PRELIMINARY ESTIMATES OF 1999 ABUNDANCE

OF FOUR DOLPHIN STOCKS

IN THE EASTERN TROPICAL PACIFIC

Tim Gerrodette

Southwest Fisheries Science Center

La Jolla, California

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ABSTRACT

The second in a three-year series of research cruises to estimate dolphin abundance in the eastern tropical Pacific Ocean was carried out from July 28 to December 9, 1999. Estimates of 1999 stock sizes for 4 dolphin stocks (management units) affected by the purse-seine tuna fishery were based on line-transect data collected during this cruise. The study area was designed to include the entire range of northeastern offshore spotted (*Stenella attenuata*), coastal spotted (*S. attenuata graffmani*), and eastern spinner (*S. longirostris orientalis*) dolphins. Searching effort was stratified into a core area where most sightings of dolphins of main interest occurred, and an outer area where fewer sightings occurred. Searching was carried out primarily with pedestal-mounted 25x150 binoculars fitted with azimuth rings and reticles for angle and distance measurements. Bias reduction methods based on aerial photography were applied to observers' estimates of school size. Estimates of dolphin density and abundance for each stock were based on encounter rate and school size estimates within each stratum, while estimates of the detection probability involved some pooling across sighting categories. Variances of abundance estimates were estimated by a bootstrap procedure that included the variance due to model selection at each iteration. Abundance estimated from sightings not identified to stock was prorated among appropriate stocks in proportion, by stratum, to the estimated abundance of those stocks based on identified sightings. Total estimates of 1999 abundance (in numbers of animals) were 73,866 (CV=0.57) for coastal spotted dolphins, 592,423 (CV=0.24) for northeastern offshore spotted dolphins, 710,793 (CV=0.45) for western/southern offshore spotted dolphins, and 338,961 (CV=0.39) for eastern spinner dolphins.

INTRODUCTION

The 1997 International Dolphin Conservation Program Act (Public Law 105-42) directed the National Marine Fisheries Service to determine if the chase and encirclement of dolphins in the purse-seine fishery for tuna in the eastern tropical Pacific (ETP) is having a significant adverse impact on depleted dolphin stocks. As part of this determination, Congress specified that research cruises be undertaken in 1998, 1999, and 2000 to generate new estimates of dolphin abundance.

The results of the second of those cruises are reported here. Summaries of the marine mammal data collected on the 1998 and 1999 cruises are given in (Kinzey et al. 1999, 2000a). Estimates of 1998 abundance of 4 spotted and spinner dolphin stocks were reported in Gerrodette (1999). Methods of data collection and analysis were the same in 1999 as in 1998, and the structure of this report follows the previous one closely. Results are considered preliminary until the final report of the project is issued in 2002.

METHODS

Stocks and stratification

On December 17-18, 1997, the Southwest Fisheries Science Center (SWFSC) convened a technical meeting in La Jolla, California, to discuss the design of the 1998-2000 surveys

(Gerrodette et al. 1998). The participants agreed that line-transect methods similar to those used on surveys from 1986-90 should be continued on the 1998-2000 surveys. Based on additional information about spotted and spinner dolphin distributions, including distributions in both El Niño and non-El Niño conditions, it was also agreed that the boundaries of the study area for the 1998-2000 cruises should be changed slightly.

The dolphin species most affected by the tuna purse-seine fishery are spotted dolphins (*Stenella attenuata*) and spinner dolphins (*S. longirostris*) (Smith 1983, Wade 1993a, b). The species are divided into stocks for management (Dizon et al. 1994). The stocks that have been designated as depleted under the Marine Mammal Protection Act, and which were therefore of primary interest in designing the survey, were the northeastern offshore spotted dolphin, *Stenella attenuata*, north of 5°N and east of 120°W (Perrin et al. 1994), and the eastern spinner dolphin, *Stenella longirostris orientalis* (Perrin 1990). The legal status of the coastal spotted dolphin, *Stenella attenuata graffmani* (Perrin et al. 1985), was uncertain, but since it might also be considered depleted, the survey was designed to produce an estimate of abundance for this stock as well. The outer boundaries of the survey area were drawn well beyond the limits of the target stocks, to be certain to include the entire populations (Gerrodette et al. 1998).

Based on densities of animals and stocks of interest, searching effort was stratified into 2 areas: a core stratum centered on the main stocks of interest, an outer stratum of lower density and effort (Fig. 1). The core stratum roughly corresponds to 2 dolphin stocks of main interest: northeastern offshore spotted and eastern spinner dolphins. 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 along the overall trackline. Search effort in the core stratum was approximately 3.3 times the effort in the outer stratum, per square unit area. Stratum areas, calculated as total area less the areas of islands within the stratum, were 6,242,200 km^2 in the core area and 15,401,200 km^2 in the outer area (Table 1).

The 1999 *Stenella* Abundance Research (STAR) survey was carried out with NOAA Ships *David Starr Jordan* and *McArthur* during the late summer and fall, at the same time as previous surveys. Both ships are oceanographic research vessels which have been used for ETP cetacean surveys for many years. The ships are similar in length (52m and 53m, respectively) and observer eye height (10.7m and 10.4m, respectively). Any differences among ships were further minimized by rotating observers between ships midway through the cruise.

