.6	0.250	0.374
	$\mathrm{E}(s)$	102.7	22.7	22.2	66.3	150.9
	$100*n/L$	0.145	0.027	18.8	0.095	0.205
	% pro	11.21	7.47	66.0	2.49	29.80
Whitebelly spinner	N	422259	236502	54.0	116459	992160
	$f(0)$	0.301	0.039	12.6	0.254	0.417
	$\mathrm{E}(s)$	179.0	75	42.5	78.1	357.7
	$100*n/L$	0.068	0.018	26.4	0.034	0.104
	% pro	5.48	2.59	46.4	2.21	11.56
Striped	N	1053945	179309	16.7	755738	1464656
	$f(0)$	0.347	0.025	7.2	0.305	0.403
	$\mathrm{E}(s)$	62.7	6.6	10.5	50.2	76.9
	$100*n/L$	0.462	0.047	10.1	0.371	0.555
	% pro	7.49	3.27	42.0	3.28	15.95
Rough-toothed	N	122454	52405	42.7	46080	238586
	$f(0)$	0.563	0.054	9.4	0.485	0.688
	$\mathrm{E}(s)$	25.1	9.1	36.6	12.3	46.6
	$100*n/L$	0.084	0.018	21.0	0.051	0.119
	% pro	7.88	5.28	60.8	2.57	21.36
Short-beaked common	N	1148256	336943	28.9	573654	1886923
	$f(0)$	0.318	0.034	10.7	0.260	0.392
	$\mathrm{E}(s)$	313.3	65.8	20.7	212.9	467.4
	$100*n/L$	0.100	0.027	26.9	0.053	0.159
	% pro	12.92	6.40	48.5	3.51	28.37
Bottlenose	N	190351	56326	28.3	108761	324815
	$f(0)$	0.340	0.044	12.6	0.277	0.447
	$\mathrm{E}(s)$	25.2	4.4	17.2	17.7	34.3
	$100*n/L$	0.216	0.032	14.8	0.157	0.282
	% pro	8.50	4.44	49.1	3.25	19.04
Risso's	N	120165	164392	131.8	41011	419940
	$f(0)$	0.570	0.056	9.6	0.488	0.710
	$\mathrm{E}(s)$	19.4	23.7	120.0	9.4	60.3
	$100*n/L$	0.100	0.025	24.8	0.057	0.153
	% pro	5.58	3.47	56.7	1.60	14.47

Table 9. 1989 estimates of abundance, pooled components of abundance, and measures of their precision. N = abundance, $f(0)$ = value of probability density function of detection at zero perpendicular distance in km^{-1}, $E(s)$ = expected school size, $100*n/L$ = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	N	1012176	246687	23.5	641315	1624213
	$f(0)$	0.270	0.017	6.1	0.249	0.313
	$E(s)$	152.4	32.7	21.1	106.1	227.9
	$100*n/L$	0.661	0.102	15.4	0.467	0.872
	% pro	11.12	4.77	43.5	3.47	21.57
W/S offshore spotted	N	1234593	403802	30.9	699684	2219923
	$f(0)$	0.288	0.017	5.8	0.269	0.337
	$E(s)$	163.5	24.9	15.1	124.2	218.5
	$100*n/L$	0.894	0.109	12.2	0.684	1.120
	% pro	19.06	10.06	52.6	3.50	41.05
Coastal spotted	N	-	-	-	-	-
	$f(0)$	-	-	-	-	-
	$E(s)$	-	-	-	-	-
	$100*n/L$	-	-	-	-	-
	% pro	-	-	-	-	-
Eastern spinner	N	617298	195391	30.9	314479	1062500
	$f(0)$	0.284	0.021	7.3	0.247	0.327
	$E(s)$	118.6	29.6	24.4	73.8	185.2
	$100*n/L$	0.242	0.040	16.6	0.166	0.329
	% pro	4.52	2.83	69.5	1.25	11.53
Whitebelly spinner	N	952381	441688	42.9	333384	2029577
	$f(0)$	0.294	0.031	10.0	0.268	0.388
	$E(s)$	208.1	47.9	22.8	127.6	313.3
	$100*n/L$	0.103	0.022	21.6	0.063	0.149
	% pro	0.82	0.94	112.1	0.25	2.70
Striped	N	1299832	306296	21.1	963433	2126277
	$f(0)$	0.353	0.035	9.2	0.321	0.452
	$E(s)$	54.9	6.2	11.0	45.1	68.6
	$100*n/L$	0.673	0.064	9.5	0.557	0.806
	% pro	2.09	1.41	70.5	0.72	5.42
Rough-toothed	N	59032	24426	41.6	25300	120001
	$f(0)$	0.495	0.069	13.6	0.394	0.663
	$E(s)$	13.9	5.1	37.4	8.4	28.6
	$100*n/L$	0.103	0.023	22.2	0.061	0.152
	% pro	3.99	2.35	62.9	1.32	10.46
Short-beaked common	N	2330910	799899	34.2	1086694	4109733
	$f(0)$	0.328	0.040	12.2	0.254	0.410
	$E(s)$	400.4	113.5	28.3	243.5	629.3
	$100*n/L$	0.157	0.034	21.4	0.099	0.227
	% pro	12.43	6.84	52.7	2.44	29.21
Bottlenose	N	141091	44770	30.5	73102	251281
	$f(0)$	0.418	0.054	13.4	0.299	0.508
	$E(s)$	17.3	4.2	23.1	11.4	28.2
	$100*n/L$	0.200	0.036	17.6	0.139	0.274
	% pro	2.54	1.76	71.9	0.76	6.60
Risso's	N	78596	30476	37.5	38772	139034
	$f(0)$	0.495	0.069	13.6	0.394	0.663
	$E(s)$	13.4	3.7	27.9	7.6	21.0
	$100*n/L$	0.135	0.027	20.0	0.088	0.194
	% pro	3.36	2.26	71.5	0.99	8.45

Table 10. 1988 estimates of abundance, pooled components of abundance, and measures of their precision. N = abundance, $f(0)$ = value of probability density function of detection at zero perpendicular distance in km^{-1}, E (s) = expected school size, 100*n/L = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	N	906369	213612	23.3	528342	1354159
	$f(0)$	0.331	0.024	7.3	0.290	0.383
	E (s)	145.1	19.5	13.4	107.0	186.2
	100*n/L	0.552	0.096	17.4	0.373	0.751
	% pro	1.44	0.77	53.1	0.60	3.19
W/S offshore spotted	N	1161047	684108	57.3	416915	2630931
	$f(0)$	0.331	0.025	7.4	0.290	0.386
	E (s)	152.9	29.2	19.0	115.5	214.4
	100*n/L	0.703	0.100	14.3	0.509	0.909
	% pro	12.87	9.31	62.1	2.49	38.69
Coastal spotted	N	-	-	-	-	-
	$f(0)$	-	-	-	-	-
	E (s)	-	-	-	-	-
	100*n/L	-	-	-	-	-
	% pro	-	-	-	-	-
Eastern spinner	N	679538	198460	30.2	303807	1094261
	$f(0)$	0.359	0.030	8.4	0.305	0.421
	E (s)	160.5	33.5	21.2	100.0	235.1
	100*n/L	0.155	0.038	24.8	0.088	0.238
	% pro	1.23	0.66	51.8	0.50	2.52
Whitebelly spinner	N	875437	250535	29.3	417373	1354965
	$f(0)$	0.359	0.030	8.4	0.308	0.422
	E (s)	101.4	24.5	24.5	59.1	154.5
	100*n/L	0.168	0.034	20.3	0.104	0.238
	% pro	2.43	1.14	44.0	1.05	5.16
Striped	N	1544721	234479	15.0	1135040	2013991
	$f(0)$	0.336	0.019	5.8	0.301	0.377
	E (s)	62.2	3.8	6.1	55.1	70.1
	100*n/L	0.760	0.075	9.9	0.616	0.915
	% pro	2.25	0.89	38.4	1.18	4.40
Rough-toothed	N	110349	35919	32.7	50173	191045
	$f(0)$	0.615	0.060	9.8	0.519	0.749
	E (s)	12.6	4.3	32.7	7.3	24.1
	100*n/L	0.147	0.047	32.0	0.069	0.250
	% pro	1.58	0.79	45.9	0.67	3.76
Short-beaked common	N	3630548	2096690	57.2	1338894	8633349
	$f(0)$	0.284	0.030	10.5	0.229	0.356
	E (s)	426.7	102	23.8	247.8	639.8
	100*n/L	0.210	0.047	22.5	0.127	0.308
	% pro	38.03	22.49	78.8	1.11	73.57
Bottlenose	N	167560	61383	35.2	79029	304083
	$f(0)$	0.354	0.043	11.8	0.291	0.461
	E (s)	23.7	6.9	28.9	13.5	36.6
	100*n/L	0.231	0.041	17.9	0.153	0.312
	% pro	1.36	0.83	60.6	0.51	3.11
Risso’s	N	128104	66660	49.9	58939	247266
	$f(0)$	0.620	0.059	9.4	0.530	0.760
	E (s)	11.4	4.9	42.0	7.3	21.1
	100*n/L	0.172	0.033	19.1	0.114	0.240
	% pro	1.44	0.74	48.2	0.52	3.38

