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Relative Abundance of Dolphins Associated with Tuna in the Eastern Tropical Pacific in 1990 and Trends Since 1975, Estimated from Tuna Vessel Sightings Data

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ABSTRACT

The relative abundance of eastern tropical Pacific stocks of three dolphin species is estimated from tuna vessel data for 1990, using the methods described by Buckland and Anganuzzi (1988), Anganuzzi and Buckland (1989) and Buckland *et al.* (In press). There is little evidence of trends in population size in recent years, as determined by five-year tests for trend. The more powerful smoothing method of Smith (1988) and Buckland *et al.* (In press) is used to assess recent patterns of change.

KEYWORDS: SPOTTED DOLPHIN; SPINNER DOLPHIN; SMALL CETACEANS; EASTERN TROPICAL PACIFIC; INCIDENTAL CAPTURE; SURVEY-SHIPBOARD; ASSESSMENT.

INTRODUCTION

Incidental mortality of dolphins in the eastern tropical Pacific caused by the tuna fishery has probably been sufficient to affect abundance of stocks of three species of dolphin, the spotted dolphin *Stenella attenuata*, the spinner dolphin *S. longirostris* (Smith, 1983) and the common dolphin *Delphinus delphis*. To monitor possible effects of incidental mortality on the size of dolphin stocks, several attempts to estimate abundance have been made, usually applying line transect methodology to data collected from either tuna vessels or research vessels or both. Holt and Powers (1982) and Holt (1985; 1987) considered analyses of research vessel data alone, and of tuna vessel data combined with research vessel data. More recently, Holt and Sexton (1989; 1990a; b) analysed data from research vessels alone. Tuna vessel data alone were analysed by Hammond and Laake (1983), Polacheck (1987), Buckland and Anganuzzi (1988) and by Anganuzzi and Buckland (1989). We present estimates for 1990 obtained from the procedures of Anganuzzi and Buckland (1989). The estimates are not absolute abundance estimates, but relative estimates designed to monitor trends over time.

METHODS

The estimation procedure is built around line transect methodology. The number of dolphins in an area for a given stock and year is estimated by

$$\hat{N} = A.\hat{s}\cdot\hat{D}$$

where A is the size of the area, $\hat{s}$ is the estimated average school size for the stock in area A and $\hat{D}$ is the estimated density of schools in area A.

The line transect method provides the estimate $\hat{D}$ (Burnham *et al.*, 1980). If schools farther than a distance w from the trackline are discarded from the analyses, then

$$\hat{D} = [n.\hat{f}(0)]/2L$$

where n is the number of schools detected in the area that are within the truncation distance w, $\hat{f}(0)$ is the estimated probability density function of the n perpendicular distances, evaluated at perpendicular distance zero and L is the total length of transect in nautical miles within the area.

If we define the encounter rate E to be the expected number of sightings detected within w of the trackline per n.mile of search, then its estimate is given by

$$\hat{E} = n/L$$

Hence $\hat{D} = 0.5\ \hat{E}.\hat{f}(0)$

and $\hat{N} = 0.5\ \hat{E}.\hat{f}(0).\hat{s}.A$

To estimate the different components of this estimator, separate stratification schemes are applied for encounter rate, effective search width and school size, following the procedures described in Anganuzzi and Buckland (1989). The hazard-rate model is fitted to the distance data, to yield the estimate $\hat{f}(0)$, and a nonparametric bootstrap technique is used to obtain the variances of the estimates. Tests for linear trends in the annual estimates over five-year periods are carried out (Buckland and Anganuzzi, 1988).