Field methods

Methods of collecting data followed standard protocols for line-transect surveys conducted by the Southwest Fisheries Science Center (Wade and Gerrodette 1993, Barlow 1995, Kinzey et al. 2000b). 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. Each 25X observer scanned from abeam (90° from the trackline) on the side of the vessel where the binoculars were mounted to 10° past the trackline on the opposite side. Together, the two 25X observers thus searched the 180° forward of the ship with a 20E area of overlap near the trackline. The 25X binoculars were fitted with azimuth rings and reticles for angle and distance measurements. Angle and distance measurements made in this way have been checked against radar measurements and found to be accurate (unpub. data). The third observer searched by eye and with hand-held 7X binoculars, covering areas closer to the ship over the whole 180°.

When a marine mammal was sighted, the angle and distance to the sighting were measured, and the third observer entered the data in a portable computer. If the sighting was less than 5.6 km (3 nm) from the trackline, the team went "off-effort" and directed the ship to leave the trackline and to approach the animal(s) sighted. The observers identified the sighting to species or subspecies (if possible) and made group size estimates. Each observer team had at least one observer 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 group sizes and, in the case of mixed-species schools, group composition, independently. The computer was connected to the ship's Global Positioning System, which recorded 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. Sightings and effort in poor conditions (visibility < 4 km or Beaufort >5) were not included, due to very low cetacean sighting rates under these conditions. Sightings and effort within a day were summed; thus, one day of search effort was considered the sampling unit. Due to a variety of factors, numbers of kilometers searched each day were not equal. To reduce heterogeneity in the length of search effort among days, effort on a few days with < 50 km/day was combined with effort on the following day.

This analyis considered 4 dolphin stocks affected by the tuna fishery in the ETP: northeastern offshore spotted, western/southern offshore spotted, coastal spotted, and eastern spinner. As noted above, eastern spinner and northeastern offshore spotted dolphins are designated as depleted under the Marine Mammal Protection Act, while the legal status of coastal spotted dolphins is ambiguous. A determination of the status of western/southern offshore spotted dolphins has not been published; data indicate that the reduction in abundance for this stock has been less than for eastern spinner or northeastern offshore spotted dolphins (Gerrodette and Wade 1995).

Six sighting categories contributed to the abundance estimates of these 4 stocks:

Offshore spotted dolphin	(*Stenella attenuata*)
Coastal spotted dolphin	(*Stenella attenuata graffmani*)
Unidentified spotted dolphin	(*Stenella attenuata*, unidentified subspecies)
Eastern spinner dolphin	(*Stenella longirostris orientalis*)
Unidentified spinner dolphin	(*Stenella longirostris*, unidentified subspecies)
Unidentified dolphin	

Abundance estimation

Estimation of abundance was based on distance sampling (Buckland et al. 1993). Thus, the cruise was designed to sample distances to dolphin schools along a transect, and line-transect methods were used to estimate the density of schools. For each sighting category in each stratum, abundance $\hat{N}$ was estimated by multiplying school density by expected school size $E(S)$ and area A, using the standard line-transect estimator

$$\hat{N} = \frac{n\, f(0)}{2L} E(S)\, A\,,$$

where n = number of sightings, L = search effort (transect length), and $f(0)$ = estimated value of the sighting probability density function evaluated at zero distance from the trackline. For the dolphin schools that were the sampled objects on this survey, the assumption that $g(0)=1$, *i.e.*, that all objects on the trackline are detected, was easily satisfied, because the dolphins occur in large schools, individual dolphins do not have long dive times, and diving is not synchronous among individuals in a school. The assumption of detection before reaction to the vessel was of greater concern. Observation from helicopters has shown that most dolphin schools are detected before they react to the research vessel (Au and Perryman 1982, Hewitt 1985). In addition, there was no consistent indication of a deficit of sightings near the trackline, further supporting the idea that no strong reaction occurred before most dolphin schools were detected.

For reasons of comparability, the analysis closely followed methods used to produce previous estimates of dolphin abundance in the ETP (Wade and Gerrodette 1993, Wade 1994, Gerrodette 1999). The estimation was carried out using Distance, version 3.5, Release 4 (Thomas et al. 1998). After being checked and edited, data were extracted and formatted for import into Distance using a Fortran program written for the purpose. Variance of each abundance estimate was estimated using the bootstrap procedure within Distance (999 resamplings, using days as the sampling unit), which included the variance due to model selection at each iteration.

<u>Encounter rate</u>

Within each stratum, encounter rate was estimated as the number of dolphin school sightings divided by the total distance travelled while in on-effort searching mode.

<u>Detection function</u>

For modelling the probability of detection, Distance uses the concept of a key function with an adjustment function (Buckland et al. 1993). For each analysis, the histograms of dolphin school sighting frequency against perpendicular distance were first examined in order to select a truncation distance which eliminated long tails to the distribution. This procedure is recommended to provide more accurate modelling of $f(0)$ (Buckland et al. 1993). Four key/adjustment function pairs, with up to 2 parameters in the adjustment function of each pair, were used to model the data in each analysis: half-normal/cosine, half-normal/simple polynomial, uniform/cosine, and hazard-rate/Hermite polynomial. Distance provides a variety of tools by which to gauge the model fit, including histograms, χ^2 goodness-of-fit tests, likelihood, Bayes Information Criterion, and Akaike's Information Criterion (AIC). Provided the fit was reasonable, the model with the lowest AIC was selected as the most parsimonious model in each analysis (Burnham and Anderson 1998).