Table 11. 1987 estimates of abundance, pooled components of abundance, and measures of their precision. N = abundance, $f(0)$ = value of probability density function of detection at zero perpendicular distance in km^{-1}, E (s) = expected school size, 100*n/L = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	N	568194	114283	19.8	378000	822845
	$f(0)$	0.304	0.022	7.2	0.270	0.359
	E (s)	84.5	10.8	12.6	66.9	109.2
	100*n/L	0.623	0.108	17.3	0.422	0.839
	% pro	5.79	2.99	53.0	2.68	12.75
W/S offshore spotted	N	1209547	302322	26.2	659156	1823084
	$f(0)$	0.333	0.024	7.3	0.291	0.384
	E (s)	114.5	13.8	12.2	88.9	141.5
	100*n/L	0.872	0.110	12.7	0.664	1.100
	% pro	41.60	12.54	32.1	15.85	64.58
Coastal spotted	N	26587	20356	75.8	0	74575
	$f(0)$	0.374	0.041	11.3	0.299	0.452
	E (s)	48.4	9.2	18.4	35.0	71.2
	100*n/L	0.018	0.013	71.2	0.000	0.047
	% pro	6.43	3.60	57.0	2.75	13.98
Eastern spinner	N	353727	108589	29.5	179919	609112
	$f(0)$	0.296	0.023	7.5	0.262	0.352
	E (s)	80.7	17.0	20.5	54.7	119.6
	100*n/L	0.192	0.042	21.9	0.115	0.277
	% pro	4.41	2.52	57.9	2.10	11.29
Whitebelly spinner	N	597239	185031	30.7	308580	1012079
	$f(0)$	0.319	0.031	9.7	0.274	0.394
	E (s)	105.9	18.8	17.7	70.6	146.4
	100*n/L	0.145	0.027	18.4	0.092	0.198
	% pro	4.41	1.70	36.8	2.40	8.30
Striped	N	1307251	220178	17.4	879557	1755476
	$f(0)$	0.444	0.041	9.6	0.356	0.509
	E (s)	53.2	3.7	6.9	46.3	60.7
	100*n/L	0.576	0.059	10.2	0.468	0.696
	% pro	4.68	1.96	39.4	2.60	9.49
Rough-toothed	N	52221	18451	31.4	27069	98876
	$f(0)$	0.429	0.056	12.5	0.349	0.577
	E (s)	17.5	4.9	25.4	11.7	30.8
	100*n/L	0.076	0.018	23.6	0.044	0.115
	% pro	3.80	1.57	38.8	2.20	7.54
Short-beaked common	N	540725	176918	31.7	261129	953921
	$f(0)$	0.312	0.040	12.7	0.246	0.400
	E (s)	184.2	36.0	19.6	118.8	255.8
	100*n/L	0.105	0.024	22.5	0.062	0.158
	% pro	4.66	2.74	56.5	2.34	11.85
Bottlenose	N	188694	71709	35.6	103137	336699
	$f(0)$	0.484	0.058	12.2	0.385	0.607
	E (s)	20.6	7.9	35.8	14.4	35.3
	100*n/L	0.217	0.034	15.4	0.157	0.287
	% pro	4.58	2.31	47.1	2.35	10.64
Risso’s	N	67959	18620	25.7	43284	109592
	$f(0)$	0.476	0.055	11.3	0.387	0.600
	E (s)	8.5	1.9	21.1	6.4	12.4
	100*n/L	0.189	0.031	16.4	0.130	0.250
	% pro	4.18	1.96	43.5	2.35	9.05

Table 12. 1986 estimates of abundance, pooled components of abundance, and measures of their precision. N = abundance, $f(0)$ = value of probability density function of detection at zero perpendicular distance in km^{-1}, E (s) = expected school size, 100*n/L = encounter rate in sightings per 100 km, % pro = percentage of abundance estimate contributed by unidentified sightings, SE = standard error, CV = coefficient of variation expressed as a percentage, and lwr95 and upr95 = limits of 95% confidence interval.

Species / stock		Estimate	SE	CV	lwr95	upr95
NE offshore spotted	N	453470	103158	22.4	294973	701806
	$f(0)$	0.270	0.017	6.3	0.241	0.307
	E (s)	79.4	10.7	13.4	61.1	100.0
	100*n/L	0.620	0.103	16.5	0.439	0.844
	% pro	2.57	1.40	52.1	1.10	5.87
W/S offshore spotted	N	920294	319579	32.5	480135	1693636
	$f(0)$	0.316	0.024	7.4	0.284	0.377
	E (s)	92.3	11.6	12.5	73.2	117.0
	100*n/L	0.831	0.105	12.6	0.630	1.060
	% pro	40.40	16.10	42.4	4.73	65.30
Coastal spotted	N	76521	54008	67.9	0	204097
	$f(0)$	0.335	0.089	26.5	0.226	0.537
	E (s)	109.0	58.5	52.2	41.9	226.0
	100*n/L	0.029	0.015	52.2	0.000	0.064
	% pro	3.37	2.02	56.8	1.39	7.72
Eastern spinner	N	649638	218155	34.0	297890	1167374
	$f(0)$	0.307	0.026	8.5	0.262	0.356
	E (s)	106.0	27.6	26.2	64.2	164.0
	100*n/L	0.229	0.034	14.9	0.165	0.301
	% pro	2.81	1.81	58.5	1.23	7.08
Whitebelly spinner	N	570848	192259	32.9	264274	1008919
	$f(0)$	0.440	0.064	14.6	0.335	0.588
	E (s)	77.8	14.3	18.3	53.8	108.0
	100*n/L	0.137	0.026	19.1	0.089	0.192
	% pro	3.68	3.69	83.8	0.89	15.50
Striped	N	830697	156232	18.8	572963	1172591
	$f(0)$	0.424	0.044	10.4	0.349	0.520
	E (s)	45.8	4.5	9.9	36.8	54.4
	100*n/L	0.506	0.070	13.7	0.383	0.658
	% pro	3.91	3.34	70.3	1.45	14.00
Rough-toothed	N	26589	7320	26.3	15436	43620
	$f(0)$	0.400	0.090	21.4	0.302	0.620
	E (s)	9.2	1.6	17.0	6.7	12.9
	100*n/L	0.096	0.027	28.2	0.052	0.158
	% pro	3.51	3.37	78.0	1.39	13.60
Short-beaked common	N	1840889	853741	44.5	621409	3892343
	$f(0)$	0.358	0.073	21.3	0.218	0.499
	E (s)	308.0	72.7	22.6	183.0	471.0
	100*n/L	0.155	0.037	23.6	0.090	0.230
	% pro	4.34	2.88	67.2	1.04	11.80
Bottlenose	N	215366	87134	38.6	102860	419717
	$f(0)$	0.422	0.040	9.8	0.329	0.483
	E (s)	23.4	9.7	38.4	13.6	46.1
	100*n/L	0.255	0.036	14.2	0.186	0.328
	% pro	3.28	2.27	61.9	1.48	9.42
Risso’s	N	77812	39792	44.5	43175	166825
	$f(0)$	0.446	0.076	15.2	0.378	0.643
	E (s)	14.3	4.8	33.8	8.4	23.3
	100*n/L	0.122	0.023	18.5	0.080	0.169
	% pro	3.83	4.15	85.7	1.37	16.10