To estimate underlying trends in abundance, we smooth the annual estimates using the methods of Bucklandet *al.* (In press). Various smoothing methods such as moving averages, running medians and polynomial regression have been investigated (Smith, 1988). We chose a compound running median method known as '4253H, twice' (Velleman and Hoaglin, 1981). Using this method, the time series is smoothed using a 4–period running median, which is in turn smoothed by a 2-period running median, smoothed again by a 5-period running median, then by a 3-period running median. The end points of the resultant time series are estimated and the series is then smoothed by a 3-year weighted moving average. The residuals (differences between the smoothed and unsmoothed estimates) are smoothed by the same method and the smoothed residuals are then added to the smoothed time series to give the final smoothed time series. The advantage of using running medians is that the magnitude of an extreme estimate does not affect the resultant smoothed time series. The smoothing procedure can perform poorly

Table 1

Search effort and number of sightings (after smearing and truncation), 1990.

Species and stock	Number of sightings	Area of stock (1000nm^2)	Search effort (1000nm)
Spotted dolphin			
N. offshore	3,087	3,797	346
S. offshore	73	1,414	19
Spinner dolphin			
Eastern	802	2,267	299
Whitebelly	570	4,195	256
Common dolphin			
Northern	80	615	49
Central	192	2,187	288
Southern	37	842	29

at the start and end of a sequence of estimates. The first and last smoothed estimates are therefore omitted from our results.

Nonparametric bootstrap replicates were generated as described by Anganuzzi and Buckland (1989), and the smoothing procedure of Buckland *et al.* (In press) was applied to each replicate in turn. The smoothed estimates at each time point were ordered, and an 85% confidence interval for relative abundance in each year obtained by the percentile method. The confidence level was selected such that estimates for two years are not significantly different at the 5% level if their respective 85% confidence intervals overlap (Buckland *et al.*, In press). The test assumes independence between smoothed estimates for different years; given the strong correlation in the smoothed estimates between successive years, it is unlikely to detect a large change between adjacent years.

RESULTS

Table 1 shows the number of nautical miles of search effort by tuna vessels with observers on board and the number of sightings made during searching periods for 1990. These data do not include cruises discarded to reduce biases (see Buckland and Anganuzzi, 1988). Also shown are the sizes of stock areas, defined by the Status of Porpoise Stock (SOPS) boundaries determined by Au *et al.*, 1979, with two exceptions. The stock area for southern offshore spotted dolphins was found to be unsatisfactory and modifed by Anganuzzi *et al.* (1991), and Perrin *et al.* (In press) recommended that the northern and southern whitebelly stocks of spinner dolphin be considered a single stock. Unsmoothed relative abundance estimates for all stocks are listed in Table 2. Also given are estimates obtained from pooling data for stocks that are generally not differentiable in the field.

Spotted dolphin

Fig. 1 indicates that abundance of the northern offshore stock of spotted dolphin has been more or less stable since 1985. In the last five years, unsmoothed estimates of relative abundance have been roughly 3.2, 3.1, 2.7, 3.0 and 2.6 million animals, suggesting that population levels are stable, or only changing very slowly. If a five–year test for trend is carried out on these estimates, there is very weak evidence of a decline (p=0.089). However, this test does not utilise the estimated precision of the five relative abundance estimates, except as weights in the regression. This precision is allowed for in the running median method, by bootstrapping and smoothing an entire sequence of estimates in each resample. With coefficients of variation typically around 10%, an estimated decline in relative abundance from 3.2 to 2.6 provides little if any evidence of a real decline, a conclusion supported by Fig. 1.

Fig. 2 shows that the 1990 relative abundance estimate for the southern offshore stock of spotted dolphins was comparable with the 1989 unsmoothed estimate. Estimates immediately preceding 1989 were substantially lower. We suspect that large movements across the boundary between northern and southern offshore stocks are not uncommon, and prefer to assess them as if they were a single stock. Fig. 3 suggests that the two stocks together are currently stable or increasing. The unsmoothed relative abundance estimates for the last five years are 3.5, 3.6, 3.0, 3.6 and 3.2 million animals; the five-year test for trend on these estimates provides no evidence of a change between 1986 and 1990.

Table 2

Relative abundance estimates for 1990. Bootstrap standard errors are given in parentheses.
* Unidentified spinner schools were prorated between eastern and whitebelly stocks.