As noted in the Results below, pooling across sighting categories or geographic strata was necessary for most stocks to obtain sufficient sample size for *f*(0) estimation.

School size

A sighting consisted of a school of dolphins; therefore, to estimate numbers of animals, estimates of school size were needed. School size was estimated separately for each stratum. In the case of mixed schools, the school size of a sighting category was calculated as the mean proportion of the category estimated by the observers for that school times the total school size. Because estimating dolphin school size is a difficult but critical part of estimating abundance, the SWFSC has put considerable effort into developing methods that produce unbiased estimates of school size (Gerrodette and Perrin 1991, Gilpatrick 1993, Barlow et al. 1998). Three kinds of bias correction procedures were applied to obtain the best possible estimates of group size.

First, calibration factors (regression coefficients) were used for each observer to correct for that observer's tendency to under- or overestimate dolphin school size. Observers made estimates of school size independently, refraining from discussing their estimates with other observers. Individual calibration factors were based on comparing observers' estimates of school size with high resolution aerial photographs of the same schools taken from a helicopter (Gilpatrick 1993). Direct calibration was used for observers for whom calibration factors from previous cruises between 1987 and 1993 could be calculated. In this procedure, an observer's best, high and low estimates of each school were combined according to weightings that gave the least variable estimates of school size for that observer, and this weighted estimate was adjusted by multiple regression coefficients specific for that observer (Gerrodette and Perrin 1991, Barlow et al. 1998). Indirect calibration was used for observers for whom direct factors were not available. In this procedure, an observer's best school size estimates from the 1999 cruise were adjusted by coefficients estimated by regressing that observer's estimates against the corrected estimates made by observers for whom direct calibration factors were available (Barlow et al. 1998).

Second, the school size for each sighting was estimated as a weighted average of all the available estimates for a sighting (typically 3). For direct calibration, we used as weights the inverses of the mean of the squared differences between the observer's calibrated estimates and the aerial photographic estimates. For indirect calibration, we used as weights the inverses of the mean of the squared differences between the observer's calibrated estimates and the other observers' calibrated estimates as weights. The purpose of using a weighted average was to give more weight to the estimates of observers whose estimates were generally more accurate and more precise. The application of calibration factors to observers' estimates together with the weighted averaging of these calibrated estimates has been shown to reduce bias and improve precision in the estimation of dolphin school sizes (Barlow et al. 1998).

Third, the logarithms of all school size estimates for a sighting category were regressed against the detection function $g(x)$, and, if this regression was significant at the $\alpha = 0.15$ level, the regression estimate of school size at $g(0)$, rather than the observed mean, was used as the expected school size (Buckland et al. 1993). This procedure within the program Distance reduces bias that arises when there is a tendency to detect only larger schools at longer distances from the ship. When this tendency is present, the observed mean school size is too large (*i.e.*, is positively biased).

Proration of unidentified sightings

Not all sightings could be identified to stock level with certainty. The first step in dealing with unidentified sightings was to assign unidentified sightings that were recorded as "probable" sightings of an identified sighting category to that sighting category. The second step was to prorate the abundance represented by the remaining unidentified sightings to stock. There were three kinds of unidentified sightings that had to be prorated to the following stocks: unidentified spotted dolphins to northeastern offshore spotted, western/southern offshore spotted, and coastal spotted dolphins; unidentified spinner dolphins to eastern spinner dolphins; and unidentified dolphins to all 4 stocks. The abundance represented by unidentified sightings was estimated in the same way as for identified sighting categories, and this abundance was then prorated among appropriate stocks in proportion, by stratum, to the estimated abundance (from identified sightings) of those stocks. In some cases, this meant estimating the abundance of sighting categories not covered in this report. For example, to prorate unidentified dolphin abundance in the core stratum, estimates of abundance in the core stratum were needed for coastal spotted dolphins, northeastern offshore spotted dolphins, eastern spinner dolphins, and an aggregate estimate of abundance for the other 17 sighting categories that could be included in the category "unidentified dolphin."

Total abundance estimation

Total abundance N_{total} for each stock was estimated by adding the appropriate sub-estimates from different strata and from prorated unidentified sightings. The coefficients of variation (CV) of the total abundance estimates were estimated by adding bootstrap variances of the sub-estimates, allowing for correlation when data had been pooled for $f(0)$ estimation. That is, for each stock in stratum or sighting category i,

$$\hat{N}_{total} = \sum_{i=1}^{s} \hat{N}_i \,,$$

$$CV(\hat{N}_{total}) = \frac{\left[\sum_{i=1}^{s} \operatorname{var}(\hat{N}_i) \right]^{1/2}}{\sum_{i=1}^{s} \hat{N}_i}$$ when estimates were independent, and

$$CV(\hat{N}_{total}) = \frac{\left\{ f^2 \sum_{i=1}^{r} \text{var}(R_i S_i) + \left[\sum_{i=1}^{r} (R_i S_i) \right]^2 + \sum_{i=r+1}^{s} \text{var}(\hat{N}_i) \right\}^{1/2}}{\sum_{i=1}^{s} \hat{N}_i}$$

when *r* of the *s* sub-estimates shared some data for estimation of $f = f(0)$ and the remaining $s - r$ sub-estimates did not share data for estimation of *f*. Encounter rate estimates $R = n/L$ and expected school size estimates $S = E(S)$ were made independently for each of the *r* sub-estimates in any case. This may have slightly overestimated the value of $CV(\hat{N}_{total})$ in some cases where the sharing of data was only partial. On the other hand, the calculation of $CV(\hat{N}_{total})$ did not include the variance of proration factors.