Table 13. Estimates of exponential rate of change *r*, with lower and upper limits of the 95% confidence interval on the estimate, for 10 ETP dolphin stocks for two time periods: 1986-2006 and 1998-2006.

	1986 - 2006			1998 – 2006		
Species / stock	*r*	lwr95	upr95	*r*	lwr95	upr95
NE offshore spotted	0.010	-0.014	0.034	0.035	-0.002	0.071
W/S offshore spotted	-0.023	-0.058	0.013	-0.080	-0.189	0.028
Coastal spotted	0.104	0.004	0.204	0.077	-0.091	0.245
Eastern spinner	0.019	-0.013	0.051	0.092	-0.017	0.202
Whitebelly spinner	-0.005	-0.054	0.043	0.062	-0.302	0.425
Striped	-0.004	-0.028	0.020	0.012	-0.095	0.119
Rough-toothed	0.026	-0.022	0.074	0.081	-0.071	0.232
Short-beaked common	0.047	-0.012	0.107	-0.006	-0.221	0.208
Bottlenose	0.040	0.020	0.060	-0.004	-0.033	0.024
Risso's	0.011	-0.017	0.040	0.039	-0.112	0.189

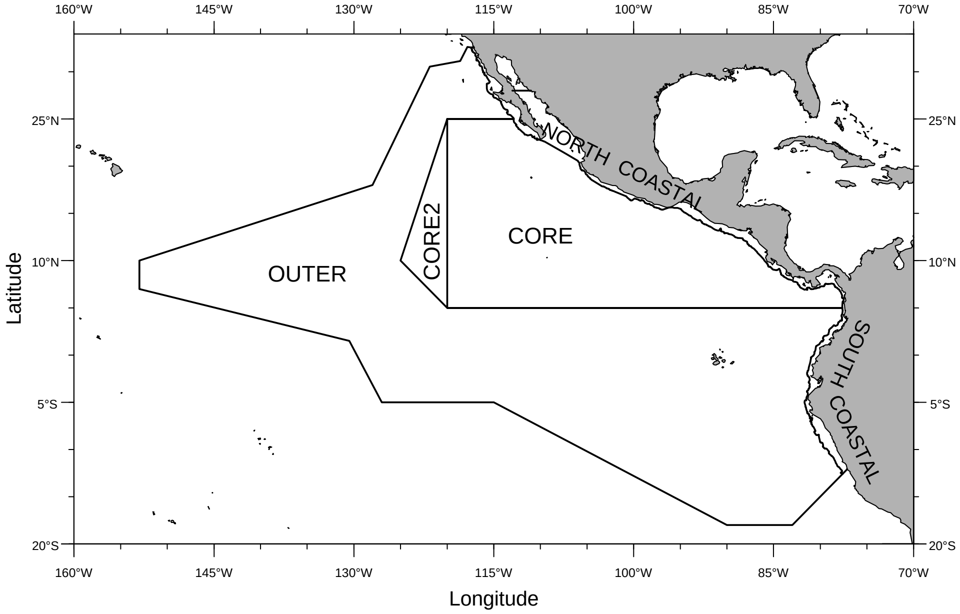

Fig. 1. Strata for the STAR06 cruise.

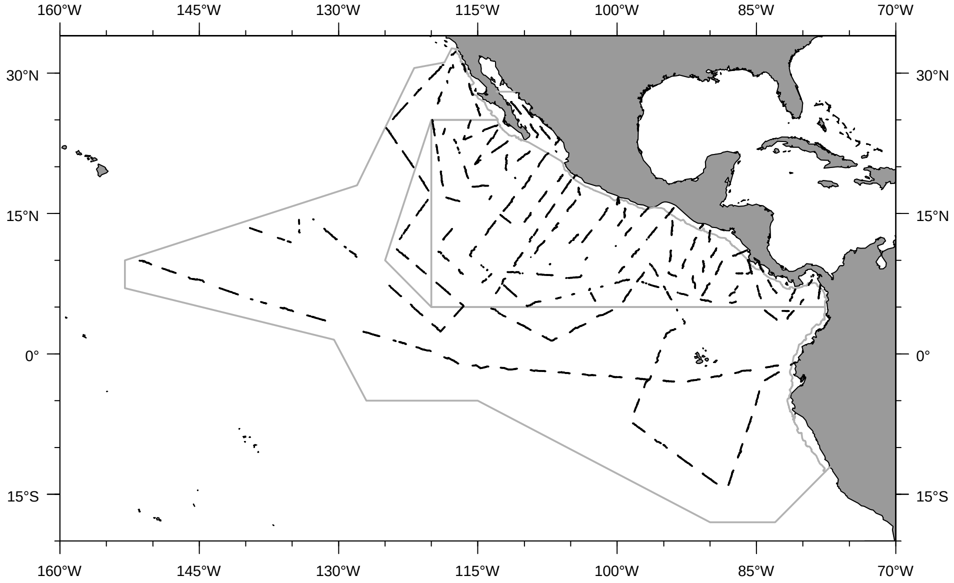

Fig. 2: Line-transect effort (broken dark lines) and stratum boundaries (solid gray lines) for the STAR06 cruise.

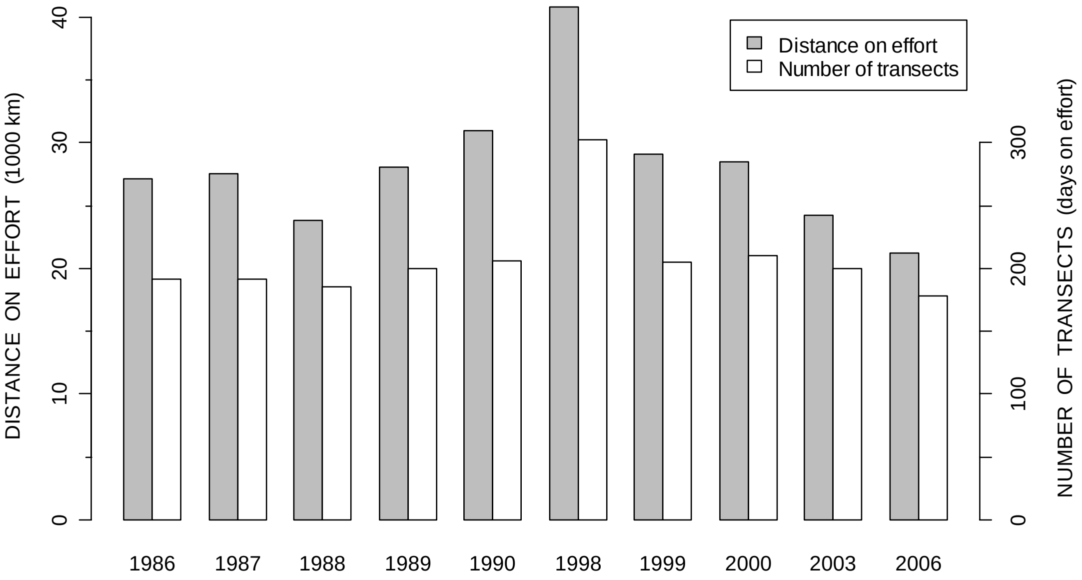

Fig. 3: Two measures of survey effort in the ETP by year.

