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AUGUST 1993

ASSESSMENT OF THE NORTHEASTERN STOCK OF OFFSHORE SPOTTED DOLPHIN *(Stenella attenuata)*

By

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ADMINISTRATIVE REPORT LJ-93-18

POPULATION ASSESSMENT OF THE NORTHEASTERN STOCK OF OFFSHORE SPOTTED DOLPHIN (*STENELLA ATTENUATA*)

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August, 1993

Administrative Report LJ-93-18

ABSTRACT

The National Marine Fisheries Service is responsible for the management of the northeastern stock of offshore spotted dolphin (*Stenella attenuata*) in the eastern tropical Pacific as required by the U.S. Marine Mammal Protection Act (MMPA), because dolphin are killed by U.S. boats in the tuna purse seine fishery. A pooled estimate of abundance for this newly defined stock from recent (1986-90) research vessel surveys was used in combination with estimates of fisheries kill from tuna vessel observer data to estimate the historical (pre-exploitation) population size, using a population dynamics model. Estimates of relative population size (current population size divided by historical population size) were calculated using a range of values for the maximum net recruitment rate and the maximum net productivity level (MNPL). The resulting estimates of relative population size ranged from 0.19 to 0.28, with a point estimate of 0.23 based on available life history data. Estimates of relative population size were all below the value of MNPL used to calculate each estimate. Calculation of confidence limits for relative population size by Monte Carlo simulation showed that the precision of the estimates was sufficient to make a status determination. The results indicated that, as of 1988, the stock of northeastern offshore spotted dolphin was depleted as defined by the U.S. MMPA. The substantial fisheries kill that occurred between 1988 and 1990 makes it unlikely that the population has experienced any significant recovery since then.

INTRODUCTION

Offshore spotted dolphins (*Stenella attenuata*) have been killed in the tuna purse seine fishery that operates in the eastern tropical Pacific (ETP) since at least 1959 (Perrin 1969). The purse seine fishery, which includes U.S. vessels, developed in the late 1950's after technological advances such as nylon nets and the power block (McNeely 1961). Dolphin are killed because the fishermen use the dolphins to locate schools of tuna, and often purposely surround and capture the dolphins in their nets in order to maximize their catch of tuna. Significant dolphin mortality did not start until 1959, when the fleet first adopted dolphin fishing techniques on a large scale (Joseph and Greenough 1979), with an estimated 391 sets made on dolphins in that year (Punsley 1983). It has been estimated that prior to the passage of the U.S. Marine Mammal Protection Act in 1972, nearly five million dolphins were killed in the fishery, 3.4 million of which were offshore spotted dolphins (Lo and Smith 1986, Wade 1993).

An assessment of the population condition or status of stocks of offshore spotted dolphin is required under the U.S. Marine Mammal Protection Act (MMPA) because of the involvement of U.S. vessels in the ETP tuna fishery. The MMPA requires that each marine mammal population be maintained at an "optimum sustainable population" (OSP) level, which has been defined by the U.S. National Marine Fisheries Service (NMFS) to be a population size between the maximum net productivity level (MNPL) and carrying capacity (Federal Register, 21 December 1976, 41 FR 55536). Therefore, assessing the status of a marine mammal stock involves, if possible, determining if it is above its MNPL. Populations shown to be below MNPL are considered depleted under the MMPA.

One method for determining a population's status relative to MNPL is to estimate its historical abundance (N_h), meaning its abundance prior to significant fisheries mortality, which is assumed to be equivalent to the equilibrium population size (i.e., carrying capacity). The current population size is then compared with what is thought to be the MNPL for the population, given the estimate of equilibrium population size (Gerrodette and DeMaster 1990). The historical abundance of several cetacean populations has been estimated by back-calculating from a current abundance estimate, using a population model and annual records of the number of animals harvested (Reilly 1981, Breiwick *et al.* 1980, 1984, Lankester and Beddington 1986).

An estimate of historical population size for a spotted dolphin stock can be very sensitive to a current abundance estimate, even one that occurs several decades later, because of their relatively low rate of increase (Smith and Polacheck 1979). Over a long time period (138 years), the estimate of N_h has been shown to be insensitive to the estimate of N_c for a baleen whale (*Balaena mysticetus*) population with a similarly low rate of increase (Breiwick and Braham 1990). However, for a population that has experienced a relatively recent decline from known losses, such as the offshore spotted dolphin, the estimate of N_h should still be sensitive to the estimate of N_c (Gerrodette and DeMaster 1990).

Until recently, it was thought that all offshore spotted dolphins north of 1° S were from one stock or population, termed the northern offshore spotted dolphin (Perrin *et al.* 1985). Smith

(1983) described a method for back-calculating historical population size (N_h) for offshore spotted dolphins from estimates of the current population size (N_c), the historical kill in the tuna fishery, the maximum net recruitment rate (R_m), and the maximum net productivity level. He used this technique to estimate historical abundance for the northern offshore stock of spotted dolphin, resulting in depleted estimates of relative population size (N_c/N_h) for 1979 ranging from 0.29 to 0.47. However, that stock was never formally ruled as depleted under the MMPA because of a lawsuit filed by the American Tunaboat Association in the U.S. District Court.[1] Amendments to the 1984 reauthorization of the Marine Mammal Protection Act directed NMFS to undertake a scientific research program to monitor the abundance and trends of stocks of dolphin killed in the tuna fishery (Holt *et al.* 1987). In response, NMFS completed five annual research vessel surveys between 1986 and 1990 designed to estimate the abundance of cetaceans, particularly the abundance of spotted dolphin stocks (Wade and Gerrodette 1992a).