The 95% confidence intervals of the total estimates of abundance were calculated from the CVs of the estimates, assuming a log-normal error distribution (Burnham et al. 1987), as

$$\hat{N}_{lower} = \hat{N}_{total} / C ,$$

and $$\hat{N}_{upper} = \hat{N}_{total} \cdot C ,$$

where $$C = \exp\left\{ z_{.975} \left[\ln\left(1 + CV^2(\hat{N}_{total})\right) \right]^{1/2} \right\},$$

and $z_{.975} = 1.96$ is the upper 2.5 percentile of the normal distribution.

RESULTS

Transects, sightings and effort

The ships departed San Diego on July 28 and returned December 9, 1999. The cruise was carried out as designed, except that Colombia did not grant research clearance and therefore waters in the Colombian EEZ were avoided. A good geographic distribution of about 30,000 km of search effort was obtained (Figs. 2-4). Restricting effort to conditions of Beaufort < 6 and visibility > 4 km resulted in a loss of 1.0% of the effort and 0.5% of the sightings. Under these conditions, there were 17,456 km of search effort in the core stratum and 12,241 km in the outer (Table 1). After combining a few days with <50 km of effort, the number of samples (transect-days) was 196 days, 121 in the core stratum and 75 in the outer (Table 1).

There were totals of 181 spotted and 110 spinner dolphin school sightings (Table 1). As expected, most sightings of spotted (Fig. 2) and spinner (Fig. 3) dolphins occurred in the core stratum. The number of sightings in each of the 6 sighting categories varied by stratum, reflecting the geographic distribution of the stocks (Table 2). A large number of unidentified dolphin sightings was recorded (Fig. 4, Table 2). An unidentified dolphin sighting could potentially be any of a number of species, including spotted and spinner dolphins. Unidentified dolphin sightings were usually small groups of animals seen at a large radial distance from the ship that subsequently could not be relocated, or groups seen at >5.6 km from the trackline that were not approached for identification. Although the number of unidentified dolphin sightings was large, the contribution of these sightings to total abundance was not large because group size was small, and because only a fraction of the estimated unidentified dolphin abundance was assigned to the stocks of interest.

Parameter estimates

Estimates of school encounter rates, estimated school sizes, *f*(0), and effective strip widths [1/*f*(0)] are shown by sighting category and stratum in Table 3. All estimates of encounter rate and school size were calculated by stratum. For *f*(0) estimation, many of the stocks of interest had too few sightings to model the detection function adequately, and pooling across strata or sighting categories was required. Specifically, referring to Table 2, the 22 sightings of coastal spotted schools, the 32 sightings of offshore spotted schools in the outer stratum, and the 17 sightings of unidentified spotted schools in the core stratum were each (individually) combined with the 110 sightings of offshore spotted schools in the core stratum for estimation of *f*(0). For spinner dolphins, all 85 sightings of spinner dolphin schools in the core area and all 25 sightings of spinner dolphin schools in the outer area were used for eastern and unidentified spinner *f*(0) estimation in the core and outer areas, respectively. All unidentified dolphin sightings were pooled to estimate a single effective strip width for this sighting category. With this pooling, the modelling of detection probability was adequate for all categories (Fig. 5). None of the detection function models differed significantly from the observed frequency of sightings, as measured by a χ^2 goodness-of-fit test at the α=0.05 level. Truncation distance varied among categories from 5 to 6 km.

Abundance of coastal spotted dolphins

There were 22 sightings of coastal spotted dolphin schools, all in the core stratum. The expected school size was 50 dolphins and they were seen at a rate of 1.26 per 1000 km (Table 3). The detection function, which included offshore spotted dolphins in the core area, is shown in Fig. 5A. These figures gave an estimate of 60,906 (CV=0.67) coastal spotted dolphins in the core stratum (Table 4). There were an estimated 83,092 unidentified spotted dolphins in the core stratum, of which 11.4% (9,446, CV=0.58) were prorated to the coastal stock. There were an estimated 116,920 unidentified dolphins in the core stratum, of which 3.0% (3,514, CV=0.32) were prorated to the coastal stock. The total estimated abundance of coastal spotted dolphins was 73,866 with a CV of 0.568 (Table 4).

Abundance of northeastern offshore spotted dolphins

The core stratum included most of the area where the northeastern (NE) stock of offshore spotted dolphins is found. Within the core area, offshore spotted dolphins were encountered at a rate of 6.19 schools per 1000 km, and the expected school size was 82.5 dolphins (Table 3). The detection function based on 108 sightings is shown in Fig. 5B. There were an estimated 474,870 (CV=0.21) dolphins in the core stratum (Table 4). In the outer stratum, offshore spotted dolphins were mostly of the western/southern stock, but 2.3% of the estimated offshore spotted abundance of 712,720, based on the area in the northern part of the outer stratum east of 120°W, was allocated to the NE stock (16,179, CV=0.46). Unidentified spotted dolphin sightings in the core stratum (detection function Fig. 5D) led to an estimated abundance of 83,092, of which 88.6% (73,646, CV=0.58) were of the NE offshore spotted stock. There were an estimated 116,920 unidentified dolphins in the core stratum, of which 23.4% (27,397, CV=0.32) were prorated to the NE stock. Finally, unidentified dolphin sightings in the outer stratum contributed an additional 331 dolphins to the estimate. The total estimated abundance of northeastern offshore spotted dolphins was 592,423 with a CV of 0.239 (Table 4).