Species and stock	Effective strip half-width (nm)		Encounter rate (schools/ 1,000nm)		Average school size		Number of schools		Number of dolphins (000's)		Number of dolphins (000's)	
Spotted dolphin												
Northern offshore	3.51	(0.16)	8.35	(0.43)	561	(28)	4,519	(332)	2,537	(257)		
Southern offshore	3.17	(0.51)	3.89	(0.55)	902	(105)	870	(176)	785	(191)		
Northern and southern offshore	3.52	(0.17)	6.87	(0.36)	632	(36)	5,088	(383)	3,216	(322)		
Spinner dolphin												
Eastern, whitebelly and unidentified	3.57	(0.20)	4.34	(0.23)	332	(35)	3,079	(257)	1,021	(138)		
Eastern	3.65	(0.28)	2.74	(0.15)	342	(56)	850	(81)	291	(55)	358*	(76)
Whitebelly	3.61	(0.29)	2.96	(0.27)	314	(28)	1,718	(221)	540	(90)	663*	(107)
Common dolphin												
Northern	1.77	(0.32)	1.61	(0.38)	1,005	(237)	279	(80)	280	(111)		
Central	2.03	(0.26)	0.45	(0.08)	353	(69)	244	(49)	86	(20)		
Southern	2.08	(0.48)	1.30	(0.51)	528	(142)	263	(108)	139	(81)		
Northern, central and southern	1.63	(0.21)	0.75	(0.19)	471	(80)	841	(266)	396	(142)		

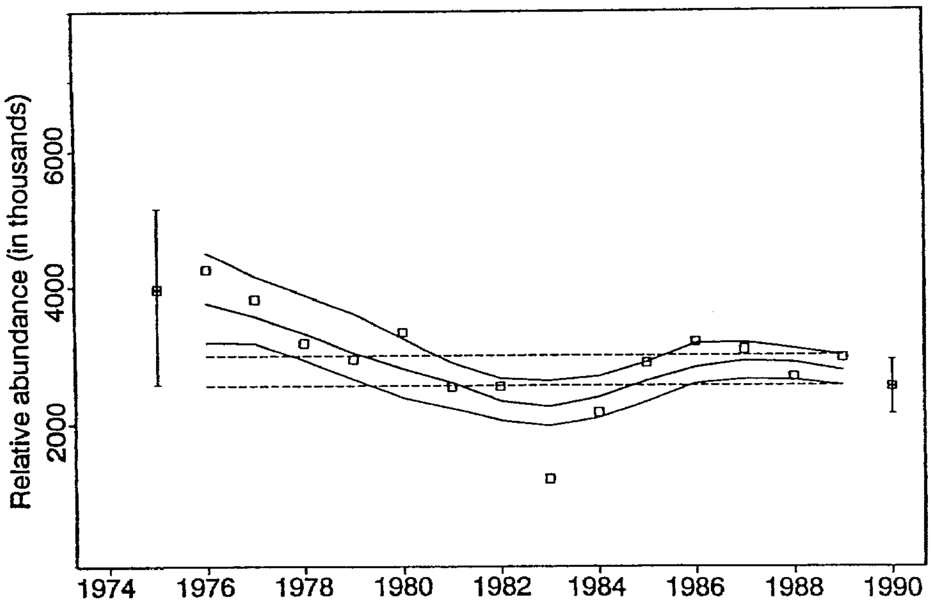

Fig. 1. Smoothed trends in abundance of the northern offshore stock of spotted dolphin. The broken lines indicate approximate 85% confidence limits. The horizontal lines correspond to 85% confidence limits for the 1989 estimate. If the lower limit lies above the upper limit for an earlier year, abundance has increased significantly between that year and 1989 ($p < 0.05$); if the upper limit lies below the lower limit for an earlier year, abundance has decreased significantly.