Dizon *et al.* (1992) recently established two new geographical stocks of offshore spotted dolphin, the northeastern and western/southern (Fig. 1), based on a re-examination of cranial morphology by Perrin *et al.* (in press), making the northern stock definition obsolete. The data from the 1986-90 NMFS surveys were pooled to give a single best estimate of abundance for this newly defined northeastern stock of offshore spotted dolphin, which resulted in an estimate of abundance of 730,900 animals (Table 1, Wade and Gerrodette 1992b). The population size of this new stock was much smaller than the abundance estimate made from the same data for the previously defined northern stock (Wade and Gerrodette 1992a). Additionally, the location of dolphin sets during 1959-72 indicated that nearly all of the large kill of offshore spotted dolphin during that time period was from the northeastern stock, as the fishery did not start to move offshore substantially until 1969 (Punsley 1983). This information indicated it was necessary to assess the population status of the new northeastern stock of offshore spotted dolphin, as it was likely to be at a lower relative population size than estimated for the northern stock by Smith (1983).

To help assess the population status of the northeastern stock, the Inter-American Tropical Tuna Commission (IATTC) recently provided NMFS with revised fisheries kill estimates for the new stock for the years 1973 to 1992[2], using the methods of Hall and Lennert (in press). Additionally, the IATTC provided NMFS with annual estimates for 1959-72 of the number of sets on dolphins stratified geographically according to the new offshore spotted dolphin stock boundaries.[3] This allowed Wade (1993) to calculate revised kill estimates for the new stocks for the years 1959-72, using the same methods as Lo and Smith (1986). As expected, the majority of the estimated kill during the years 1959-72 was of northeastern offshore spotted dolphins, with a total of about 3.0 million killed, an average of more than 200,000 per year for 14 years (Table 2). After passage of the MMPA in 1972, kill of the northeastern stock fell to

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[1]ATA v. Baldrige, 738 F.2d 1013, 9th Cir., 1984.

[2]Data provided by J. Joseph, Director, IATTC, La Jolla, CA, May 18 1993.

[3]Data provided by M.G. Hinton, Senior Scientist, IATTC, La Jolla, CA, 24 June 1993.

an average of about 46,000 per year from 1973-75 (Table 2). The kill declined further in 1976 because of a quota placed on the number of dolphins killed from all species by the U.S. fleet, following litigation and a U.S. District Court ruling that NMFS had failed to discharge its obligations under the MMPA (Joseph and Greenough 1979). In 1977, individual quotas for each stock were first imposed, which led to a dramatic decrease in the kill, which averaged about 6,000 northeastern spotted per year from 1977-84 (Table 2). In the mid-1980's, the tuna purse seine fleet became increasingly composed of non-U.S. boats, which were not subject to the quotas, but were required to maintain MPS rates that were similar to the U.S. fleet. This allowed the kill of dolphins to again increase, reaching a high of 52,000 northeastern offshore spotted dolphins in 1986, averaging about 32,000 per year from 1985-90 (Table 2).

The current abundance estimate for 1988 (Table 1) and the entire time series of fisheries kill estimates through 1987 (Table 2) provided the necessary data to estimate historical population size in 1959 using the method of Smith (1983). Therefore, in this paper I used these data to estimate the historical population size for the northeastern spotted dolphin, using the same methods and the same ranges for the parameters R_m and MNPL as Smith (1983). The estimated relative population size was then used to assess the status of this stock. Confidence limits for the estimates of relative population size (current relative to historical) were calculated using Monte Carlo simulation methods as developed by Wade (in press) for a recent stock assessment of the eastern spinner dolphin (*Stenella longirostris orientalis*). This analysis will help NMFS to rule on a recent proposal (September, 1992, 57 FR 40168) to list the northeastern stock of offshore spotted dolphin as depleted under the U.S. Marine Mammal Protection Act.

METHODS

POPULATION MODEL

The methods of Wade (in press) were duplicated, using the simple recursive relationship

$$N_{t+1}=N_t-K_t+R_t\left(N_t-\tfrac{1}{2}K_t\right) \qquad (1)$$

where

N_t = population abundance in year t
K_t = fisheries kill in year t
R_t = net recruitment rate in year t.

Density-dependence is incorporated into the equation through the net recruitment rate, which is defined as

$$R_t = R_m \left[1 - \left(\frac{N_t}{N_h} \right)^z \right] \qquad (2)$$

where

R_m	=	maximum net recruitment rate
z	=	shape parameter that sets the maximum net productivity level (MNPL)
N_h	=	historical population size (assumed to be the equilibrium population size)

For any value of R_m and MNPL, z can be calculated as in Polachek (1982). Equation 1 can be solved for N_t as a function of N_{t+1}, R_t, and K_t. Therefore, by specifying an initial population size, the number of animals killed in each year, the maximum net recruitment rate, and the maximum net productivity level, these two equations can be iteratively solved for N_h. Because the abundance estimate was calculated from data pooled over 1986-90, the population trajectory was back-calculated from the mid-point of that time period, 1988, using the fisheries kill data through 1987.

