STATUS OF DOLPHIN STOCKS IN THE EASTERN TROPICAL PACIFIC

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Abstract. Since the passage of the U. S. Marine Mammal Protection Act, approximately 1.25 million dolphins have been killed incidentally during purse seine fishing operations for yellowfin tuna (*Thunnus albacares*) in the eastern tropical Pacific Ocean. The three species of pelagic dolphins primarily involved in this fisheries interaction are the spotted dolphin (*Stenella attenuata*), spinner dolphin (*Stenella longirostris*), and common dolphin (*Delphinus delphis*). We review the status of these species relative to stock structure, current population size, levels of fishery-related mortality, and trends in abundance. Abundance estimates have been derived from two sources: data collected by observers on research vessels and data collected by observers on tuna vessels. Estimates of incidental mortality are currently derived only from data collected by observers on tuna vessels. There is no evidence of any significant change in abundance for any of these three species since 1985. However, declines in abundance have been detected over the last 15 yr.

INTRODUCTION

The National Marine Fisheries Service (NMFS) is responsible for assessing the status of dolphin stocks subject to incidental mortality by tuna purse seiners in the eastern tropical Pacific Ocean (ETP). Over 1.25 million dolphins are estimated to have been killed by this fishery since the passage of the U. S. Marine Mammal Protection Act (MMPA) in 1972 (Table 1). The major species affected are the spotted dolphin (*Stenella attenuata*), spinner dolphin (*S. longirostris*), and common dolphin (*Delphinus delphis*).

In 1984, the Service was mandated under the MMPA to commence a scientific research program to monitor trends in abundance of dolphin stocks that may be adversely affected by the purse seine fishery for yellowfin tuna (*Thunnus albacares*) in the ETP. Should declines in any stocks be detected, the Secretary of Commerce would be required to modify the applicable quotas as necessary to ensure that none of the stocks are disadvantaged. The NMFS dolphin monitoring program consists of three elements: (1) a series of seven research vessel surveys over eleven years (1986-1996) using dedicated research vessels; (2) analyses of marine mammal sightings data collected by observers aboard U. S. and non-U. S. tuna vessels; and (3) analyses of life history data collected by observers aboard U. S. tuna vessels. The research vessel surveys were designed

TABLE 1. Number of eastern tropical Pacific dolphins estimated to have been killed in commercial tuna purse seine fishing operations form 1973 through 1990. Data from Smith (1979, 1983), Wahlen (1986), and Punsley (1983) for the years 1973-1978, Inter-American Tropical Tuna Commission (1989, 1991, 1992) for the years 1979-1990, in addition to Hall and Boyer (1990, 1992) for the years 1989-1990. Abbreviations are as follows: NSpot (northern offshore spotted dolphin), SSpot (southern offshore spotted dolphin), ESpin (eastern spinner dolphin), WSpin (whitebelly spinner dolphin), NCom (northern common dolphin), CCom (central common dolphin), and SCom (southern common dolphin).

Year	NSpot	SSpot	ESpin	WSpin	NCom	CCom	SCom
1973	74 448	10 152	18 400	30 800	5100	5100	0
1974	76 900	0	17 800	25 900	4300	4500	0
1975	75 068	1532	17 100	26 200	5000	5000	0
1976	50 183	24 717	14 700	29 400	4000	4000	0
1977	18 522	378	1800	4900	2000	2000	0
1978	12 825	675	1100	3400	1100	1100	0
1979	8870	2348	1460	1312	4161	2342	94
1980	13 058	6828	1108	8132	1060	963	188
1981	16 324	6376	2261	6412	2629	372	348
1982	15 427	4504	2606	3716	989	487	28
1983	3414	3608	745	4337	845	191	0
1984	15 940	4042	6033	7132	0	7403	6
1985	31 309	2786	8853	6979	0	6839	304
1986	67 989	5125	19 526	11 042	13 289	10 884	134
1987	51 685	3285	10 358	6026	8216	9659	6759
1988	36 137	2192	18 793	3545	4829	7128	4219
1989	52 093	3863	15 245	8302	1066	12 711	576
1990	32 267	1584	5378	6952	704	4053	272
Total	652 459	83 995	163 266	194 487	59 288	84 729	12 928

specifically to detect an annual change of approximately 10% per year for the northern offshore stock of spotted dolphin, and were not designed to estimate absolute abundance per se. The analysis of sightings data collected by observers on tuna vessels is being done cooperatively with the Inter-American Tropical Tuna Commission (IATTC), with the IATTC taking the lead on this research. The results of the studies will be included in a report to Congress in 1992. The purpose of this report is to provide a preliminary summary of findings to date. Any conclusions from this report should likewise be considered preliminary.