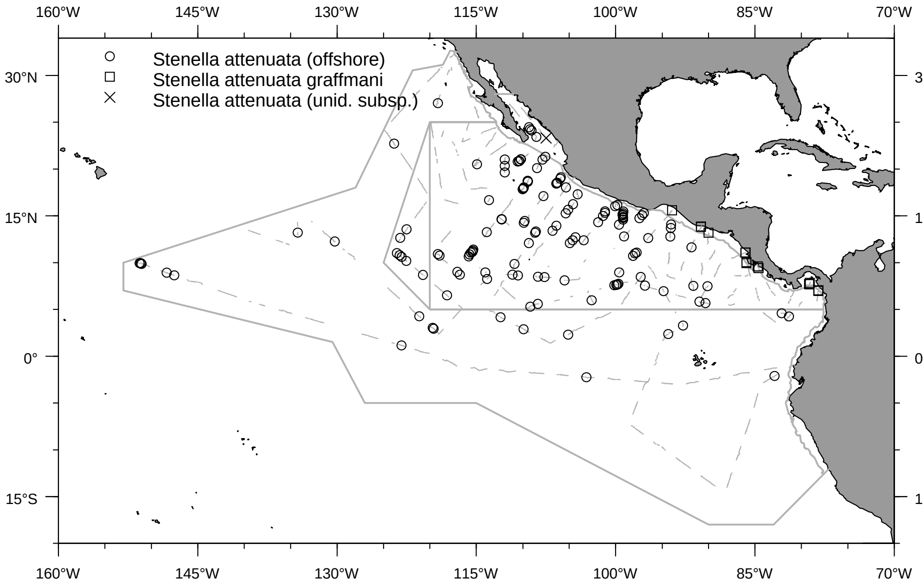

Fig. 4: Spotted dolphin sightings during STAR06. Gray lines are stratum boundaries and survey effort.

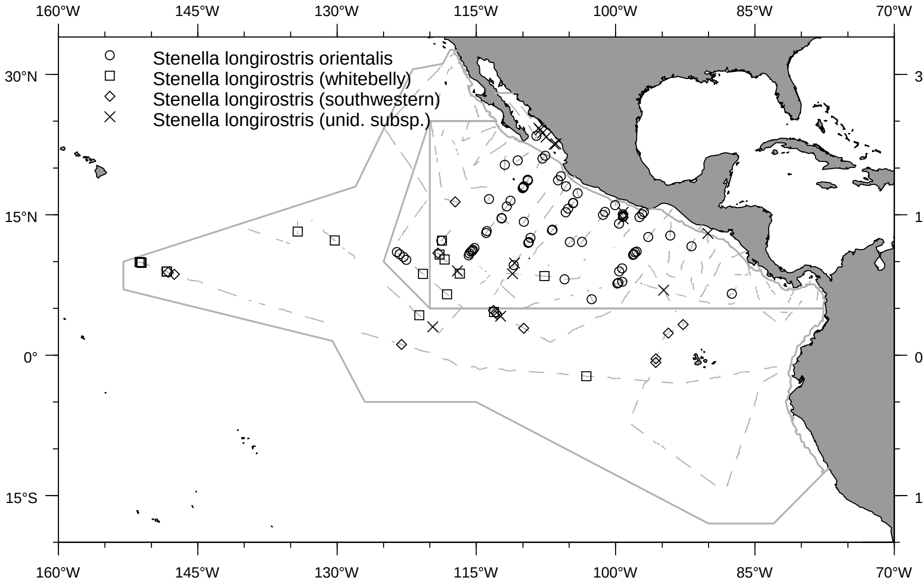

Fig. 5: Spinner dolphin sightings during STAR06. Gray lines are stratum boundaries and survey effort.

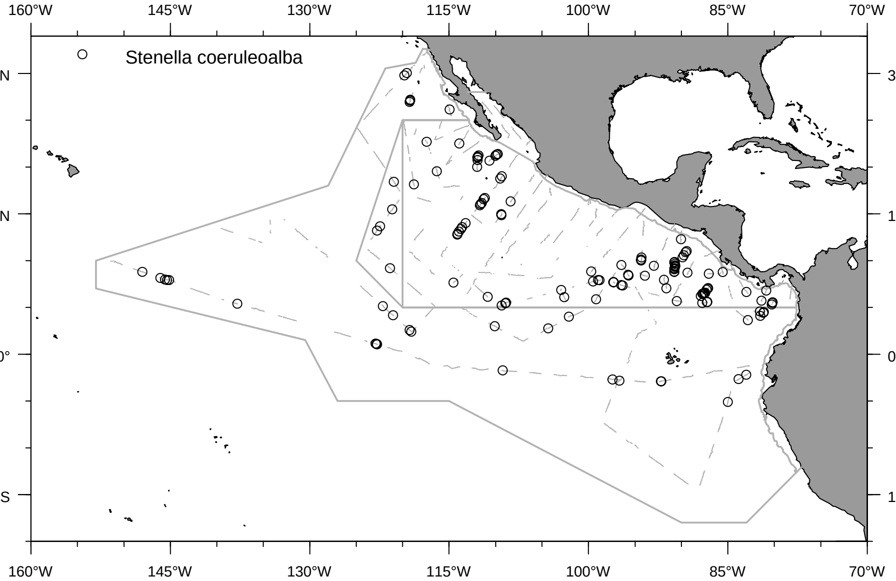

Fig. 6: Striped dolphin sightings during STAR06. Gray lines are stratum boundaries and survey effort.

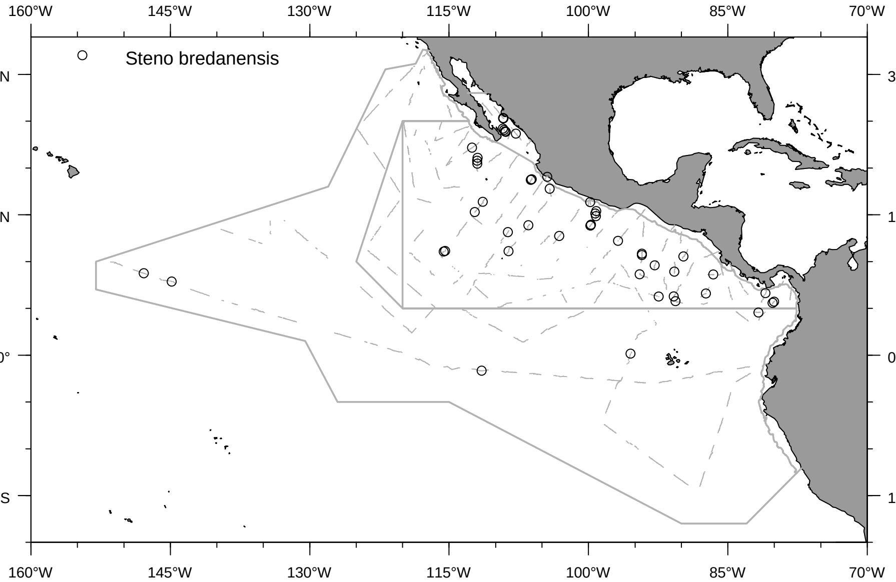

Fig. 7: Rough-toothed dolphin sightings during STAR06. Gray lines are stratum boundaries and survey effort.