CONFIDENCE LIMITS FOR N_h

For every combination of the parameters R_m and MNPL, confidence limits for relative population size were calculated by a Monte Carlo simulation (Buckland 1984) which incorporated the sampling error of the current abundance and kill estimates. This was the same method used by Wade (in press) to estimate the precision of estimates of relative population size for the eastern spinner dolphin. For completeness, the method will be fully described here.

On each of 1000 iterations, an artificial data set was randomly generated by sampling values for the current abundance and for the fisheries kill in each year. These values were each drawn from Gaussian distributions with means and variances equal to the appropriate point estimates. Relative population size was then estimated for each of these artificial data sets, and 95% confidence limits for relative population size were calculated using the percentile method (Efron 1982).

The kill estimates for 1959-72 were not independent from each other, as Wade (1993) estimated the kill in each year by multiplying stratified mortality-per-set rates from pooled 1964-72 observer data by the numbers of sets on dolphin in each stratum in each year. Therefore, on each simulation iteration the kill values for 1959-72 were randomly generated using the same random deviate. This resulted in the kill values for those years being perfectly correlated amongst themselves from simulation trial to trial, which correctly reflected the lack of independence in the actual estimates. The kill values for all other years were sampled independently.

ESTIMATES OF R_m AND MNPL

R_m can be estimated from appropriate life history data. The northern offshore spotted dolphin was estimated to have an age of sexual maturity (ASM) of 12.2 years and a calving interval (CI) of 3 years (Myrick *et al.* 1986). Fortunately, nearly all the dolphins used in that study were from the northeastern stock area, and a re-calculation of Myrick *et al.*'s (1986) data excluding the few animals that were outside the northeastern stock area did not change the estimate of ASM (personal communication, Susan Chivers, Southwest Fisheries Science Center, La Jolla, CA). Therefore, the estimates of Myrick *et al.* (1986) can be used as estimates for the northeastern stock.

An ASM of 12 years and a CI of 3 years leads to an estimate of the rate of increase of about 0.04 from Reilly and Barlow (1986), using the highest adult survival rate they considered of 0.97. The same estimates for ASM and CI were used with more realistic survival curves based on model life tables from northern fur seals, Old World monkeys, and humans, to give estimates for R_m between 0.972 and 0.042 (Barlow and Boveng, 1991). The value of 0.042 resulted from using the most optimistic survival schedule patterned after a human population. If the true values for the population were as low as an ASM of 10 years and a CI of 2 years, the estimate of R_m would be about 0.06, again using the highest considered survival rate of 0.97 from Reilly and Barlow (1986). Therefore, 0.06 was likely the highest possible value of R_m for this population, and the rounded value of 0.04 from Barlow and Boveng (1991) can serve as a point estimate. I used values ranging from 0.01 to 0.06 by increments of 0.01, for a total of 5 values. 0.06 was the same maximum value used by Smith (1983) and Wade (in press).

Values used by Smith (1983) for MNPL were 0.50, 0.65, and 0.80 (MNPL is expressed as a fraction of equilibrium population size in this paper), corresponding to z values (see Eq. 4) of 1.0, 3.482, and 11.216, respectively. These encompassed the range of estimated values of MNPL for long-lived marine mammals, such as dolphins, based on work by Fowler (1981). No direct estimate of MNPL exists for the northeastern spotted dolphin. Fowler (1984) gave evidence that MNPL was greater than 0.50 for cetaceans. A value of 0.60 is currently being used for management of cetaceans under the U.S. MMPA (Federal Register, 31 October, 1980, 45 FR 64548), and for this paper, will be considered the best point estimate of MNPL currently available for the northeastern spotted dolphin. Values of z were used so that MNPL ranged from 0.50 to 0.80 (the same range as in Smith, 1983), using increments of 0.05, for a total of 7 values. The 6 values used for R_m and the 7 values used for MNPL produced a total of 42 parameter combinations for which relative population size was estimated.

RESULTS

Relative population size (N_c/N_h) ranged from 0.19 to 0.28 (Table 3). Relative population size increased with both R_m (recruitment rate) (Fig. 2) and MNPL (the amount of non-linearity in the density-dependence response). The lowest relative population size of 0.19 was for the case of a value of 0.01 for R_m (i.e., 1% net growth in the population before fisheries kill was included) and a value of 0.50 for MNPL. The highest relative population size of 0.28 was for the case of the highest R_m of 0.06 and a value for MNPL of 0.80. These low and high estimates of relative population size correspond to estimates of pre-exploitation abundance in 1959 of

3,827,000 and 2,573,000 respectively. There were no combinations of parameter values such that relative population size was estimated to be above MNPL. Using point estimates of 0.04 for R_m and 0.60 for MNPL resulted in an estimated relative population size of 0.23, with an estimate of N_h of 3,141,000.