SPOTTED DOLPHIN

Distribution and stock structure

Three stocks of spotted dolphins are currently recognized: northern offshore, southern offshore, and coastal (Anonymous 1987). Perrin et al. (1985) recommended that schools of spotted dolphins should not be identified as coastal or offshore on the basis of geographic location alone. In addition they recommended that the division of northern and southern stocks be retained. Recent information on seasonal movement patterns (Reilly 1990) and patterns of morphological variation (Perrin et al. 1985) suggests that spotted dolphins move between the western and southern portions of their range. NMFS is currently evaluating the existing definitions of stock structure in spotted dolphins.

Population estimates

Holt and Powers (1982) estimated the absolute abundance of spotted dolphins in 1979 using data from research vessels alone (RVD) and from research and tuna vessel data combined (RVTVD). A preferred approach was not identified by Holt and Powers (1982); therefore, both estimates are given (Table 2). Seventy to 80% of the spotted dolphins were from the northern stock. The coastal stock estimates were 189 000 (RVD) and 114 400 (RVTVD). The coefficient of variation (CV) for these estimates varied between 20 and 30%.

Based on the first four research vessel surveys under the Congressionally mandated program to monitor changes in the abundance of ETP dolphins (1986-1989; Table 3), hereafter referred to as the Monitoring of Porpoise Stocks survey (MOPS) estimates, the population size of the northern stock of offshore spotted dolphin varied between 1 212 800 and 2 838 300, and averaged 1 992 750 (Sexton et al. 1992, Gerrodette and Wade 1992). The population estimate for the southern stock varied between 314 000 in 1986 to 721 400 in 1989, with an average of 508 525. The CV for all stocks ranged between 16 and 19%.

The objective of the MOPS surveys was to monitor trends in relative abundance. That is, Sexton et al. (1992) and Gerrodette and Wade (1992) attempted to minimize the

TABLE 2. Absolute abundance estimates of eastern tropical Pacific dolphins from research vessel data (RVD) and tuna vessel-research vessel data (TVRVD) for 1979 (Smith 1979).

	Northern spotted	Southern spotted	Eastern spinner	Whitebelly spinner	Common (pooled)
RVD 1979	1 682 000	584 600	292 900	570 200	921 000
RVTVD 1979	2 775 000	465 500	292 700	607 000	1 373 100

variance of the population estimates, while holding potential sources of bias constant from year to year. For example, in estimating stock abundance, Sexton et al. (1992) and Gerrodette and Wade (1992) assumed that the number of animals in each stock was a constant (over time) proportion of the area occupied by that stock and, therefore, sighting data from different strata could be pooled. This has the effect of reducing the variance of the population estimate, but increasing the potential for the estimates to be biased (see discussion in Sexton et al. 1992). Furthermore, no information on the probability of detecting a school of dolphins on the track line or the response of dolphins to the survey vessel (i.e., possible avoidance or approach) was available. Therefore, using the relative abundance estimates reported by Sexton et al. (1992) or Gerrodette and Wade (1992) as estimates of absolute abundance requires the assumption that all dolphin schools on the trackline were detected and that dolphins did not respond to the survey vessel.

Wade and Gerrodette (1992) reanalyzed the data from the first 5 yr (1986-1990) of the MOPS surveys using a different statistical analysis. By not pooling sightings data over all species and strata their analysis produced less precise but, presumably less biased estimates of relative abundance (Table 4). From this analysis, the estimated population size for the northern stock of offshore spotted dolphin for 1986-1990 varied between 658 300 and 2 205 500 with CVs between 26 and 36%. An average abundance estimate for the northern stock using this method is approximately 1 514 800. Estimates for the southern stock were between 85 800 and 475 800 with CVs between 48 and 86% with a mean of 267 400 animals.