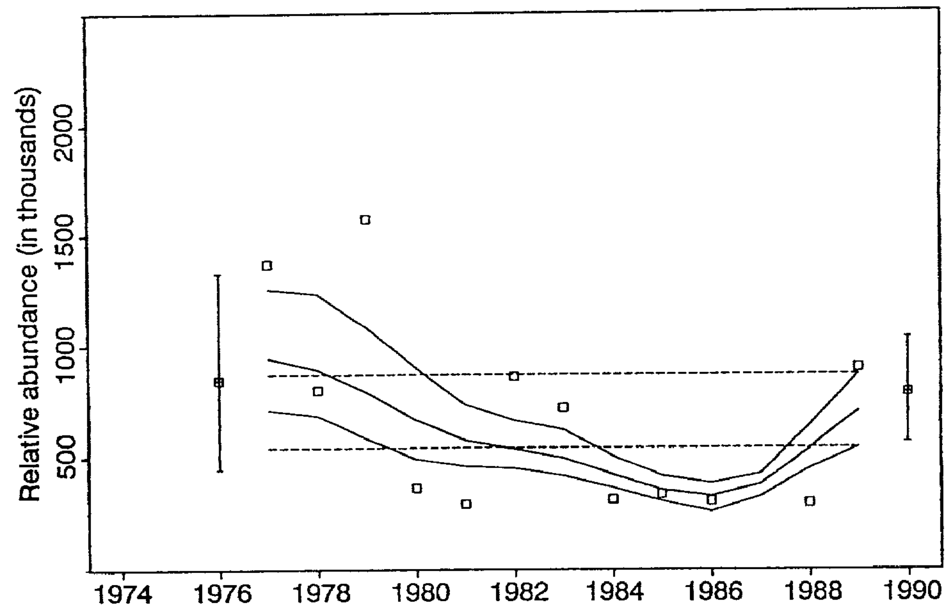

Fig. 2. Smoothed trends in abundance of the southern offshore stock of spotted dolphin. The broken lines indicate approximate 85% confidence limits. See caption to Fig. 1 for more details.

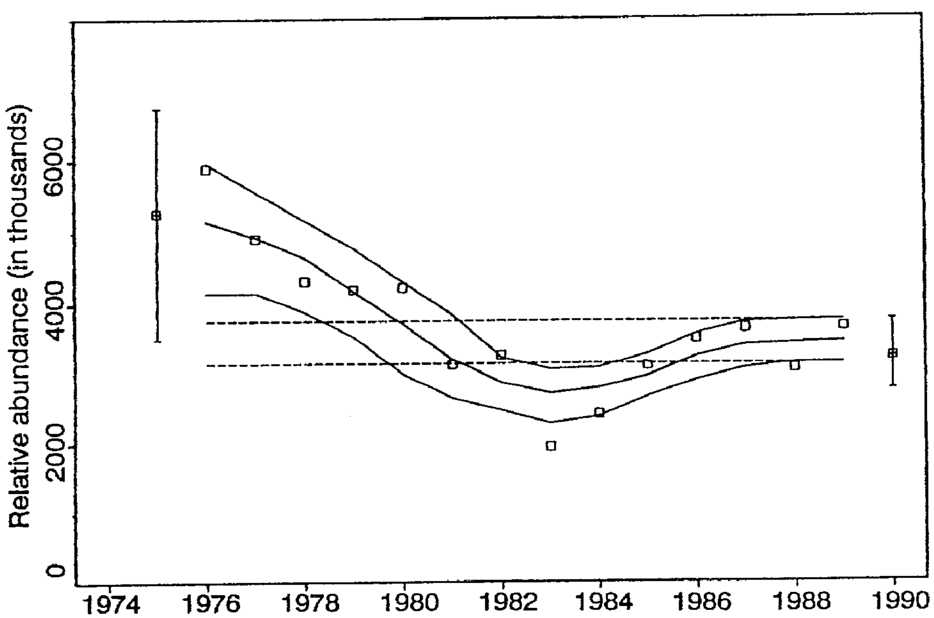

Fig. 3. Smoothed trends in abundance of the pooled northern and southern offshore stocks of spotted dolphin. The broken lines indicate approximate 85% confidence limits. See caption to Fig. 1 for more details.