The upper 95% confidence limit for relative population size as a function of R_m and MNPL, based on the sampling error of the abundance and kill estimates, ranged from 0.36 to 0.61 (Table 3). The upper confidence limit was also below the value used for MNPL for all parameter combinations. The lower 95% confidence limit for relative population size as a function of R_m and MNPL, ranged from 0.12 to 0.17.

When the point estimates of 0.04 for R_m and 0.60 for MNPL were used, the population trajectory declined until 1977 (Fig. 3), at which time the estimated fisheries kill declined substantially (Table 2). The population trajectory showed a slightly increasing trend from 1978 to 1986, and then declined slightly again in 1987 and 1988 (Fig. 3).

DISCUSSION AND CONCLUSIONS

The population size in 1988 of northeastern spotted dolphins was estimated to be well below MNPL for all parameter values used in this study. Because the ranges of values used should span the true values for this stock, the uncertainty in these values does not prevent a definitive conclusion from being reached. At best, the population was estimated to be at only 28% of its 1959 population size. As can be seen from the population trajectory (Fig. 3), this decline was mostly due to the large fisheries kill that occurred between 1960 and 1976. For all 42 parameter combinations, the population was estimated to be at less than half of MNPL, indicating the stock is not close to being at OSP. For example, for the point estimates of 0.04 for R_m and 0.60 for MNPL, the population was estimated to be at 23% of historical population size, far below the MNPL value of 60%.

Calculation of confidence limits for relative population size showed that the precision of the estimates was sufficient to make a status determination. Incorporating the sampling error of the current abundance estimate and the fisheries kill estimates provided confidence limits around the estimated relative population sizes (Fig. 2), but in all cases the upper 95% confidence limit was still below MNPL, and never exceeded 61% of historical population size. Viewed in a hypothesis testing context, this result indicated that the null hypothesis that relative population size was greater than MNPL in 1988 could be rejected for all parameter combinations.

The confidence limits around relative population size were all greater proportionally than the confidence limits around N_c. From the simulation, it was also possible to calculate a coefficient of variation (CV) for relative population size, in addition to the confidence limits. These estimated CV's for relative population size ranged from 29% to 37%, much larger than the 14% CV on the current abundance estimate. The CV of relative population size reflects the large uncertainty in the fisheries kill estimates, particularly in the early years. However, if it can be assumed that there was no large positive bias in the fisheries kill estimates, then the imprecision of the fisheries kill estimates was not so large as to prevent a definitive stock assessment. Any large potential biases in the fisheries kill appear to be negative, indicating that fisheries kill may have been under estimated (Wade in press, Wade 1993). An under estimate of fisheries kill would lead to an over estimate of relative population size, which would not change the result from a management perspective, as the population would still be considered depleted.

The accuracy of the fisheries kill estimates prior to 1971 depended on several important assumptions, the primary one being that the stratified MPS rates were constant from 1959-72 (Wade 1993). However, it must be emphasized that the number of sets made on dolphin for that time period were known with very high precision (Punsley 1983), and what was lacking were more observations of MPS prior to 1971. The kill estimates were made based on only 3 observed trips prior to 1971 pooled with 17 observed trips from 1971-72, although there is information from at least four other trips prior to 1971 that their kill rates were consistent with the observed trips (Wade 1993). Because the three observed trips prior to 1971 were not part of an established observer program (Smith and Lo 1983), Wade (1993) showed that removing the data from those three trips had an insignificant effect on the kill estimates. However, it will probably never be possible to conclusively test all the assumptions implicit in estimating kill for that time period. Therefore, it is worthwhile to ask the question, how biased must the kill estimates for that time period have been for the stock to not currently be depleted? To answer that question, I solved for how much lower the 1959-70 mortality would have to have been for the population to currently be at MNPL. I re-calculated relative population size assuming R_m of 0.04 and an MNPL of 0.60, and found that for the northeastern stock to be at MNPL, 1959-70 mortality would have to be 12% of the estimates in Table 2. This means that the kill would have to have been overestimated by almost an order of magnitude, extremely unlikely given the fairly similar MPS rates observed in 1973, for which much more data were available.

I addressed this issue in another way by re-calculating estimates of the 1959-72 kill using the methods of Wade (1993) but using the greater amount of data available by pooling 1971-73 observer data, rather than using the pooled 1964-72 observer data. These were likely underestimates of the kill because of the decline in MPS in 1973. Using these kill estimates and the same values as above for R_m and MNPL, the northeastern stock of offshore spotted was estimated to be at a relative population size of 0.46. Finally, I estimated 1959-72 kill by multiplying the number of dolphin sets in the northeastern stock area (Wade 1993) by the average dolphin MPS from 1974 (the first year a formal randomized design was used to place observers on fishing vessels) as calculated from Wahlen (1986), prorating by the observed 1971-72 proportion of spotted dolphins in the kill of 0.964. Using these estimates of the kill, the northeastern stock was still estimated to be at a population size of less than MNPL. The population was thus also estimated to be depleted even using these later kill rates, which were undoubtedly lower than the kill rates before the passage of the MMPA in 1972. Therefore, it can be concluded the northeastern stock of offshore spotted dolphin was not estimated to be depleted because of an artifact of the small sample size of observer data available prior to 1973.