In addition to the MOPS estimates, estimates of relative abundance have been produced for the northern and southern stocks (Table 5) based on sightings data from observers aboard tuna vessels (Anganuzzi and Buckland 1989, Anganuzzi et al. 1992*a,b*). For the northern stock, the abundance estimates (1986-1990) ranged from 2 553 000 to 3 165 000. The average estimate for the northern stock was 2 854 000. For the southern stock, the estimates were between 79 000 and 785 000, and averaged 394 500 (no estimate for the southern stock was reported for 1987). Because tuna vessels search nonrandomly, and tend to concentrate in areas of high dolphin abundance, these relative abundance indices may be positively biased if treated as estimates of absolute abundance.

Mortality estimates and mortality rates

Estimates of incidental mortality of dolphins in the tuna fishery show considerable mortality in the 1960s, with reductions thereafter due to regulations (Smith 1983, Table 1). Quotas of incidental mortality for U. S. fishermen were set for the northern offshore, southern offshore, and coastal stocks (20 500, 5697, and 250, respectively) in 1987 (Anonymous 1987). It should be noted that incidental mortality estimates (hereafter referred to as mortality estimates) for the coastal stock are considered unreliable because of the difficulty in separating the offshore and coastal stocks and because of the low level of observed fishing effort in nearshore waters. Also, estimates of mortality between 1959 and 1972 are considered very imprecise because of the small number of observed trips during this time period, uncertainty as to whether backdown procedures were used, and changes in the fleet towards larger vessels and therefore, are not included in this report (Lo and Smith 1986).

TABLE 3. Relative abundance estimates of eastern tropical Pacific dolphins from monitoring of porpoise stocks survey data (Sexton et al. 1992, Gerrodette and Wade 1992).

	Northern spotted	Southern spotted	Eastern spinner	Whitebelly spinner	Northern common	Central common	Southern common	Common (pooled)
1986	1 212 800	314 000	715 900	657 200	284 700	1 093 000	429 300	1 810 000
1987	1 901 700	486 800	707 200	750 400	163 200	619 600	243 500	1 026 300
1988	2 018 200	511 900	901 800	820 700	836 900	3 177 400	1 248 700	5 263 000
1989	2 838 300	721 400	1 200 000	1 170 100	411 200	1 561 100	613 500	2 585 700
MEAN	1 992 750	508 525	881 225	849 600	424 000	1 612 750	633 750	2 671 250

TABLE 4. Relative abundance estimates from monitoring of porpoise stocks survey data (Wade and Gerrodette 1992).

Year	Northern spotted	Southern spotted	Eastern spinner	Whitebelly spinner	Northern common	Central common	Southern common	Common (pooled)
1986	1 134 200	236 000	603 700	706 100	390 000	306 700	2 217 300	2 913 500
1987	1 582 600	475 800	444 700	1 220 700	23 500	348 100	152 000	523 600
1988	2 205 500	85 800	754 200	1 398 400	1 272 400	1 487 600	2 896 500	5 656 500
1989	1 993 600	451 900	748 800	1 280 000	473 600	261 000	3 664 000	4 398 600
1990	658 300	87 700	391 200	363 300	177 700	568 000	1 657 500	2 403 200
MEAN	1 514 840	267 440	588 520	993 700	467 440	594 280	2 117 460	3 179 080

TABLE 5. Relative abundance estimates from tuna vessel observer data (Anganuzzi and Buckland 1989, Anganuzzi et al. 1992*a*,*b*).

Year	Northern spotted	Southern spotted	Eastern spinner	Whitebelly spinner	Common (pooled)
1986	3 165 000	154 000	584 000	451 000	644 000
1987	2 953 000	-	384 000	650 000	364 000
1988	2 689 000	79 000	717 000	572 000	817 000
1989	2 910 000	560 000	389 000	705 000	547 000
1990	2 553 000	785 000	376 000	675 000	507 000
MEAN	2 854 000	394 500	490 000	610 600	575 800

Since 1986, increased observer coverage of U. S. and international fleets has yielded much more reliable estimates of mortality. The average estimated annual mortality between 1986 and 1990 for the northern stock was 48 040 animals, while the average for the southern stock was 3220. Furthermore, since 1986, estimated mortality of northern offshore spotted dolphins has declined, on average, by 7104 animals per year (linear regression of mortality versus years, $P=0.12$), and the southern stock by 650 animals per year ($P=0.16$).

