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INTRODUCTION

The purse-seine fishery for tuna in the eastern tropical Pacific (ETP) Ocean results in the mortality of several species of cetaceans. The primary species affected are spotted dolphins, *Stenella attenuata*, spinner dolphins, *Stenella longirostris*, and common dolphins, *Delphinus delphis* (Smith 1983, Wahlen 1986, Lennert and Hall 1995, Wade 1995). The northeastern stock of spotted dolphins and the eastern subspecies of spinner dolphins have been so reduced in size that they have been declared "depleted" under the U.S. Marine Mammal Protection Act (Wade 1993a, b).

CALCULATION OF MORTALITY LIMITS

Mortality limits under U.S. law

Under the U.S. Marine Mammal Protection Act (MMPA) of 1972, marine mammal populations are supposed to be managed so that each is maintained at an optimum sustainable population (OSP) level, defined as a level between carrying capacity and the maximum net productivity level. Various methods have been used to estimate whether populations are at such a level (Gerrodette and DeMaster 1990). However, in 1980, management of ETP dolphins was separated from other U.S. marine mammal populations by the establishment of a specific annual mortality quota of 20,500 dolphins. Although quotas have been modified and other provisions added since then, ETP dolphins continue to be managed differently from other marine mammals.

Beginning in 1984, amendments to the MMPA required that non-U.S. fishermen adopt fishing methods and achieve dolphin mortality rates comparable to U.S. fishermen. Failure of some countries to meet these comparability standards has resulted in embargoes of tuna products into the U.S (Joseph 1994). After 1992 the number of dolphins killed by U.S. fishermen was required to decline "by statistically significant amounts each year to levels approaching zero by December 31, 1999" (MMPA, Sec. 306). Due to various factors, the number of U.S. boats in this fishery has declined over the years, and fewer and fewer of these boats caught tuna by setting on dolphins. In 1995, no U.S. fishermen set on dolphins, and the U.S. kill of dolphins in the ETP was 0. Therefore, beginning in 1996, even a single dolphin mortality by U.S. fishermen is not allowed. With no dolphin mortality by U.S. fishermen, it is nearly impossible for non-U.S. fishermen to meet the comparability standards except by stopping dolphin fishing altogether. At the present time, Congress is considering amendments to the MMPA that would change this situation.

U.S. management of incidental mortality of marine mammals (other than ETP dolphins) changed significantly in 1995. The 1994 amendments to the MMPA specified that the maximum number of marine mammals of a particular stock (management unit) that will be permitted to be

removed from the population each year is computed according to a simple formula (Barlow et al. 1995)

$$PBR = N_{min} \frac{1}{2} r_{max} F_R ,$$

where N_{min} = a minimum estimate of population size,
r_{max} = the maximum intrinsic net recruitment rate for the population,
F_R = a "recovery" factor between 0.1 and 1.0.

This calculation of allowable anthropogenic mortality is termed Potential Biological Removal (PBR). While ETP dolphins are specifically exempted from this management scheme, there is utility in computing what such limits would be in order to compare them to limits under other management plans, such as the La Jolla Agreement and the Declaration of Panama.

The first term of the PBR equation is a minimum estimate of population size. The Southwest Fisheries Science Center carried out line-transect surveys in 1986-90, 1992, and 1993 with the specific objective of estimating population sizes for dolphins affected by the ETP purse-seine tuna fishery. Estimates of abundance for all species, together with coefficients of variation for those estimates, were published by Wade and Gerrodette (1993) (Table 1). These estimates pooled data collected over a 5-year period from 1986-90, and the estimates of abundance were therefore applied to 1988, the middle year of the series. In 1992 and 1993 surveys were carried out to improve the estimates for central and northern common dolphins, respectively, which were not well estimated by the 1986-90 surveys. Estimates of abundance from these cruises have not been published, although preliminary results from the 1992 survey were reported to the Scientific Committee of the International Whaling Commission as a working document (Gerrodette 1993). In this paper unpublished analyses of the 1992 and 1993 data are used to provide better (and more recent) estimates of abundance for central and northern common dolphins (Table 1).