Abundance of western/southern offshore spotted dolphins

The outer stratum includes the main area of the western/southern (WS) stock of offshore spotted dolphins; by definition of the stock (Perrin et al. 1994), WS offshore spotted dolphins are not found in the core stratum. There were 32 offshore spotted school sightings in the outer stratum, an encounter rate of 2.61 schools per 1000 km, and an expected school size of 118 dolphins (Table 3). The detection function, which included offshore spotted sightings in the core stratum, is shown in Fig. 5C. Based on identified sightings, the abundance of the WS offshore spotted stock in the outer stratum was estimated to be 696,551 (CV=0.46) (Table 4). This was 97.7% of the total offshore spotted abundance in the stratum, a small part being allocated by area to the NE offshore spotted stock. Of the estimated 169,680 unidentified dolphins in the outer stratum, 8.4% (14,242, CV=0.48) were estimated to be WS offshore spotted animals. The total estimated abundance of western/southern offshore spotted dolphins was 710,793 with a CV of 0.450 (Table 4).

Abundance of eastern spinner dolphins

Eastern spinner dolphins are a subspecies of spinner dolphin with a distinct external appearance, found primarily in the core stratum of this survey. There were 70 sightings of eastern spinner schools, all in the core stratum (Table 2). The detection function is shown in Fig. 5E. Expected school size was 99.3 dolphins, and these schools were encountered at a rate of 3.90 per 1000 km (Table 3). Based on identified eastern spinner sightings, there were an estimated 319,470 (CV=0.38) dolphins in the core stratum and none in the outer stratum (Table 4). There were only a few unidentified spinner sightings in each stratum (Table 2), so this sighting category contributed only 1,059 dolphins to the eastern spinner estimate from the core stratum, and no dolphins from the outer stratum. For unidentified dolphins, of the estimated 116,920 unidentified dolphins in the core stratum, 15.8% (18,432, CV=0.32) were estimated to be eastern spinners (Table 4). The total estimate of abundance for eastern spinner dolphins was 338,960 with a CV of 0.385 (Table 4).

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Table 1. Eastern tropical Pacific study area, survey effort, number of samples, and number of sightings of spotted and spinner dolphins, total and by stratum, during on-effort periods in conditions of Beaufort < 6 and visibility > 4 km during the 1999 STAR cruise.

	Core	Outer	Total
Area (1000 km^2)	6,242.2	15,401.2	21,643.4
Effort (km)	17,456	12,241	29,697
Samples (transect-days)	121	75	196
Spotted dolphin sightings	149	32	181
Spinner dolphin sightings	85	25	110

Table 2. Number of sightings of 6 sighting categories, by stratum, during on-effort periods in conditions of Beaufort < 6 and visibility > 4 km, before truncation for *f*(0) estimation.

Stratum	Sighting category					
	Coastal spotted	Offshore spotted	Unid. spotted	Eastern spinner	Unid. spinner	Unid. dolphin
Core	22	110	17	70	3	146
Outer	0	32	0	0	1	35

Table 3. Parameter estimates for line-transect analyses, by sighting category and stratum. n = number of dolphin school sightings after truncation, R = school encounter rate in schools/1000 km, $f(0)$ = probability density at the trackline in km^{-1}, ESW = effective strip half-width in km, S = expected school size, CV=coefficient of variation.

Sighting category	Stratum	n	R	CV(R)	$f(0)$	ESW	CV($f(0)$)	S	CV(S)
Coastal spotted	Core	22	1.26	0.500	0.310	3.22	0.047	49.9	0.366
Offshore spotted	Core	108	6.19	0.154	0.298	3.35	0.084	82.5	0.109
Offshore spotted	Outer	32	2.61	0.297	0.301	3.33	0.072	117.8	0.342
Unidentified spotted	Core	17	0.97	0.419	0.274	3.65	0.077	99.8	0.243
Eastern spinner	Core	68	3.90	0.205	0.265	3.78	0.106	99.3	0.175
Unidentified spinner	Core	2	0.12	0.741	0.265	3.78	0.106	14.5	0.241
Unidentified spinner	Outer	1	0.08	1.012	0.327	3.06	0.176	10.0	0.000
Unidentified dolphin	Core	96	5.50	0.111	0.669	1.49	0.237	10.2	0.173
Unidentified dolphin	Outer	23	1.88	0.203	0.669	1.49	0.237	17.5	0.326

Table 4. Estimates and sub-estimates of 1999 abundance for 4 ETP dolphin stocks, with coefficients of variation (CV). An entry of zero means an estimate of zero dolphins, while a blank means an estimate does not apply.