Because of variability and bias in estimates of both population and incidental mortality, estimates of percent mortality can not be determined reliably. If the most recent estimates of relative abundance from the MOPS surveys are used to approximate absolute abundance, percent mortality can be estimated by dividing annual estimates of mortality by annual or average estimates of population abundance. Because trends in abundance were not detected between 1986 and 1990, the mean estimate for the years 1986-1990 from Wade and Gerrodette (1992) were used to estimate annual percent mortality (Table 6).

By this method, the northern offshore spotted dolphin had an average mortality rate of 3.2%, while the southern stock had an average mortality rate of 1.2% between 1986 and 1990. The mortality rates for northern offshore spotted dolphins have declined between 1986 and 1990 from 4.5 to 2.1%, while the southern offshore spotted dolphin mortality rates declined from 1.9 to 0.6%. It is likely that these estimates of percent mortality are positively biased, but the magnitude of the bias is unknown.

Assessment and status

Currently, the most reliable information on trends in abundance is based on sighting data collected aboard tuna vessels. At this time, too few data points (annual estimates) have been determined from the MOPS surveys to yield results with adequate statistical power. Using tuna vessel observer data, Anganuzzi and Buckland (1989)

TABLE 6. Percent dolphin mortality using average population estimates for the years 1986-1990 (Wade and Gerrodette 1992), and mortality estimates (Inter-American Tropical Tuna Commission [1989, 1991], and Hall and Boyer [1990, 1992]) for spotted, spinner and common dolphins in the eastern tropical Pacific. Estimates for common dolphins are pooled.

Year	Northern spotted	Southern spotted	Eastern spinner	Whitebelly spinner	Common*
1986	4.49	1.90	3.30	1.10	0.76
1987	3.41	0.30	1.77	0.60	0.77
1988	2.38	0.80	3.20	0.40	0.51
1989	3.44	1.50	2.60	0.80	0.45
1990	2.13	0.60	0.90	0.70	0.16
MEAN	3.2	1.2	2.4	0.7	0.5

* Northern, Central, and Southern stocks

reported on trends (5-yr moving mean) between 1975 and 1987. The only significant trends were for the northern stock from 1975 to 1979 (declining) and the southern stock from 1982-1986 (declining). Edwards and Perkins (1991) investigated the likelihood of trends over all of the data published by Anganuzzi and Buckland (1989) using a 10-yr moving mean. Significant declines were found only for the northern offshore stock in years 1975-1984 and 1976-1985. A power analysis with type 1 and type 2 error levels set at 0.1 indicated that significant trends would have had to be on the order of a 5-6% decline per year over the 10-yr period, to be statistically detectable.

A more recent analysis by Anganuzzi et al. (1992*b*), using smoothed indices of abundance following the methods proposed by Buckland et al. (1992), indicated that the number of animals in the northern stock of the offshore spotted dolphin was more or less stable between 1986 and 1990. A similar pattern was reported for the southern stock, except that the 1990 index of abundance was substantially greater than preceding indices. Anganuzzi et al. (1992*b*) reasoned that this latter estimate was influenced by large-scale movements of animals from the northern stock.

If there were no incidental mortalities of spotted dolphins in the purse seine fishery, we would expect the northern and southern stocks of this species to recover to prefishery levels at a rate of approximately 2-6% per year (see Reilly and Barlow 1986). The northern stock would take substantially longer to recover because it was presumably exploited to a greater extent than the southern stock. For the northern offshore stock, the current rate of incidental mortality approximates the expected rate of increase. Therefore, it is not surprising that significant trends in abundance have not been detected in recent years. The lower kill rate of the southern stock would still reduce the rate of recovery to a level that would be difficult to detect over a 5-yr period.