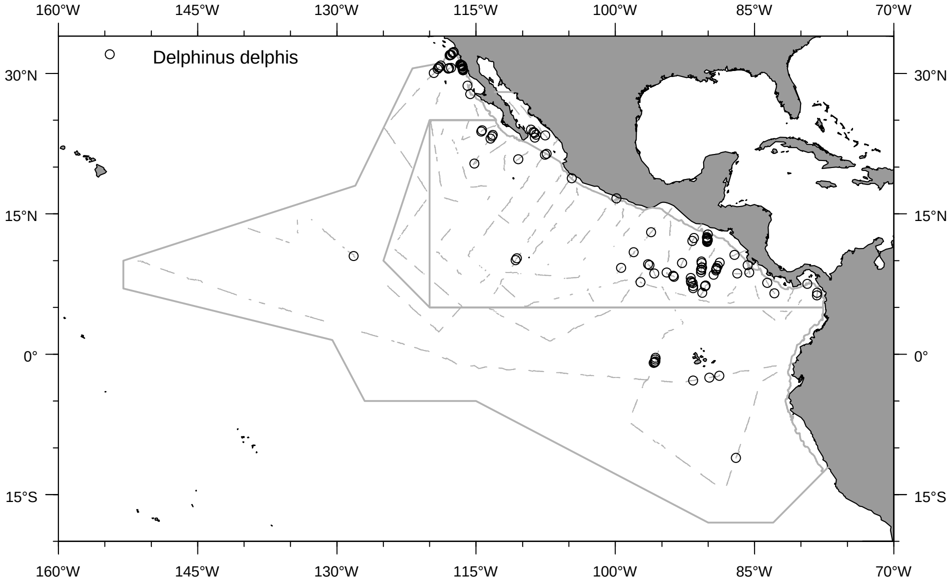

Fig. 8: Common dolphin sightings during STAR06. Gray lines are stratum boundaries and survey effort.

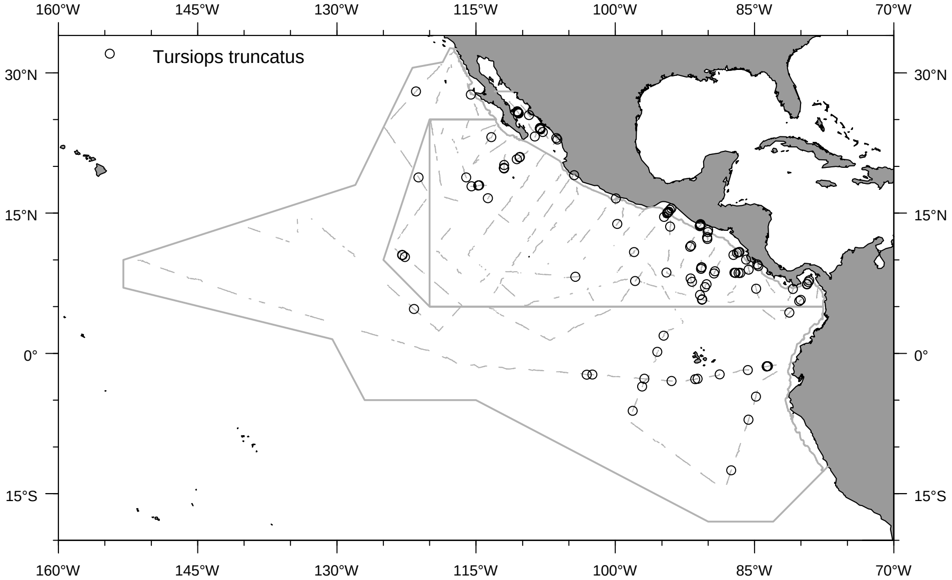

Fig. 9: Bottlenose dolphin sightings during STAR06. Gray lines are stratum boundaries and survey effort.

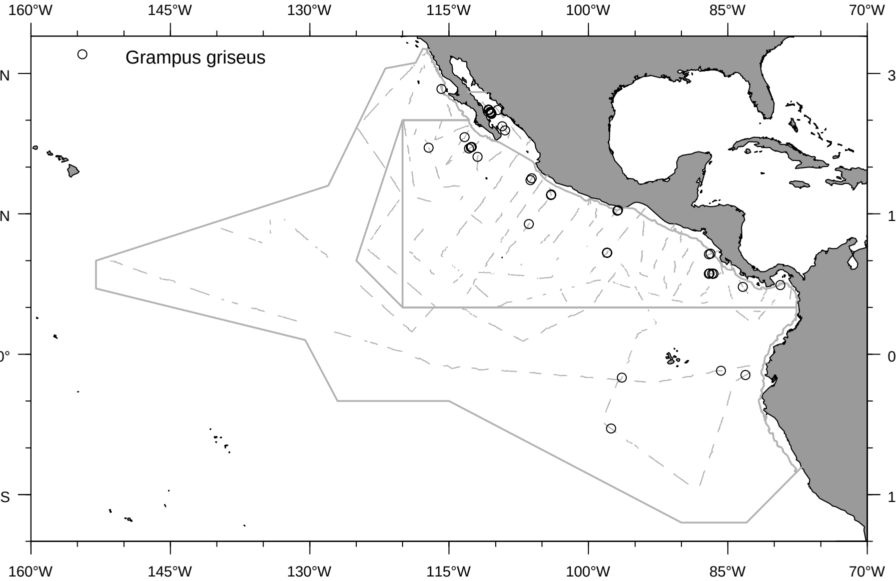

Fig. 10: Risso's dolphin sightings during STAR06. Gray lines are stratum boundaries and survey effort.

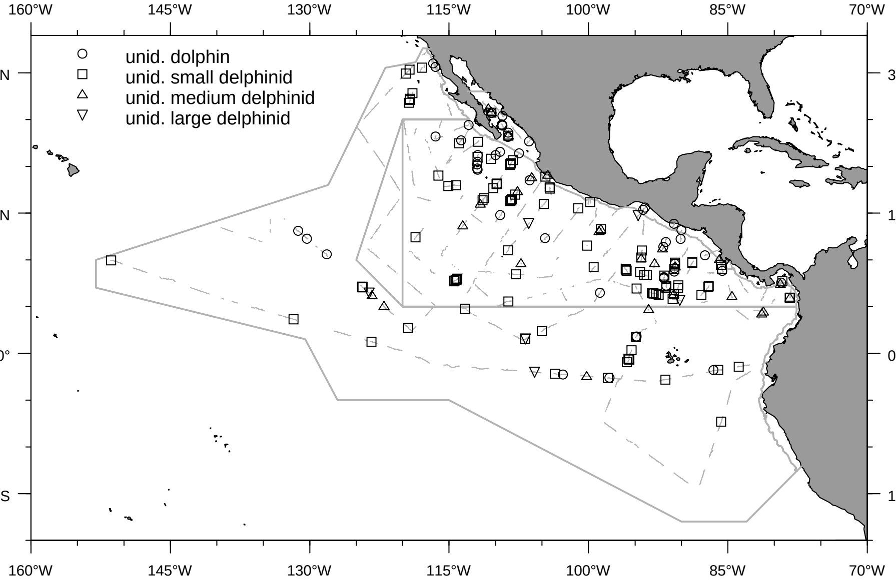

Fig. 11: Unidentified dolphin sightings during STAR06. Gray lines are stratum boundaries and survey effort.