CURRENT STATUS

An independent assessment of population trend of the northeastern spotted dolphin is available from the population abundance index calculated by Anganuzzi and Buckland (1993) from tuna vessel observer data (Edwards 1989). Their estimated population trend starts in 1975, and shows a statistically significant decline until 1983. This represents a population decline of 35% over those eight years. This population trajectory declines for several more years than the population trajectory calculated here, but this may be explained by the fact that the population model used here does not take into account the age structure of the kill, as discussed in Wade (in press) and Goodman (1984). The fisheries kill was biased towards mature animals (Barlow and Hohn 1984), meaning that after the fisheries kill dropped in 1977 to a level that would allow for positive population growth at stable age distribution, the population apparently continued to decline because of the natural lag induced by the relatively old ASM of 12 years. The population may only have been able to start growing when a sufficient number of females had become sexually mature, apparently around 1984 according to the population trend of Anganuzzi and Buckland (1993).

Although the estimates of Anganuzzi and Buckland (1993) indicated the population grew between 1983 and 1986, it has apparently been fairly level since 1986, at a level in 1991 still significantly below the population level in 1976, with the population estimated to be at approximately 75% of its size in 1976. Given the large fisheries kill known to have occurred before 1975 (Table 2), this would be sufficient evidence in itself to indicate that the northeastern stock of offshore spotted dolphin was depleted. A population that, as of 1975, had sustained an average fisheries kill of an estimated 190,000 animals per year for 16 years (Table 2), and then declined a further 25% to a level of about 730,000 animals, is highly likely to be at less than 60% of its initial population size in 1959. The trend of Anganuzzi and Buckland (1993) thus corroborates the analysis done in this paper, giving a second independent assessment indicating the population is depleted.

The lack of significant growth between 1988 and 1992 (Anganuzzi and Buckland 1993) indicates that the status as calculated in this paper for 1988 is the same in 1992. Fisheries kill estimates in 1988, 1989, and 1990 (26,625, 28,898, and 22,616, respectively) were between 3% and 4% of the population abundance estimate of 730,900, which would have prevented any substantial population growth given the estimated rate of increase of only 4%. The fisheries kill declined dramatically in 1991 and 1992 to only 9,005 and 4,636, respectively, values of approximately 1% and 0.5% of the population size. This evidence indicates the population should have increased slightly between 1990 and 1992, which was supported by the trend data (Anganuzzi and Buckland 1993). However, the population could only have grown by about 6% in total, which would make the status in 1992 unchanged from the status in 1988. If fisheries kill remains at the current lower level of less than 5,000 per year, the population should eventually increase and recover.

Although there are uncertainties associated with this analysis, especially with the early kill data, the results indicated that the northeastern spotted dolphin population was well below historical abundance levels in 1988. It can therefore be concluded that, as of 1988, the northeastern stock of offshore spotted dolphins was depleted as defined by the U.S. MMPA. The substantial fisheries kill that occurred between 1988 and 1990 makes it unlikely that the population has experienced any significant recovery since then.

ACKNOWLEDGEMENTS

I would like to thank the many people who contributed to the collection and analysis of the data used in this paper, particularly the observers on the research and tuna vessels. I also thank Robert Brownell, Tim Gerrodette, Stephen B. Reilly, and Barbara L. Taylor for their helpful comments which improved this manuscript considerably.

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Table 1

Estimate of abundance (in thousands of animals) of the northeastern spotted dolphin (*Stenella attenuata*) from National Marine Fisheries Service research vessel surveys, 1986-90 (Wade and Gerrodette 1992b).

	Abundance
From:	
Northeastern spotted dolphin schools	663.3
Prorated from unid. spotted dolphins	5.5
Prorated from unid. dolphins	62.1
Total estimate	730.9
Standard error	103.6
Coefficient of variation	0.142
Upper 95% confidence limit	970.4
Lower 95% confidence limit	588.7

Table 2

Estimates of fisheries kill in thousands by year for the northeastern stock of offshore spotted dolphin (*Stenella attenuata*). CV is the coefficient of variation of the kill estimate. Sources for the estimates are (1) 1959-72 from Wade (1993) and (2) 1973-92 from the Inter-American Tropical Tuna Commission (data provided by J. Joseph, Director, IATTC, La Jolla, CA, May 18, 1993).