SPINNER DOLPHIN

Distribution and stock structure

There are currently four recognized stocks of spinner dolphins in the ETP (northern whitebelly, southern whitebelly, eastern, and Costa Rican) (Anonymous 1987). Due to the high degree of overlap in distribution between spinner dolphin stocks, Perrin et al. (1985) recommended the following changes to the existing stock definitions: (1) south of 16°N, north of 7°N and within 81 km of the coast, schools of spinner dolphins should not be assigned to a stock by position alone, but rather by modal length and relative beak length; and (2) identification of spinner schools as eastern or whitebelly should be based on modal adult color pattern or adult-male dorsal-fin shape or both. Perrin (1990) suggested that the northern and southern whitebelly stocks should be combined into a single management unit. Subsequent references to whitebelly spinner dolphins in this paper will follow this recommendation.

Population estimates

Holt and Powers (1982) estimated abundance levels for eastern spinner dolphins in 1979 (Table 2) as 292 900 (RVD) and 292 700 (RVTVD) with CVs of 22 and 24%, respectively. Based on the first 4-yr of the MOPS surveys (Table 3: 1986-1989) Sexton et al. (1992) and Gerrodette and Wade (1992) estimated abundance of the eastern stock to be between 707 200 and 1 200 100 with an average for the 4-yr of approximately 881 200. CVs were approximately 20% in all years. Wade and Gerrodette (1992) estimated the eastern spinner abundance based on the five MOPS surveys (Table 4: 1986-1990) to be between 391 200 and 754 200 with CVs between 37 and 42%. Wade and Gerrodette's (1992) average estimate for 5-yr of data was 588 500. Tuna vessel observer data (Table 5) yields relative abundance estimates in the range of 376 000 to 717 000 between 1986 and 1990, averaging 490 000 (Anganuzzi and Buckland 1989, Anganuzzi et. al. 1992*a,b*). Because U. S. fishermen are not allowed to set on pure schools of eastern spinner dolphins, and therefore are less likely to chase and identify these schools, it is not surprising that estimates of abundance based on tuna vessel data for this stock are slightly lower than those from research vessels.

Abundance estimates for the whitebelly stock (Tables 2 and 3) varied between 570 200 and 607 000 (RVD and RVTVD, respectively) in 1979 (Holt and Powers 1982: CV=25%) and 657 200 to 1 170 100 between 1986 and 1989 (Sexton et al. 1992, Gerrodette and Wade 1992: CV approximately 20%). Wade and Gerrodette (1992) reported abundance estimates for the whitebelly stock (Table 4) ranging from 363 300 to 1 398 400 with CVs between 38 and 64% and an average estimate for the 5-yr of 993 700. Tuna vessel observer data has provided relative abundance estimates ranging from 451 000 to 705 000, and averaging 610 600 for the years 1986-1990 (Table 5).

Mortality estimates and mortality rates

Incidental mortality estimates for the eastern stock declined between 1986 and 1990 by an average of 2341 animals per year (P=0.26; Table 1). Between 1986 and

1990, mortality averaged 13 860 animals per year. The estimated level of mortality, expressed as a percent of population size (based on MOPS data; Wade and Gerrodette 1992), declined from 3.3% in 1986 to 0.9% in 1990 (Table 6). For the whitebelly stock, estimated mortality has been much lower than for the eastern stock both in numbers and as a percent. Between 1986 and 1990, mortality varied between 3500 and 11 000 per year (Table 1). The mortality rate has not exceeded 1.1% in recent years (Table 6).

Assessment and status

Anganuzzi and Buckland (1989) reported a significant increase in abundance between 1982 and 1986 and a significant decrease between 1975 and 1979 for eastern spinner dolphins. Edwards and Perkins (1991) detected no significant trends over four 10-yr periods (1975/1984, 1976/1985, 1977/1986, and 1978/1987). However, consistent with Anganuzzi and Buckland's results, during the first two 10-yr periods, the slope of the regression was negative (i.e., population declining), while during the second two periods the slope was positive (i.e., population increasing). The 1989 smoothed index of abundance of Anganuzzi et al. (1992*b*) was not significantly different from any of the earlier years. As was the case for the northern spotted dolphins, the current rate of incidental mortality is similar to the expected rate of recovery. Therefore, in view of the variance associated with the indices of abundance, it is not surprising that trends in abundance have not been detected.