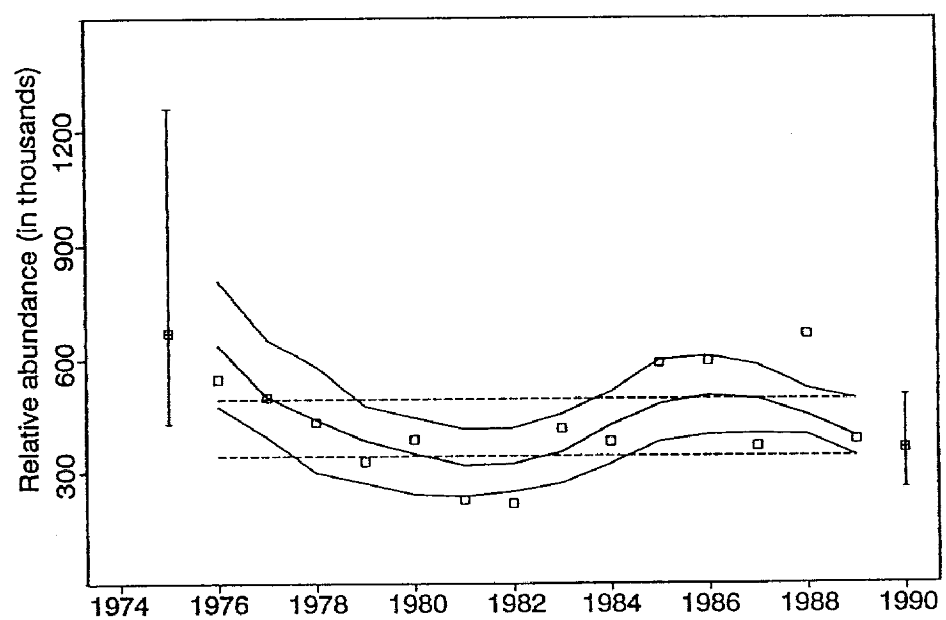

Fig. 4. Smoothed trends in abundance of the eastern stock of spinner dolphin. The broken lines indicate approximate 85% confidence limits. See caption to Fig. 1 for more details.

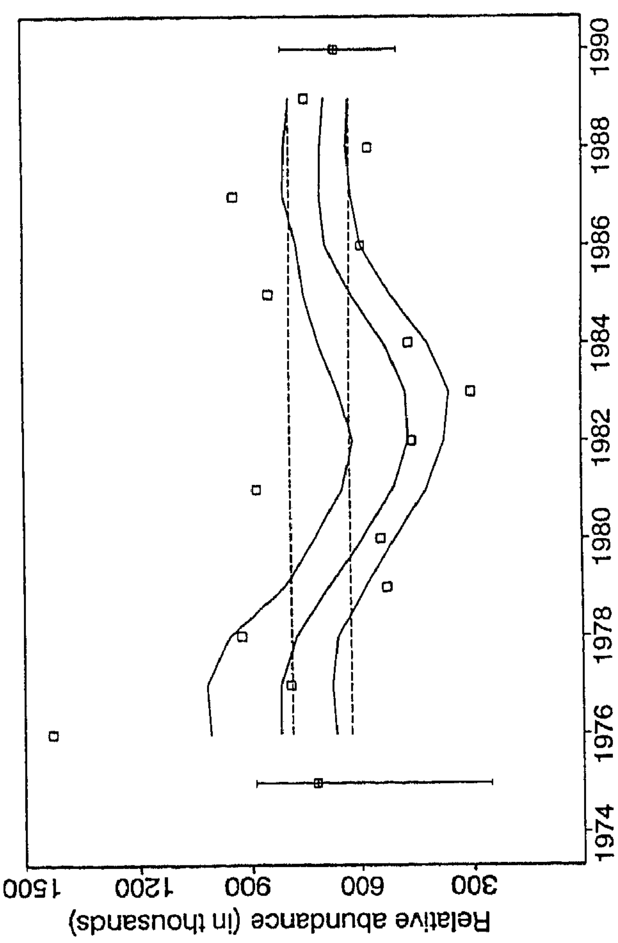

Fig. 5. Smoothed trends in abundance of the whitebelly stock of spinner dolphin. The broken lines indicate approximate 85% confidence limits. See caption to Fig. 1 for more details.