Year	Kill	CV
1959	15.9	0.53
1960	344.0	0.52
1961	366.0	0.48
1962	141.0	0.42
1963	158.2	0.36
1964	272.3	0.28
1965	318.5	0.29
1966	244.1	0.22
1967	171.8	0.23
1968	161.2	0.22
1969	271.5	0.22
1970	218.7	0.22
1971	111.3	0.22
1972	168.1	0.17
1973	49.9	0.18
1974	37.4	0.11
1975	49.4	0.18
1976	20.4	0.23
1977	5.9	0.12
1978	4.2	0.20
1979	4.8	0.17
1980	6.5	0.15
1981	8.1	0.19
1982	9.3	0.17
1983	2.4	0.27
1984	7.8	0.19
1985	26.0	0.12
1986	52.0	0.16
1987	35.4	0.12
1988	26.6	0.10
1989	28.9	0.11
1990	22.6	0.11
1991	9.0	0.11
1992	4.6	0.07

Table 3

Estimates of relative population size, defined as current abundance divided by initial abundance (N_c/N_h) for the northeastern stock of offshore spotted dolphin, for 42 combinations of R_{max} (the maximum intrinsic rate of increase), and MNPL (maximum net productivity level). Also shown in parentheses are the lower and upper 95% confidence limits on relative population size.

MNPL \ R_{max}	.01	.02	.03	.04	.05	.06
.50	.19 (.12,.36)	.20 (.13,.38)	.21 (.13,.41)	.22 (.13,.42)	.23 (.14,.43)	.23 (.14,.45)
.55	.19 (.12,.38)	.20 (.12,.38)	.22 (.13,.40)	.23 (.13,.46)	.24 (.14,.46)	.25 (.15,.49)
.60	.20 (.12,.37)	.21 (.12,.39)	.22 (.13,.42)	.23 (.14,.46)	.25 (.15,.47)	.26 (.15,.50)
.65	.20 (.12,.39)	.21 (.13,.38)	.23 (.13,.44)	.24 (.15,.48)	.25 (.15,.51)	.27 (.15,.54)
.70	.20 (.12,.37)	.21 (.13,.42)	.23 (.14,.48)	.24 (.14,.51)	.26 (.15,.52)	.27 (.16,.55)
.75	.20 (.12,.38)	.22 (.13,.43)	.23 (.14,.46)	.25 (.15,.49)	.26 (.15,.54)	.28 (.16,.57)
.80	.20 (.12,.37)	.22 (.13,.42)	.23 (.14,.47)	.25 (.15,.52)	.27 (.16,.61)	.28 (.17,.60)

LIST OF FIGURES

Figure 1

All sightings of offshore spotted dolphins (squares) from National Marine Fisheries Service research vessel surveys, 1986-90. The dashed line represents the dividing line for assigning sightings to the offshore stocks, with all offshore spotted sightings to the north and east of the line assigned to the northeastern stock (northeast), and offshore sightings to the south and west of the line assigned to the western/southern stock (west/south).