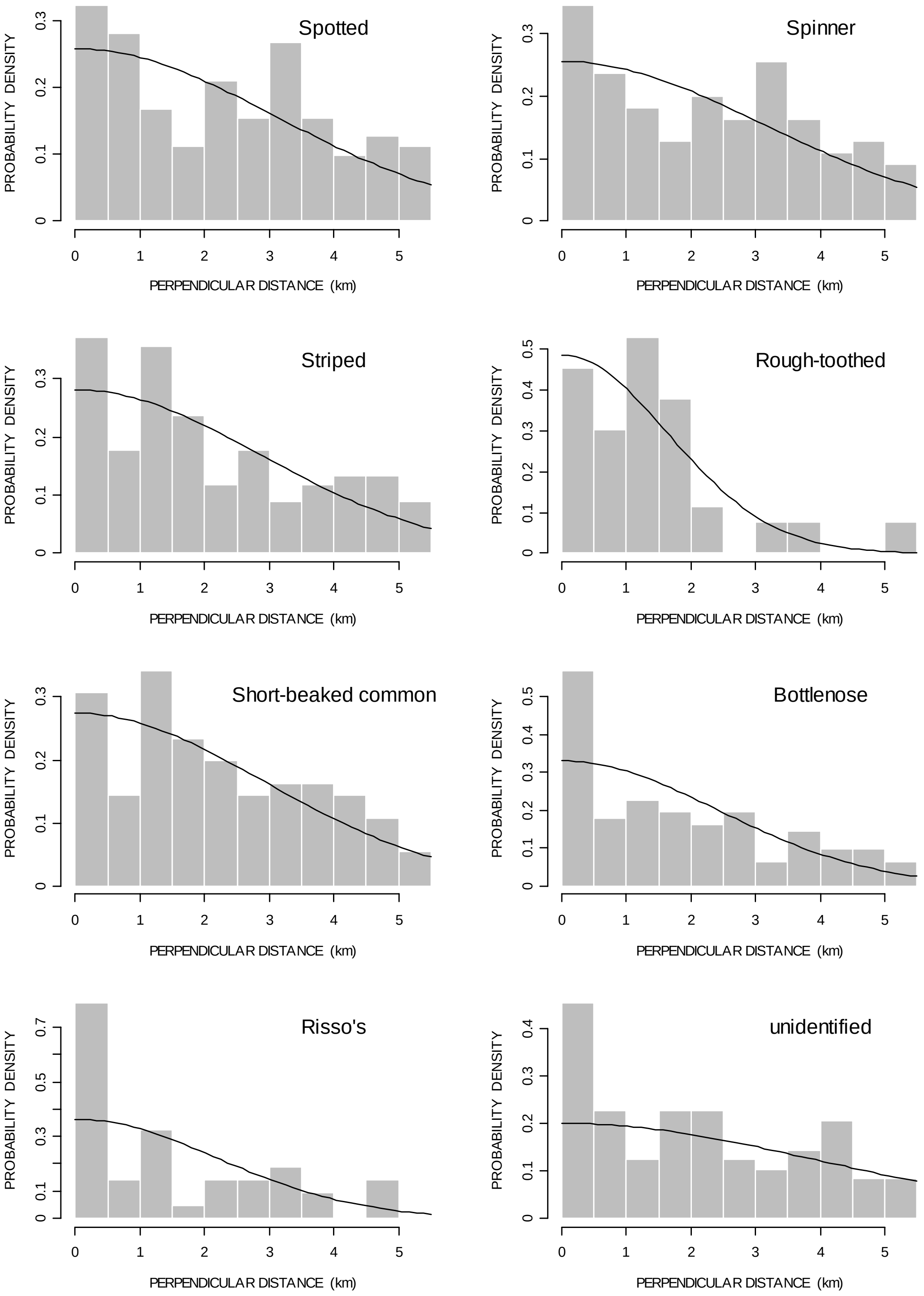

Fig. 12: Histograms of perpendicular distances to sightings of dolphins of different species during STAR06, with half-normal detection functions.

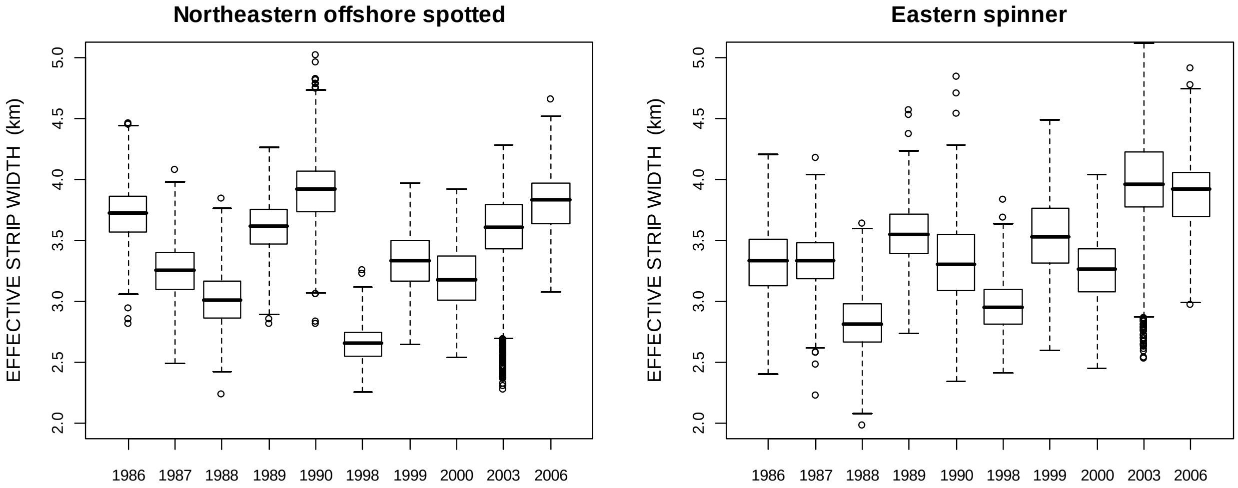

Fig. 13: Bootstrap distributions of pooled effective strip width [1/ $\hat{f}(0)$, eq. 2] by year for northeastern offshore spotted and eastern spinner dolphins. Dark horizontal lines show medians, open boxes first and third quartiles, and dashed vertical lines the range of values within twice the interquartile range.