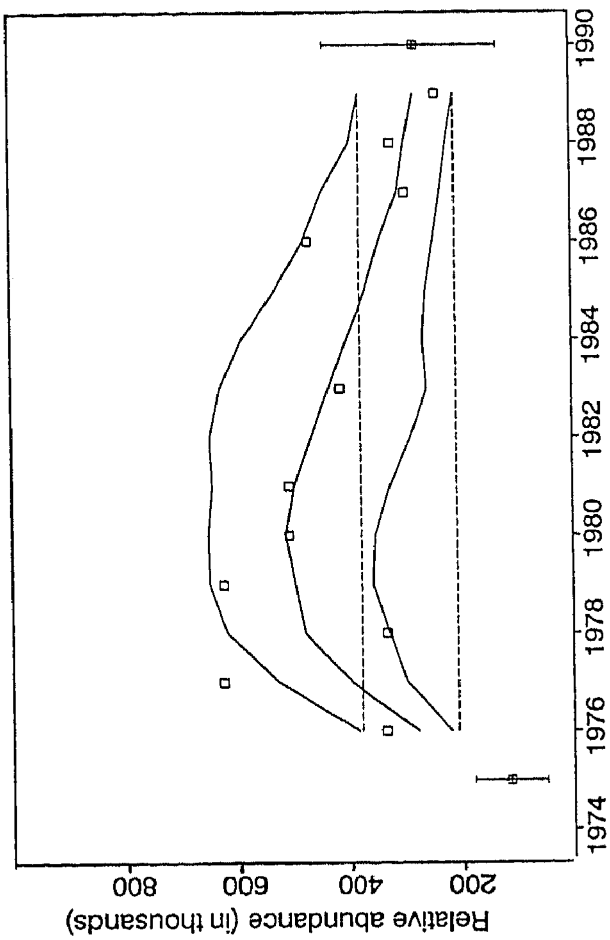

Fig. 6. Smoothed trends in abundance of the northern stock of common dolphin. The broken lines indicate approximate 85% confidence limits. See caption to Fig. 1 for more details.

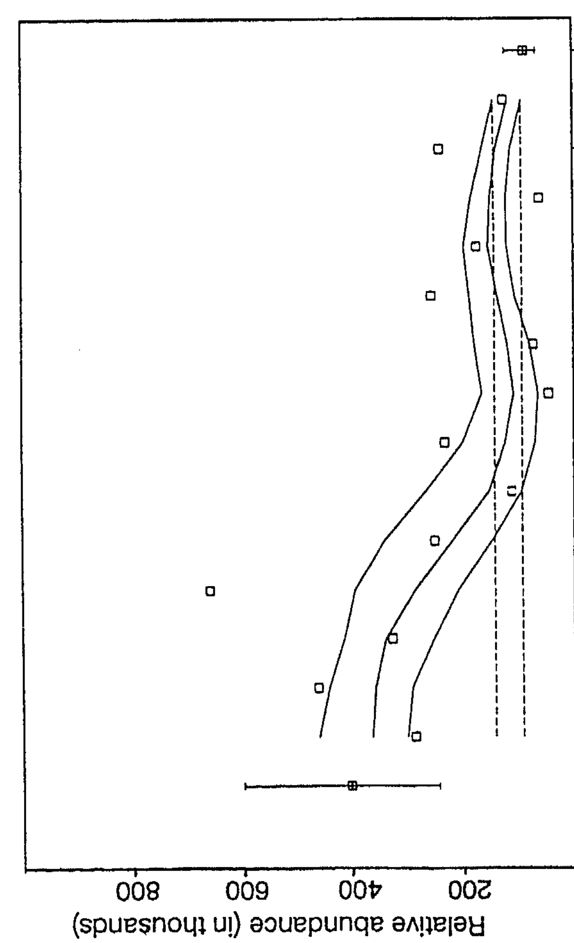

Fig. 7. Smoothed trends in abundance of the central stock of common dolphin. The broken lines indicate approximate 85% confidence limits. See caption to Fig. 1 for more details.