Level of identification	Source of estimate	Coastal spotted Estimate	Coastal spotted CV	NE offshore spotted Estimate	NE offshore spotted CV	WS offshore spotted Estimate	WS offshore spotted CV	Eastern spinner Estimate	Eastern spinner CV
Stock	identified in core stratum	60,906	0.666	474,870	0.207			319,470	0.379
	identified in outer stratum	0		16,179	0.459	696,551	0.459	0	
Species	unid. spotted in core stratum	9,446	0.579	73,646	0.579				
	unid. spinner in core stratum							1,059	0.767
	unid. spinner in outer stratum							0	
Family	unid. dolphin in core stratum	3,514	0.324	27,397	0.324			18,432	0.324
	unid. dolphin in outer stratum	0		331	0.483	14,242	0.483	0	
	Total estimate	**73,866**	0.568	**592,423**	0.239	**710,793**	0.450	**338,961**	0.385
	Lower 95% confidence limit	26,202		373,259		306,346		163,564	
	Upper 95% confidence limit	208,237		940,274		1,649,203		702,443	

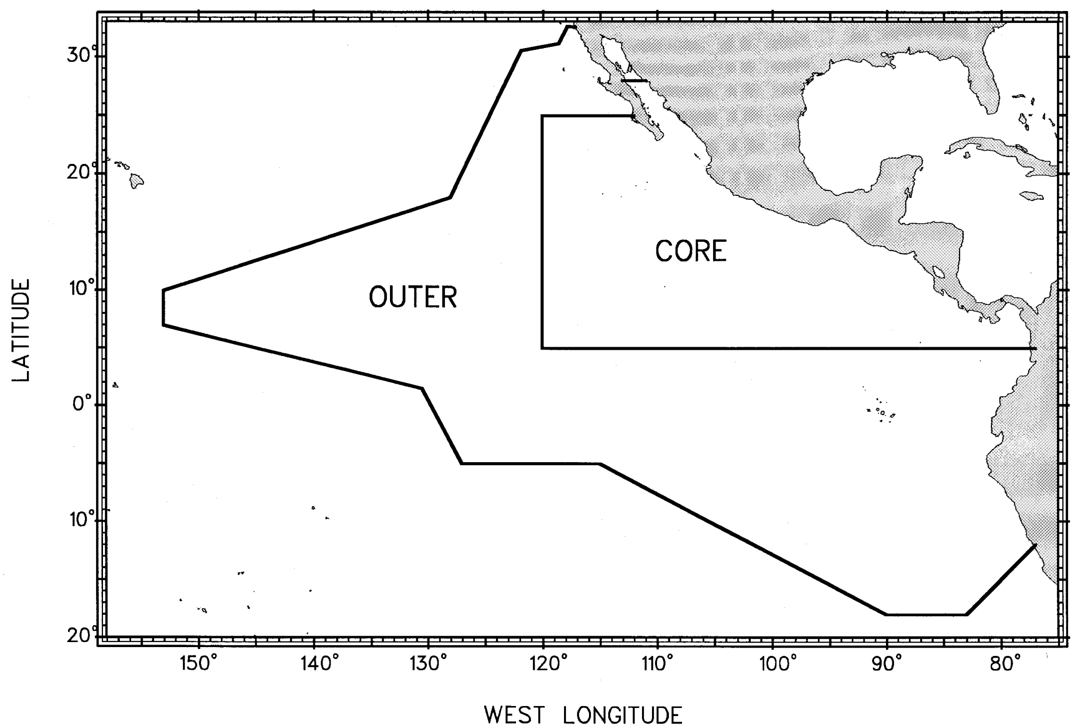

Fig 1. Sampling strata for the 1999 STAR survey.