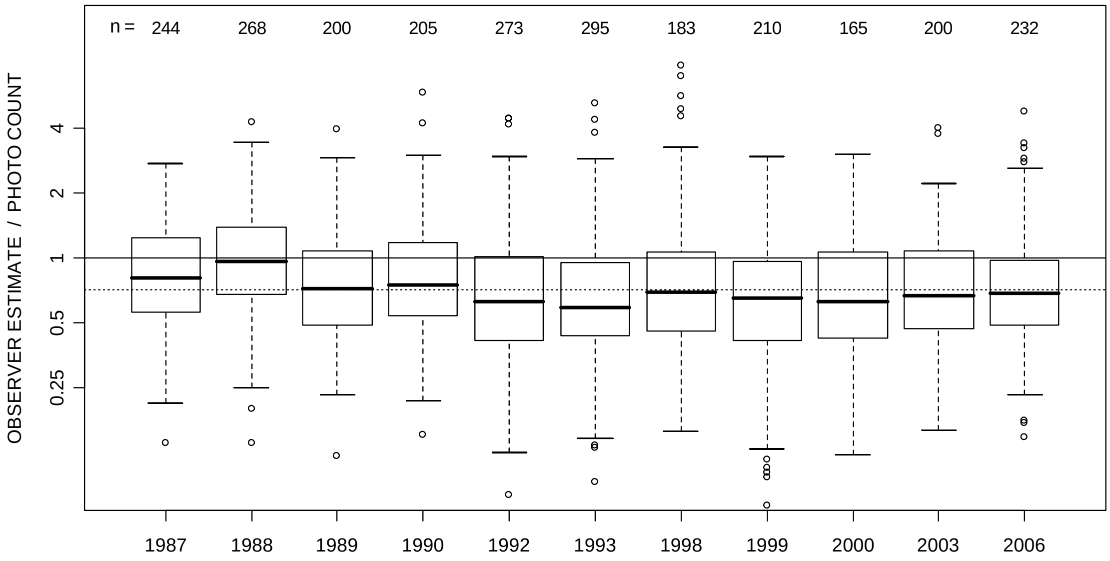

Fig. 14: Distributions of the ratio of an observer's best estimate of school size to the count of dolphins in an aerial photograph of the school, by year. Sample size is given along the top. Note the logarithmic scale, and that calibration photographs were carried out in 1992 and 1993 although abundance estimates are not available in those years. The solid horizontal line indicates estimates equal to the photo count (a ratio of 1.0). The dotted horizontal line is the overall median ratio of 0.71.

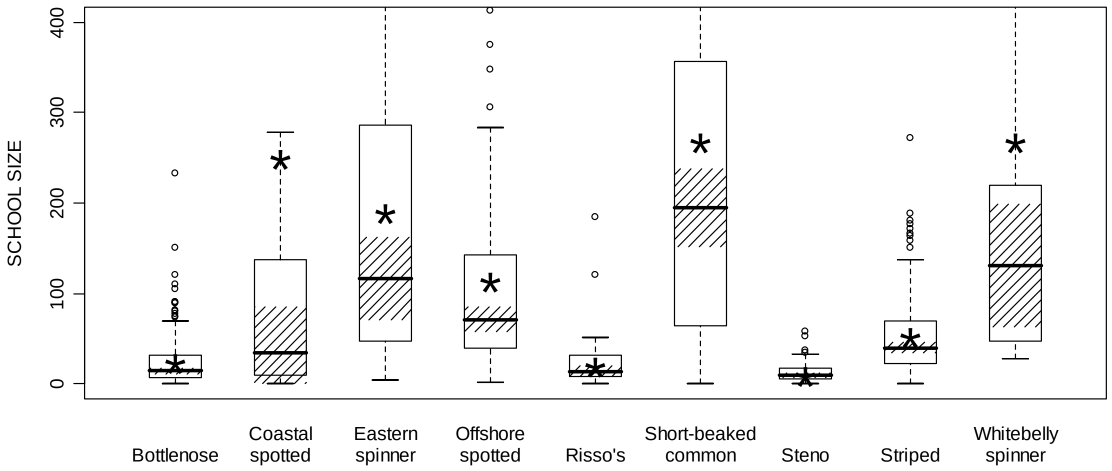

Fig. 15: Distributions of school sizes observed on STAR06 by stock. Means (*), medians (dark horizontal lines), 95% confidence intervals on the medians (hatched boxes), interquartile ranges (open boxes), standard spans (dashed lines), and outliers (circles) are shown for sightings used in abundance estimation. Some outliers are not shown.

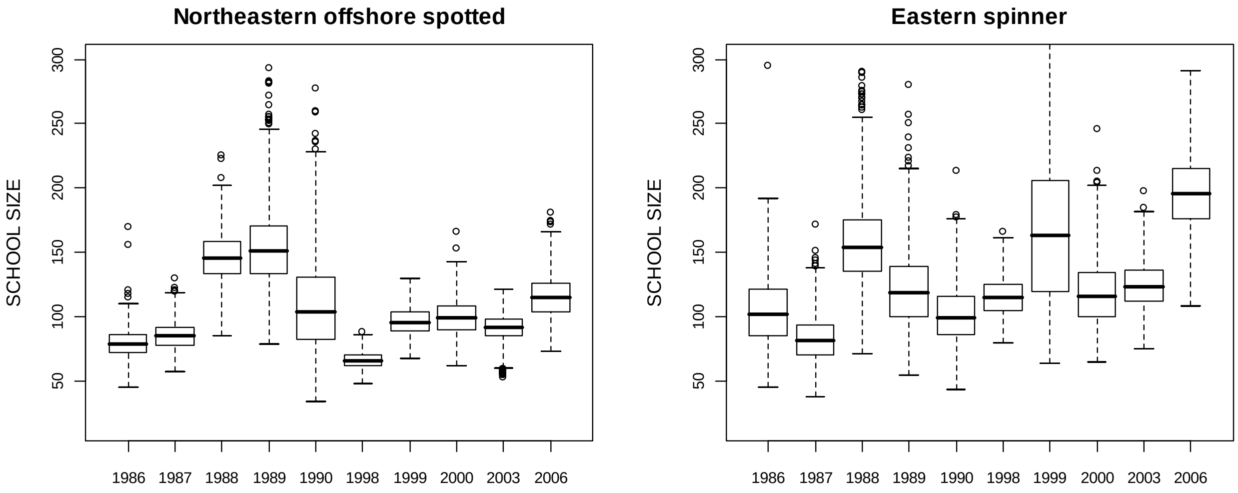

Fig. 16: Bootstrap distributions of pooled expected school size [$\hat{E}(s)$, eq. 3] by year for northeastern offshore spotted and eastern spinner dolphins. Dark horizontal lines show medians, open boxes first and third quartiles, and dashed vertical lines the range of values within twice the interquartile range.

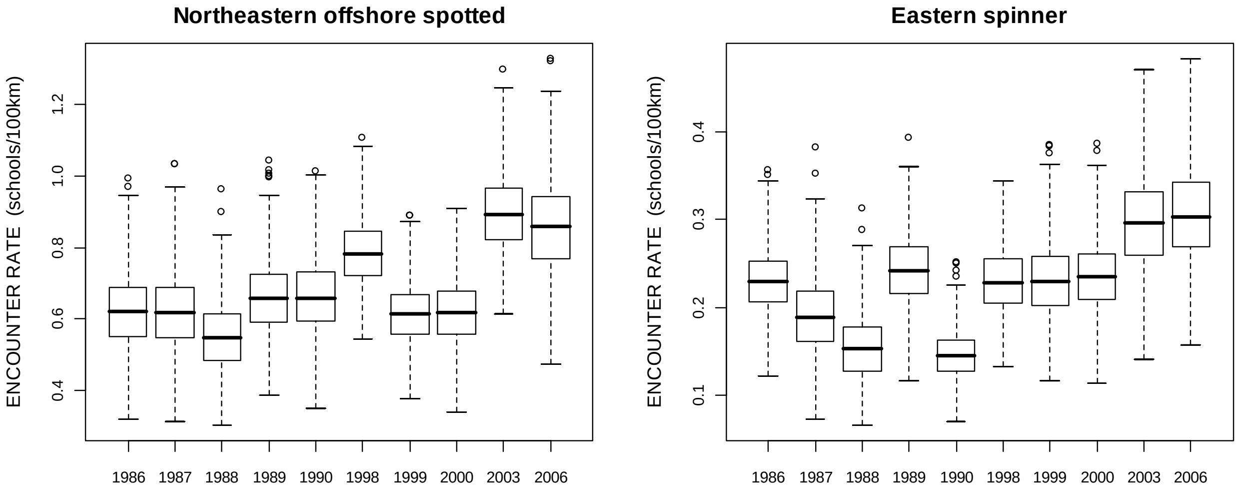

Fig. 17: Bootstrap distributions of pooled encounter rate (schools/100km, $100n/L$, eq. 4) by year for northeastern offshore spotted and eastern spinner dolphins. Dark horizontal lines show medians, open boxes first and third quartiles, and dashed vertical lines the range of values within twice the interquartile range. Note the different ordinate scales.