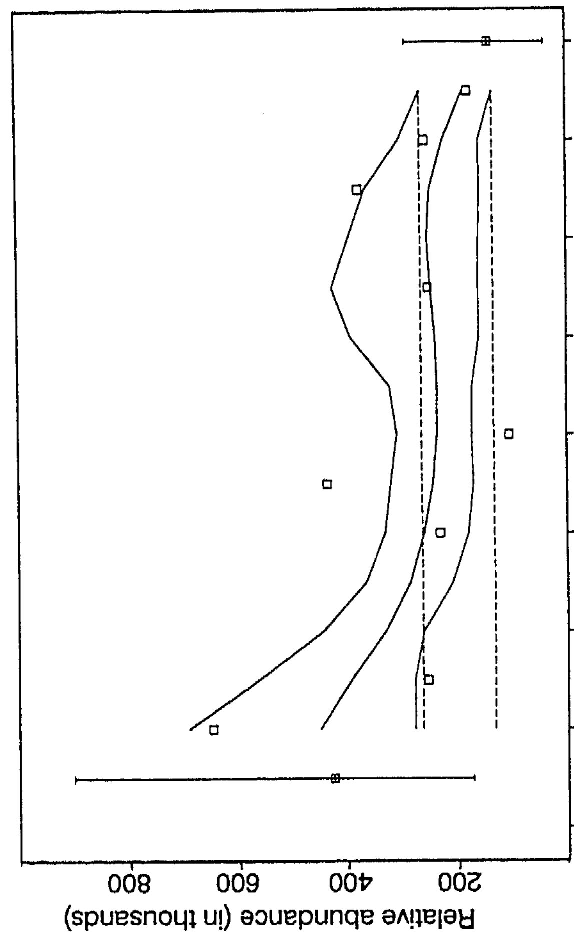

Fig. 8. Smoothed trends in abundance of the southern stock of common dolphin. The broken lines indicate approximate 85% confidence limits. See caption to Fig. 1 for more details.

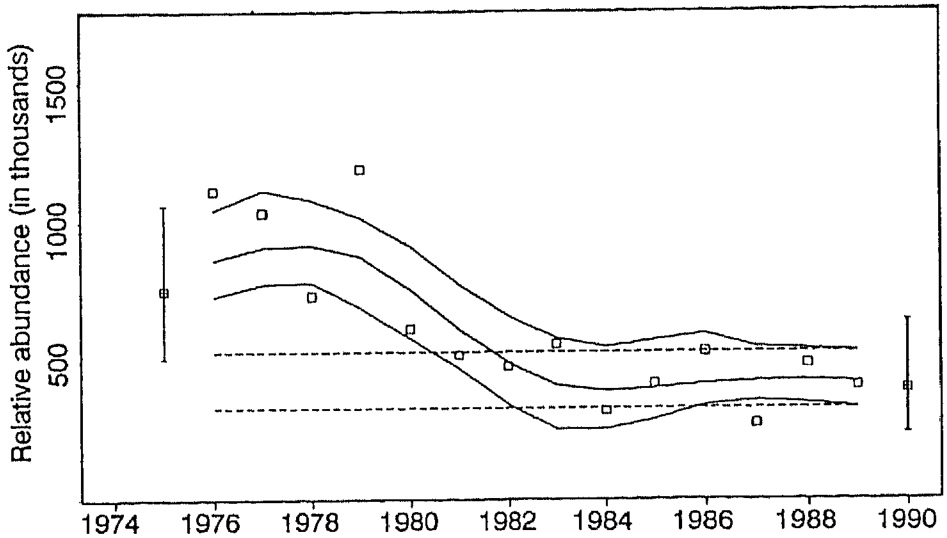

Fig. 9. Smoothed trends in abundance of the pooled northern, central and southern stocks of common dolphin. The broken lines indicate approximate 85% confidence limits. See caption to Fig. 1 for more details.