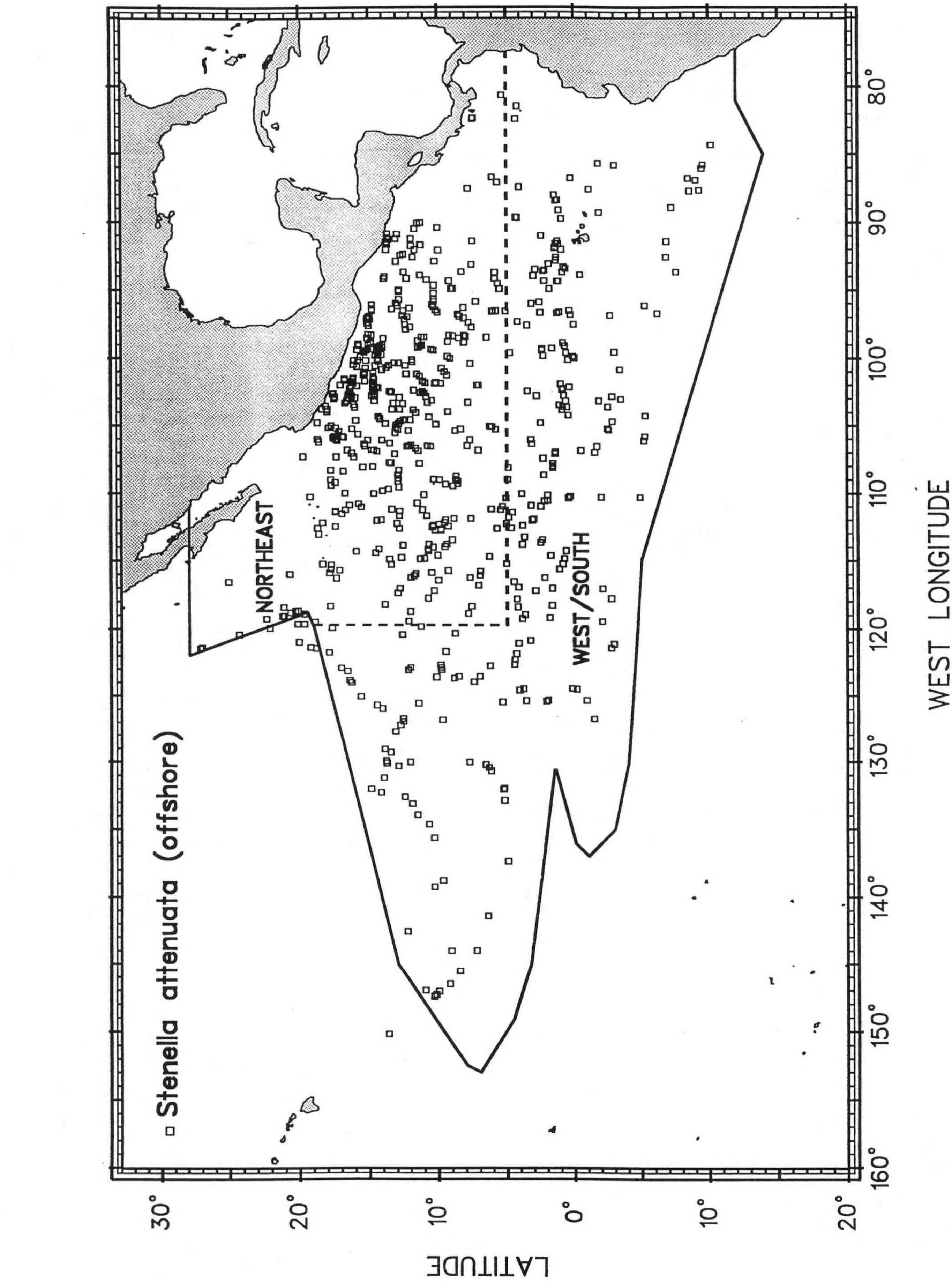
Figure 2

Point estimates and 95% confidence limits for relative population size for the northeastern offshore spotted dolphin (*Stenella attenuata*), as a function of the maximum net recruitment rate (R_m), for the estimate of the maximum net productivity level (MNPL=0.60) currently used for management under the U.S. Marine Mammal Protection Act.

Figure 3

Population model trajectory for the northeastern stock of spotted dolphin (*Stenella attenuata*) for the point estimates of 0.04 for the maximum net recruitment rate (R_m) and 0.60 for the maximum net productivity level (MNPL), leading to an estimate of historical (pre-exploitation) size in 1959 of 3,141,000 and an estimate of relative population size (current population size divided by historical population size) of 0.23. Also plotted are the upper and lower 95% confidence limits of population size for each year for those parameter values.

Figure 1



Stenella attenuata (offshore)
NORTHEAST
WEST/SOUTH
WEST LONGITUDE
LATITUDE
80°
90°
100°
110°
120°
130°
140°
150°
160°
30°
20°
10°
0°
10°
20°