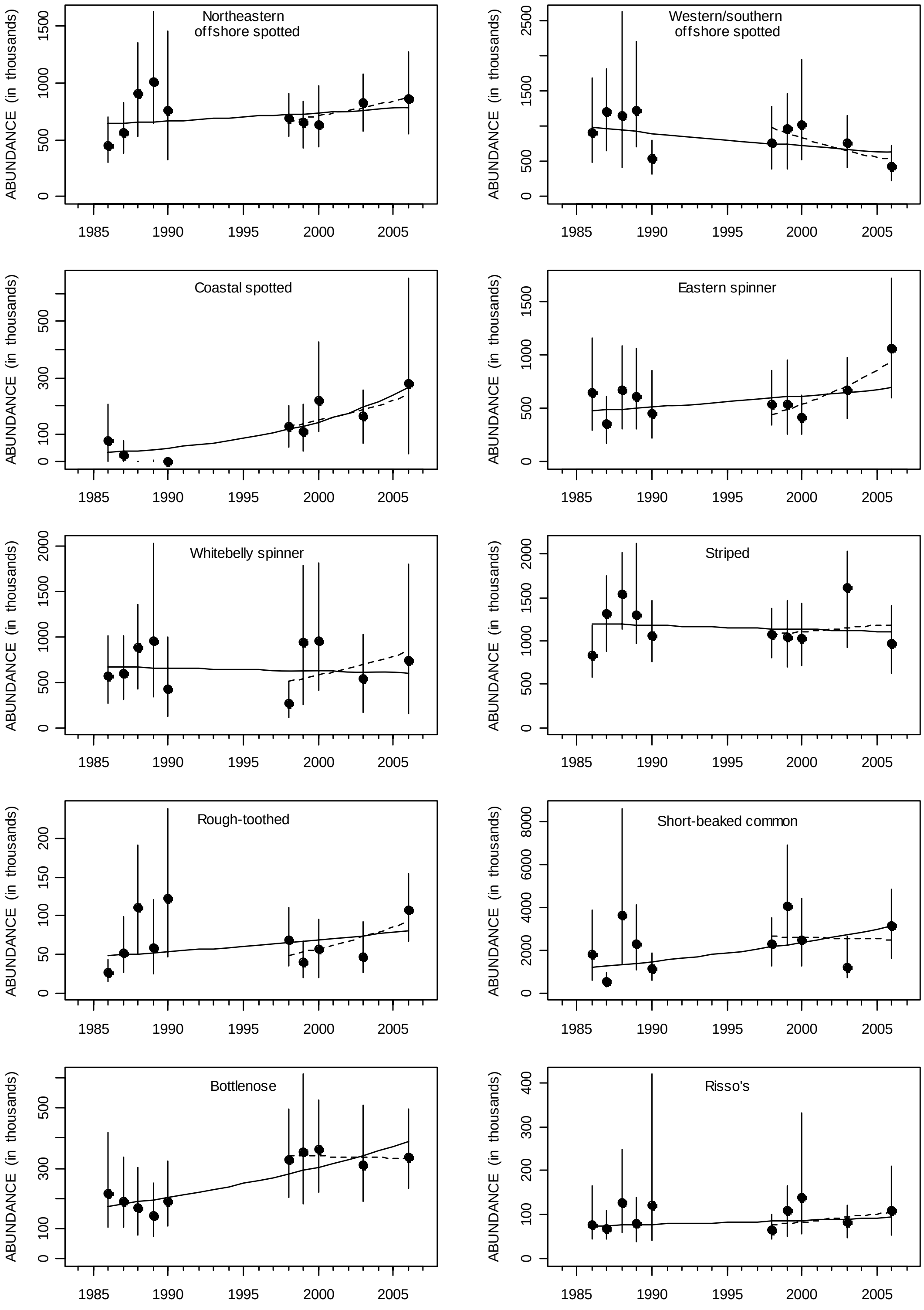

Fig 18: Estimates of abundance for 10 dolphin stocks for 10 surveys between 1986 and 2006. Vertical lines show 95% confidence intervals on the point estimates based on a bootstrap procedure. Solid lines show fit of a model of exponential change from 1986-2006, dashed lines from 1998-2006. Statistics of model fit are summarized in Table 13.

RECENT TECHNICAL MEMORANDUMS

Copies of this and other NOAA Technical Memorandums are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22167. Paper copies vary in price. Microfiche copies cost $9.00. Recent issues of NOAA Technical Memorandums from the NMFS Southwest Fisheries Science Center are listed below:

NOAA-TM-NMFS-SWFSC-412 Updated estimates of mortality and injury of cetaceans in the Hawaii-based longline fishery, 1994-2005.
K.A. FORNEY and D.R. KOBAYASHI
(November 2007)

413 Assessment of the Pacific sardine resource in 2007 for U.S. Management in 2008.
K.T. HILL, E. DORVAL, N.C.H. LO, B.J. MACEWICZ, C. SHOW and R. FELIX-URAGA
(December 2007

414 U.S. Pacific marine mammal stock assessments: 2007.
J.V. CARRETTA, K.A. FORNEY, M.S. LOWRY, J. BARLOW, J. BAKER, B. HANSON, and M.M. MUTO
(December 2007)

415 California current ecosystem survey 2006 acoustic cruise reports for NOAA FSV Oscar Dyson and NOAA FRV David Starr Jordan
G.R. CUTTER, JR., Editor and D.A. DEMER
(January 2008)

416 An assessment of the accuracy and precision of localization of a stationary sound source using a two-element towed hydrophone array.
S. RANKIN, J. BARLOW, and J. OSWALD
(January 2008)

417 A guide to consturcting hydrophones and hydrophone arrays for monitoring marine mammal vocalizations.
J. BARLOW, S. RANKIN, and S. DAWSON
(February 2008)

418 Diet of the striped dolphin, *Stenella coeruleoalba*, in the eastern tropical Pacific ocean.
W.F. PERRIN, K.M. ROBERTSON, and W.A. WALKER
(March 2008)

419 Report of a hydrographic survey of Clipperton Ridge conducted aboard the *David Starr Jordan* during the *Stenella* abundance research cruise 2006.
C. HALL, K.W. ROBERTS, S.M. FINNEY, W.P. MOWITT, D. GOTHAN, and L.T. BALLANCE
(March 2008)

420 Marine mammal data collected during the Pacific islands cetacean and ecosystem assessment survey (PICEAS) conducted aboard the NOAA ship *McArthur II*, July - November 2005.
J. BARLOW, S. RANKIN, A. JACKSON, and A. HENRY
(March 2008)

421 Marine mammal data collected during a survey in the eastern tropical Pacific ocean aboard NOAA ships *David Starr Jordan* and *McArthur II*, July 28 - December 7, 2006.
A. JACKSON, T. GERRODETTE, S. CHIVERS, M. LYNN, S. RANKIN, and S. MESNICK
(April 2008)