Anganuzzi et al. (1992*b*) reported that the whitebelly stock has shown "little evidence of any recent trend in abundance" since 1983. Between 1976 and 1983, they reported detecting a decline in abundance.

Estimates of historic abundance of eastern spinner dolphins were produced by Wade (1991) based on recent estimates of population size, back-calculation techniques, and input parameters of Smith (1983). This is the only stock whose entire distribution is within the MOPS study area, and, therefore, at least incomplete coverage does not introduce bias into the estimate of abundance. Wade found that over the range of parameter estimates explored, relative population size (defined as the current abundance estimate [N_c]) divided by the historical abundance estimate [N_h])is most sensitive to initial population abundance. Starting the population at 391 200 versus 754 200 (lowest and highest N_c used in simulations), which is equal to the range in population size estimate from Wade and Gerrodette (1992), resulted in a 12-27% increase in relative abundance. Of even more significance was the range over which relative population sizes change. Whereas Smith (1983) estimated relative population size for the eastern spinner dolphin population to be from 0.17 to 0.25, Wade (1991), using an N_c of 391 200, estimated relative population sizes from 0.21 to 0.33, and using an N_c of 754 200, estimated relative populations sizes to be from 0.33 to 0.60.

For ETP dolphins the results of back-calculation models are confounded by lack of information on which to estimate mortality for the period 1959-1972 (see Lo and Smith 1986, Smith and Lo, 1983). Repeating the above calculations using mortality estimates 20% lower and 20% higher resulted in estimated relative population sizes from 0.18 to 0.41 using an N_c of 391 200, and estimated relative population sizes from 0.29 to 0.73 using an N_c of 754 200 (Wade 1991). It is not possible at this time to ascertain whether the range of mortality estimates used by Wade (1991) includes the actual level of eastern spinner dolphin mortality between 1959 and 1972.

COMMON DOLPHIN

Distribution and stock structure

Presently there are three recognized stocks of common dolphins taken by the U. S. fleet in the ETP (northern tropical, central tropical, and southern tropical) (Anonymous 1987). Perrin et al. (1985) recommended changing the existing definition within 162 km of the coast of Baja California and in the Gulf of California, such that common dolphins should be identified to stock as Baja neritic or northern based on modal length, coloration, and relative beak length. Reilly (1990) recently reported that common dolphins do not seem to have seasonal shifts in distribution centers, as do spotted and spinner dolphins. Rather, common dolphin stocks occupy year-round density centers in areas of upwelling near the Revillagigedos Islands, along the coast of Baja California and Ecuador, and near the Costa Rican Dome. The extent to which this pattern of distribution confounds traditional stock identification methods is currently being examined by NMFS.

Population estimates

Holt and Powers (1982) estimated the total number of common dolphins in the ETP (Table 2) to be approximately 921 000 (RVD) and 1 373 100 (RVTVD). Estimates of abundance from the first 4 yr of MOPS (Table 3) ranged from 163 200 to 836 900 for the northern stock, 619 600 to 3 177 400 for the central stock, and 243 500 to 1 248 700 for the southern stock. Abundance estimates of common dolphin stocks made by Wade and Gerrodette (1992) based on MOPS data from 1986 through 1990 were between 23 500 and 1 272 400 for the northern stock, 261 000 and 1 487 600 for the central stock, and 152 000 and 3 664 000 for the southern stock (CVs between 50 and 77%, Table 4). The average estimate of abundance for common dolphins, pooled over all stocks between 1986 and 1990, was approximately 3 179 000 (Table 4).

Differences between some of the annual estimates for this species from MOPS surveys are probably great(see Table 4). It is possible that the variance has been underestimated, that there was extensive immigration of animals from the south or west into north and central areas, or that bias in the abundance estimate was not constant from year to year (or all of the above).