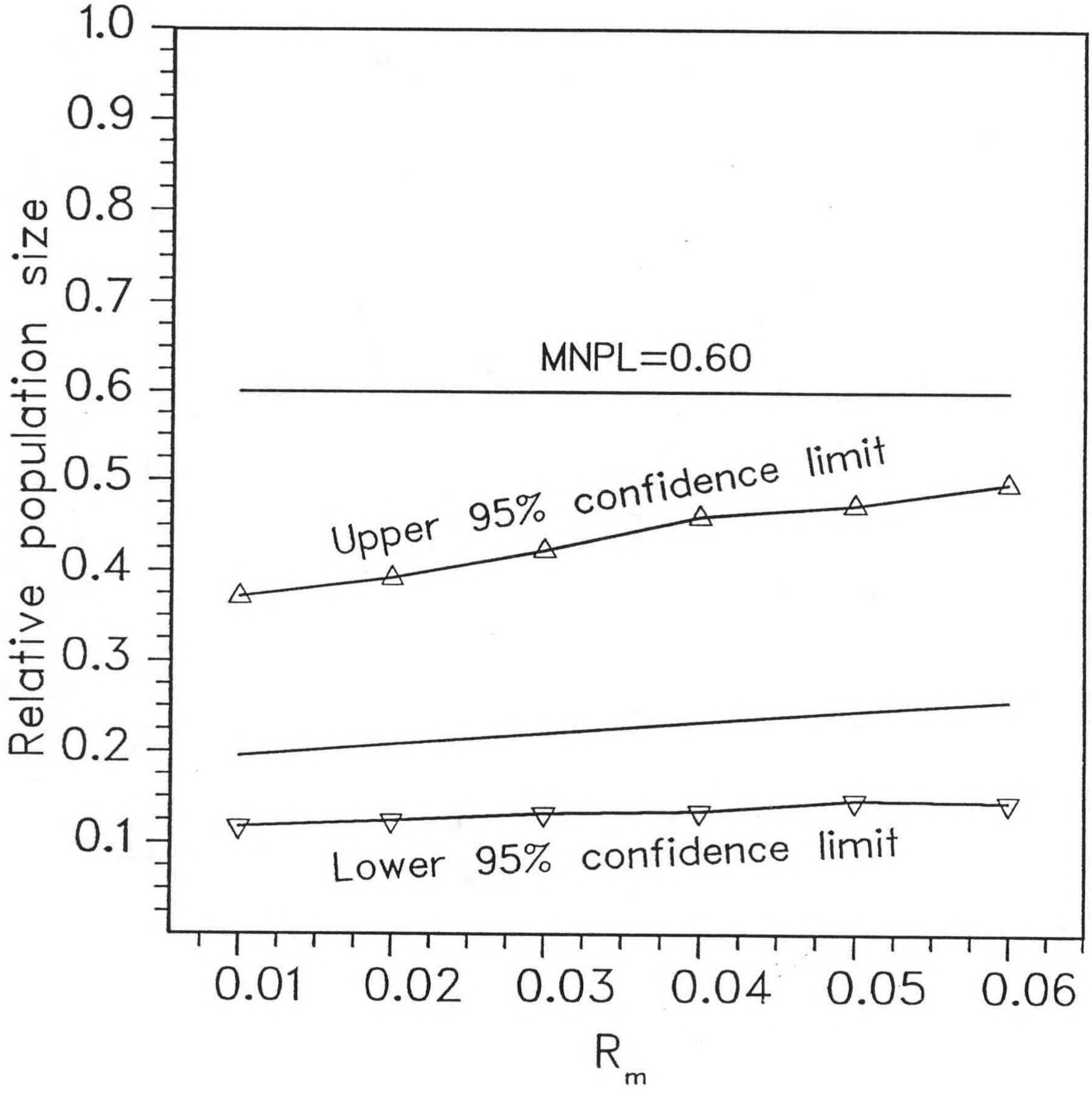
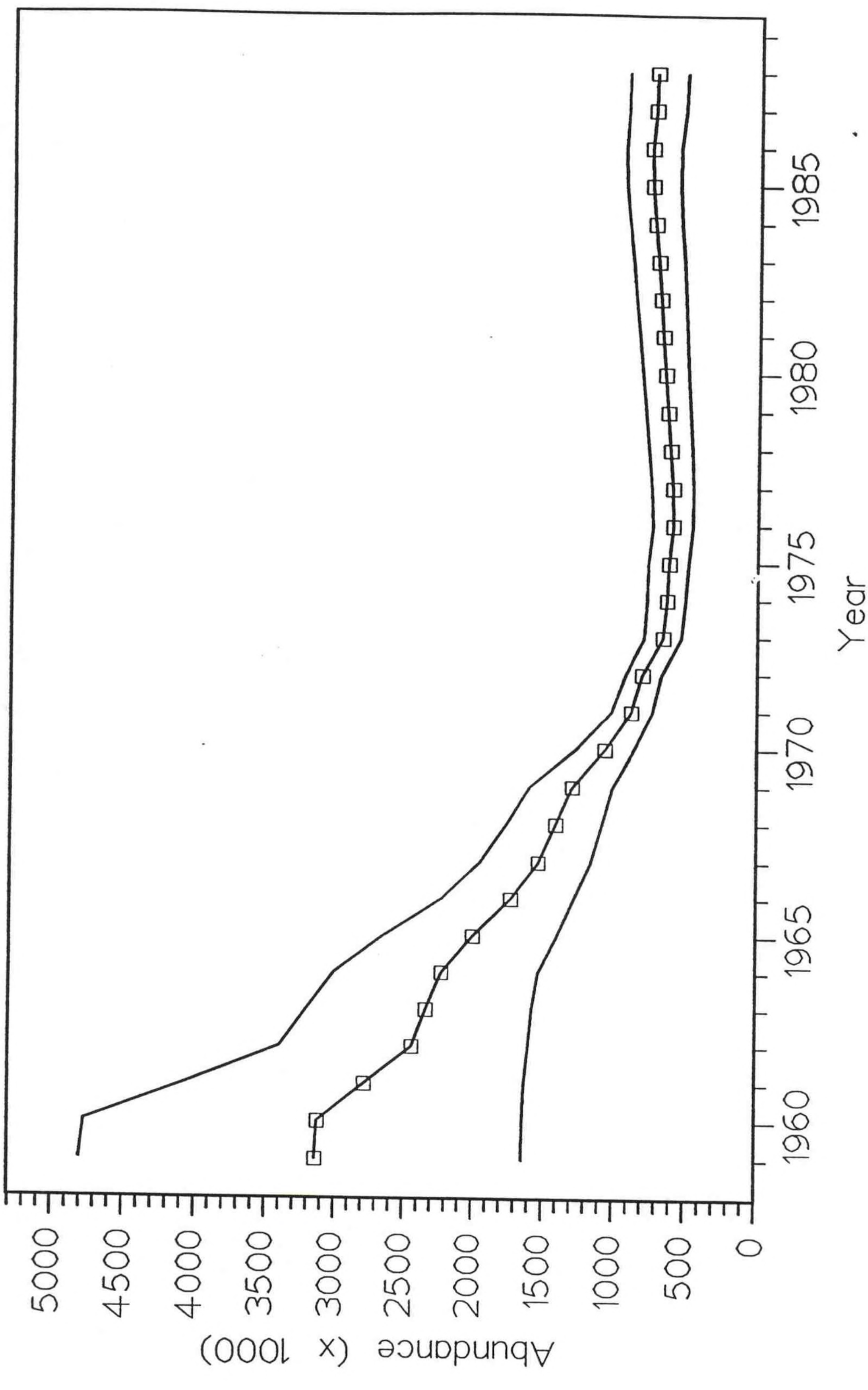

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Relative population size
MNPL=0.60
Upper 95% confidence limit
Lower 95% confidence limit
0.01
0.02
0.03
0.04
0.05
0.06
R m

Figure 3



Abundance (x 1000)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Year
1960
1965
1970
1975
1980
1985