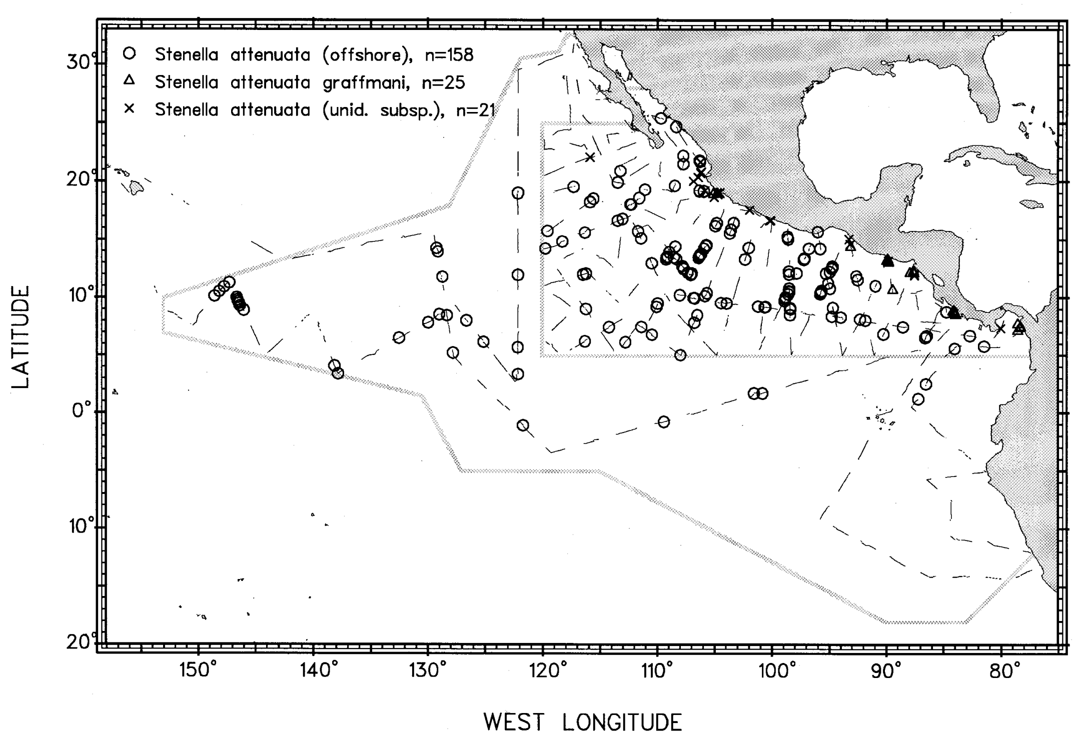

Fig. 2. Search effort and sightings of spotted dolphins for the 1999 STAR survey during on-effort periods in Beaufort < 6 and visibility > 4 km.

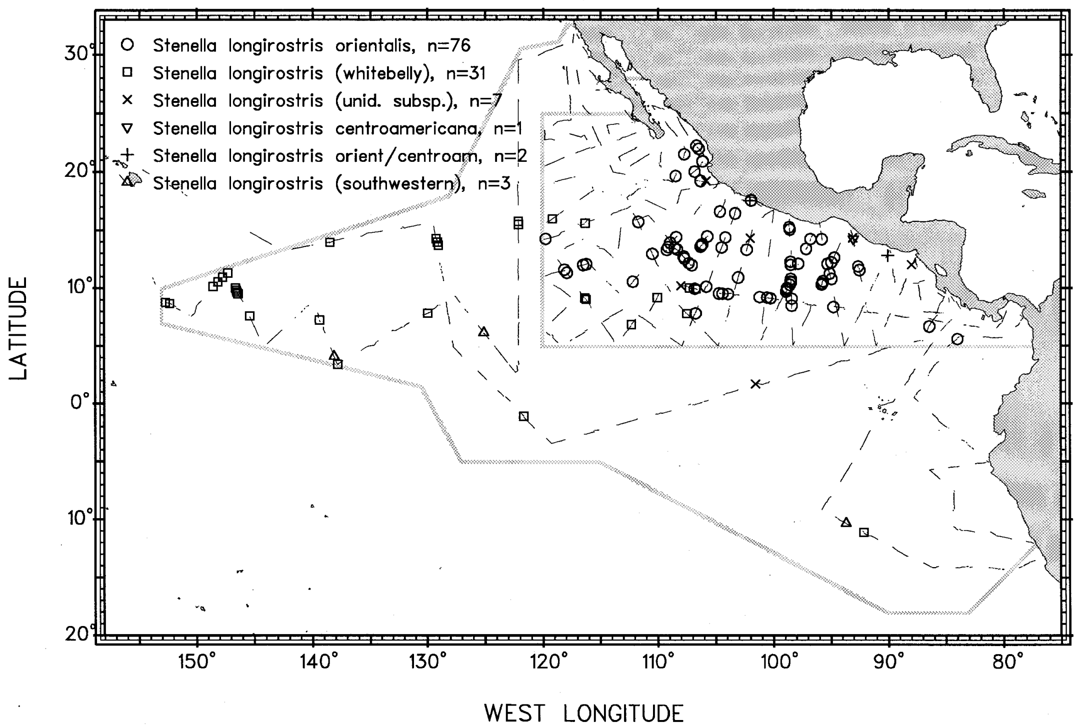

Fig. 3. Search effort and sightings of spinner dolphins for the 1999 STAR survey during on-effort periods in Beaufort < 6 and visibility > 4 km.