The estimated average abundance based on tuna vessel data from 1986 through 1990 pooled over all stocks was 575 800 (Table 5). Abundance estimates for the three stocks of common dolphins were for 1990: northern stock 281 000, central stock 87 000, and the southern stock 139 000 (Anganuzzi et al. 1992*b*). The range of abundance estimates from tuna vessel and research vessel data was 364 000 to 817 00 and 523 000 to 5 656 500, respectively.

Mortality estimates and mortality rates

Mortality estimates for the three stocks are highly variable from year to year, but considerably less in absolute number than for northern offshore spotted dolphins or eastern spinner dolphins. Quotas for U. S. fishermen exist for all three stocks (northern stock 1890, central stock 8112, and southern stock 4045)(Anonymous 1987). In recent years, the central stock has suffered the greatest absolute amount of incidental mortality of the three common stocks.

Assuming the abundance of each stock has remained constant, the average estimate for the years 1986-1990 can be used to determine the annual mortality rate for each stock. Because of uncertainty in estimating the abundance of common dolphin stocks, their abundance estimates have been pooled. The average mortality rate decreased from 0.76% in 1986 to 0.16% in 1990 (Table 6). The average mortality rate is approximately 0.5%, pooled over all 5 yr and all three stocks.

Assessment and status

Anganuzzi and Buckland (1989) reported only one significant decline during a 5-yr period for any of the three stocks of this species: the central stock declined between 1977 and 1981. Edwards and Perkins (1991) reported a significant increase in the northern stock between 1975 and 1984 and significant decreases in the central stock between years 1975 and 1984, 1976 and 1985, and 1978 and 1987.

The most recent analysis of sightings data from observers aboard tuna vessels indicates that all three stocks declined between the late 1970s and 1989 (Anganuzzi et al. 1992*b*). Since 1985, there has been no indication of significant trends for any of the three stocks. Based on the analysis of Anganuzzi et al. (1992*b*), the increase in the northern stock between 1975 and 1984 reported by Edwards and Perkins (1991) is likely an artifact of the very low abundance estimate for 1975.

DISCUSSION

Since the early 1970s, over 1.25 million dolphins have been incidentally killed in purse-seine fishing for yellowfin tuna in the ETP. Over half of this take has been composed of northern offshore spotted dolphins; at least 80% of the take is northern offshore spotted dolphins and spinner dolphins. Currently, fishermen take significant numbers of spotted (northern and southern offshore stocks), spinner (eastern and whitebelly stocks) and common dolphins (northern, central, and southern stocks). Over the last 5 yr, the total estimated dolphin mortality has decreased from 133 174 animals in 1986 to 52 531 animals in 1990. Based on annual estimates of stock specific mortality and the average population size of stocks from the recent series of five research vessel surveys over the last 5 yr, the average estimated percent mortality has exceeded 2% of stock for eastern spinner dolphins and northern spotted dolphins and less than 2% per year for all of the other stocks. Because stock-specific rates of incidental mortality have been declining since 1986, the current levels of take of individual stocks are likely to be sustainable. This interpretation is supported by the available information on trends in abundance.

Based on an analysis of smoothed abundance indices, all of the stocks of ETP dolphins that interact with the tuna fishery have been more or less stable since 1985. The only exception is the southern stock of offshore spotted dolphins which may have increased during this period. However, over the last 15 yr, significant declines in abundance have been reported for stocks of the northern and southern offshore spotted dolphin, the whitebelly stock of spinner dolphins, and the northern, southern, and central stocks of common dolphin. The eastern stock of spinner dolphin has been relatively constant over the last 15 yr. Apparently most of this decline occurred in the years prior to 1985.

Concerning future management practices, the authors note the following: (1) geographically defined management units are not necessarily biologically meaningfull, (2) abundance can be estimated for a management unit, but trends in abundance must be determined by pooling stocks that are thought to mix or overlap in distribution, and (3) where quoata management is considered appropriate, quotas should be established for each management unit. The management of dolphin stocks in the ETP will likely be most effective if future decisions are based on both the results of trend analysis and estimates of fishery caused mortality expressed as a percentage of population size. The former takes advantage of a long time series of tuna vessel observer data, while the latter can be used to prevent additional declines or to encourage depleted stocks to recover.

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