Based on simulations of the performance of the PBR algorithm (Taylor 1993, Wade 1994b, 1996), a minimum estimate of population size, N_{min}, is calculated for each stock by taking the lower 20th percentile of a log-normally distributed estimate of abundance (Barlow et al. 1995). This is calculated as

$$N_{min} = \frac{N}{\exp[0.842\sqrt{\ln(1+CV^2)}\,]}$$

where N is the estimate of abundance and CV is the coefficient of variation of the estimate (Table 1). Because any estimate becomes less certain with time, N_{min}, which is a number that

"provides reasonable assurance that the stock size is equal to or greater than the estimate" (MMPA, Sec. 3) should decline as the data on which it is based become older. To address this issue, the first version of the PBR guidelines specified that F_R (and hence *PBR*) should be progressively reduced by 10%/year when the estimates of abundance are more than 5 years old, unless "compelling evidence indicates that a stock has not declined since the last census" (Barlow et al. 1995). A later workshop, however, recommended that F_R not be reduced after 5 years, but that estimates of abundance more than 8 years old not be considered valid estimates of current abundance (Wade and Angliss 1996). By the latter criterion, after 8 years N_{min} (and hence *PBR*) cannot be determined. For most ETP dolphin stocks, estimates of abundance are based on data centered on 1988, and estimates of abundance will thus no longer be considered valid after 1996. However, estimates of abundance for the central and northern stocks of common dolphins will be valid until 2000 and 2001, respectively (Table 1).

The second factor in the PBR equation is r_{max}, the maximum intrinsic net rate of increase. For northeastern spotted and eastern spinner dolphins, specific estimates of 0.038 and 0.022 are available (Wade 1994a); for other stocks, the default value for cetaceans of 0.04 is used (Barlow et al. 1995) (Table 1).

The third term is the recovery factor F_R, a factor designed to provide an additional safety margin for populations that are endangered, threatened, or depleted, or when information about the population is uncertain (Wade 1996). The PBR guidelines (Barlow et al. 1995) set default values for endangered populations (F_R=0.1), for threatened or depleted populations (F_R=0.5), and for populations of unknown status (F_R=0.5). Northeastern spotted and eastern spinner dolphins are currently far below their former population sizes (Smith 1983, Wade 1993a, b, 1994a), and they have been officially classified as depleted under the MMPA; therefore, F_R = 0.5 (Table 1). There is strong evidence that southern common dolphins have not been reduced in abundance by the tuna fishery (Gerrodette and Wade, in prep.), so F_R=1.0 for this stock (Table 1). Western/southern spotted, whitebelly spinner, and northern and central common dolphins have been reduced to 65-80% of their former abundance (Gerrodette and Wade, in prep.). For these stocks, for which there is less certainty about their status, F_R=0.75 (Table 1).

Other factors that may affect the value of F_R are the quality and quantity of the information on stock structure, abundance, and mortality. In the case of the ETP tuna fishery, there is generally good information for all of these. The stock structure has been well-studied (Perrin et al. 1985, 1991, 1994, Dizon et al. 1994). Information on incidental mortality for each stock is precise and current (Hall and Lennert 1996), although such data provide minimum estimates of mortality because they do not include deaths due to injuries or to the stressful effects of chase and encirclement (Myrick and Perkins 1995). Estimates of relative abundance are made annually based on a very detailed analysis of large numbers of dolphin sightings from tuna vessels (Anganuzzi and Buckland 1989) and show declines for most stocks in the last decade (Anganuzzi and Buckland 1995). Estimates of absolute abundance are based on dedicated, large-scale, line-transect surveys conducted by research vessels (Wade and

Gerrodette 1993), although, as noted above, estimates for most of the ETP dolphin stocks are 8 years old and, hence, at the limit of what are considered current estimates of abundance. Simulations have shown that a value of $F_R = 0.5$ or lower is necessary if there are significant biases in the estimates of abundance, mortality, or growth rate, or if estimates of abundance are made at intervals as long as 8 years (Wade 1996), as is the case here. F_r as low as 0.15 is necessary to prevent a delay in recovery if a population has been reduced to 5% of its former abundance (Wade 1996); northeastern spotted and eastern spinner stocks have been reduced to 16-20% of their former abundance. Given the generally high quality of the data on ETP dolphins, however, it is considered reasonable to assign values of $F_R > 0.5$ for most stocks (Table 1). In the case of the depleted northeastern spotted and eastern spinner stocks, using $F_r = 0.5$ will delay the recovery of these stocks if incidental mortality were equal to *PBR* each year (Wade 1996).