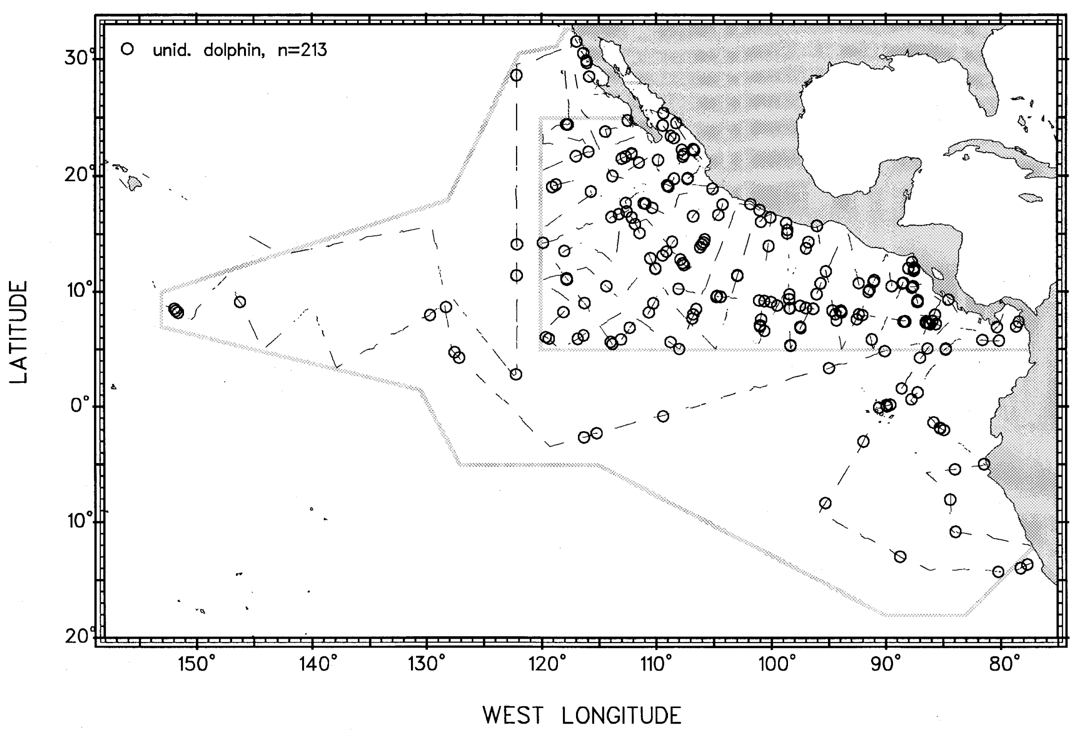

Fig. 4. Search effort and sightings of unidentified dolphins for the 1999 STAR survey during on-effort periods in Beaufort < 6 and visibility > 4 km.

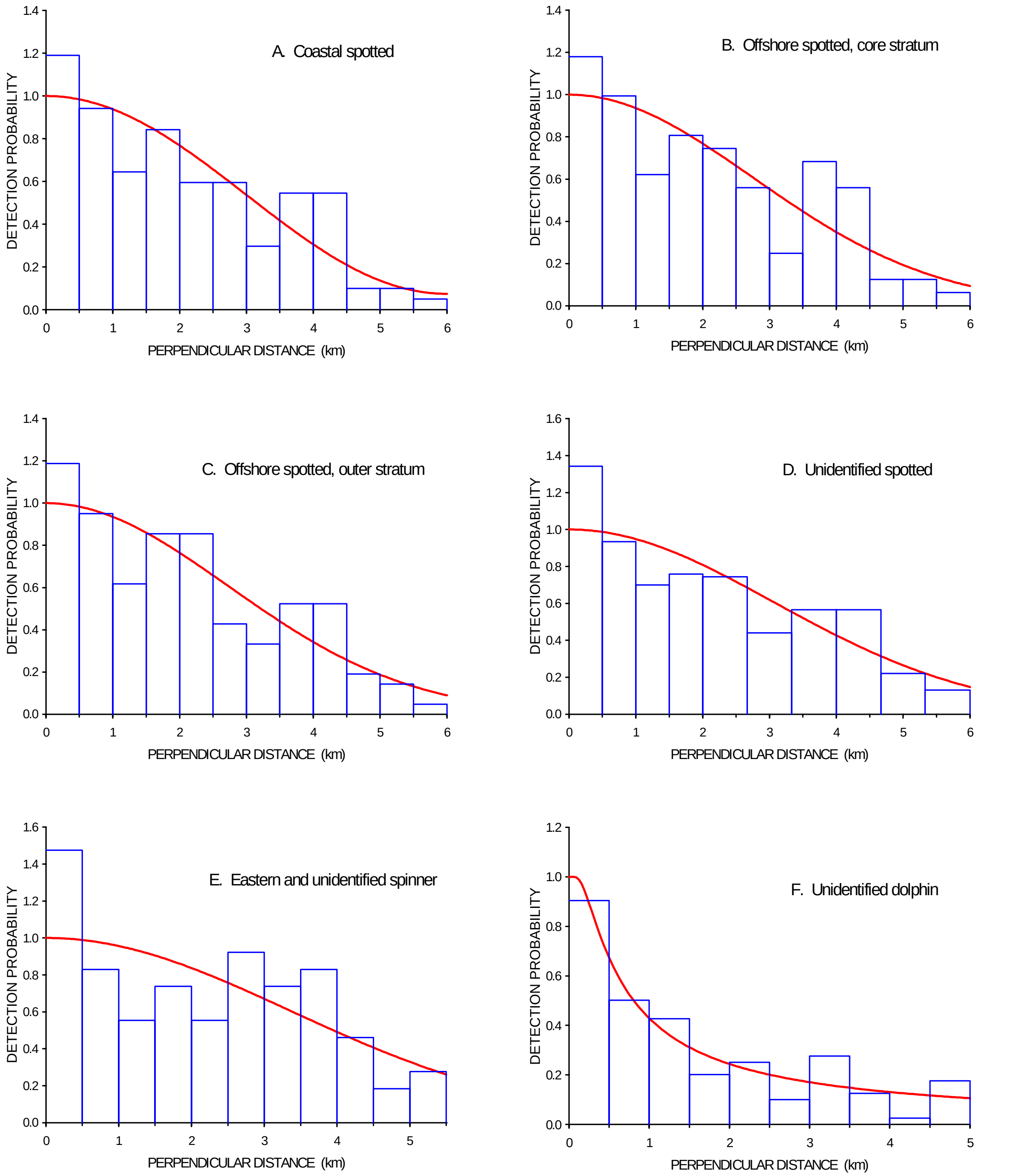

Fig. 5. Detection probability functions (curved lines) and sighting frequency histograms (bars) for spotted, spinner, and unidentified dolphins used in the 1999 abundance estimation. See text for further details. The histograms show relative frequency of sightings, not probabilities.