Spinner dolphin

The smoothed 1989 relative abundance estimate for the eastern stock of spinner dolphins is not significantly lower than that for any of the earlier years (Fig. 4), although the unsmoothed estimates for 1989 and 1990 are on the low side, causing the estimated trend to dip slightly since 1986. Unsmoothed estimates since 1986 are 0.59, 0.36, 0.66, 0.38 and 0.36 million animals.

As for offshore stocks of spotted dolphin, we prefer to assess the northern and southern whitebelly stocks of spinner dolphin as if they are a single stock. Perrin *et al.* (In press) recommend that these two stocks be combined, and we adopt that recommendation here. Fig. 5 shows little evidence of any recent trend in abundance of the pooled stock, following an apparent decline up to around 1982, and perhaps some recovery in the mid-1980s. The five unsmoothed relative abundance estimates for 1986/90 are 0.60, 0.94, 0.57, 0.75 and 0.66 million animals.

Common dolphin

Small sample sizes for the mid-1980s make assessment of current trends in the size of the northern stock of common dolphins problematic. Fig. 6 gives a visual impression of declining numbers since 1980, but the decline is not statistically significant. The five unsmoothed relative abundance estimates since 1986 have been 0.47, 0.30, 0.32, 0.24 and 0.28 million animals, compared with an average of 0.44 million during 1975/83. Fig. 7 suggests that the central stock of common dolphins may be more or less stable but at a reduced level relative to the 1970s. Data for the southern stock are sparse, making trends in abundance difficult to assess (Fig. 8). If data for northern, central and southern stocks of common dolphin are pooled, there is little evidence of any recent trend in abundance, although there is strong evidence of a decline between 1979 and 1982 (Fig. 9).

CONCLUSIONS

The use of smoothed estimates, combined with the test for overlapping 85% confidence intervals, is not presented as a rigorous statistical procedure, but rather as a way to assess graphically the trends in relative abundance of the populations. In principle, the comparison of 85% confidence intervals can be done on the unsmoothed estimates, for which the assumption of independence between estimates is more reasonable. However, the inter-annual variability of the estimates cannot be attributed to sampling error alone, but also to fluctuations in biases, for example due to variation in oceanographic conditions. The smoothing procedure increases the precision of each estimate by incorporating information from adjacent years, and reduces the effect of outliers on estimated trends. As a trade-off, a dependency between estimates that are close in time is introduced. However, the effect of this dependency on the test diminishes rapidly with separation in time between the estimates.

Using five-year tests for trend on the unsmoothed estimates, no significant linear trends in abundance were detected for the period 1986/90. The more informative method of Buckland *et al.* (In press), adopted here, indicates that stocks have been more or less stable, with some showing evidence of increase, since the mid–1980s, following a period of declining numbers during the late 1970s and early 1980s. Trend estimates obtained from data pooled across both offshore stocks of spotted dolphin are smoother than for either stock separately, and we believe separate assessment of trends in the respective stocks is confused by movement of animals between the two stock areas. In the case of the southern stock, evidence for large movements across the putative boundaries of its range was presented by Anganuzzi *et al.* (1991). Other contributory factors to large fluctuations, such as changes in bias between years, cannot be ruled out. However, estimated trends will still be valid provided there are no trends in bias. A comparison between estimates derived from research vessels and from tuna vessels for the period 1986 to 1989 showed that fluctuations in tuna vessel estimates were biologically plausible when full account was taken of the precision of the estimates. By contrast, those from research vessel data were more variable on average and were not biologically plausible in some instances (Buckland *et al.*, In press).

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