Mortality limits calculated according to the PBR equation are presented in Table 2 from 1996 to 2001 for the major ETP dolphin stocks affected by the tuna purse-seine fishery.

Mortality limits under international agreements

In April, 1992, 10 governments, including the U.S., agreed to a program of dolphin mortality reduction in a document called the La Jolla Agreement. The objectives of the Agreement were "1) progressively reducing dolphin mortality in the EPO [Eastern Pacific Ocean] fishery to levels approaching zero through the setting of annual limits and 2), with a goal of eliminating dolphin mortality in this fishery, seeking ecologically sound means of capturing large yellowfin tuna not in association with dolphins while maintaining the populations of yellowfin tuna in the EPO at a level which will permit maximum sustained catches year after year." A series of annual limits on dolphin mortality were established that would reduce total mortality to fewer than 5,000 dolphins by 1999 (Joseph 1994). The annual dolphin mortality limits were implemented through individual vessel allocations and a program of 100% observer coverage. This voluntary agreement has been extremely successful in reducing dolphin mortality, and the 1999 goal of fewer than 5,000 dolphin mortalities was achieved by 1993 (Lennert and Hall 1995).

In October, 1995, representatives of 12 governments, including the U.S., signed the Declaration of Panama. If this agreement were ratified into law by the U.S. and other countries, the mortality limit schedule of the La Jolla Agreement would be accelerated by imposing a 5,000-dolphin limit immediately instead of in 1999, and new per-stock limits of 0.2% of N_{min} (as calculated above) would be instituted. In 2001, these limits would be reduced to 0.1% of N_{min}. Mortality limits under the Declaration of Panama for each major dolphin stock are shown in Table 2.

RESULTS AND DISCUSSION

Mortality limits for ETP dolphins by PBR calculation are higher than would be allowed under the Declaration of Panama. PBR mortality limits for 1996 are 3-10 times higher than allowed under the Declaration of Panama, depending on stock (Table 2). In 2001 mortality limits under the Declaration of Panama will become half of their previous amount, shifting from 0.2% to 0.1% of N_{min}. At that time, however, PBR mortality limits for most ETP dolphin stocks will be undefined unless new surveys are undertaken, because the abundance estimates will be considered out of date. The Declaration of Panama does not explicitly address the issue of how current estimates of abundance must be. The figures in Table 2 assume that no new cruises will be undertaken to provide updated estimates of abundance. If new abundance surveys are undertaken, *PBR* for each stock could either increase or decrease, depending on the new values for N_{min} that resulted from the survey.

The 1994 MMPA created two goals for maintaining low mortality levels of marine mammals incidental to fisheries in U.S. waters. PBR calculation is a short-term goal to reduce mortality to a level that would allow each population to recover to or to remain at its OSP level. The Zero Mortality Rate Goal (ZMRG) is a longer-term goal to reduce incidental mortality rates to "insignificant levels approaching zero mortality and serious injury rate" by the year 2001. For the ETP purse-seine tuna fishery, however, the ZMRG is defined in a technological sense as "the continuation of the application of the best marine mammal safety techniques and equipment that are economically and technologically practicable." For other fisheries, the PBR guidelines define ZMRG as 10% of the PBR (Barlow et al. 1995). The mortality limits under the Declaration of Panama in 2001 (0.1% of N_{min}) are equivalent to zero mortality rate goal limits (10% of PBR) with default values in the PBR equation (r_{max}=0.04, F_R=0.5). As shown in Table 2, current dolphin mortality is less than 1996 PBRs for all stocks. Current mortality also meets the ZMRG (10% of PBR) for 5 of the 7 stocks; mortality is greater than 10% of PBR for northeastern spotted and eastern spinner dolphins (Table 2).

CONCLUSION

Mortality limits proposed under the Declaration of Panama are considerably less than would be allowed if the PBR management regime specified by the 1994 MMPA amendments were to be applied to ETP dolphins. The differences vary by stock from a factor of 2.75 for eastern spinner dolphins to 10 for southern common dolphins. Computation of mortality limits under the Declaration of Panama only requires a minimum estimate of abundance for each stock, while the PBR equation requires other information. Finally, estimates of abundance must be no more than 8 years old to be considered valid when used in PBR calculation, while the Declaration of Panama does not address the issue of how current an estimate of abundance must be.

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Table 1. Estimates of abundance (N), coefficient of variation (CV), period during which estimate of abundance is considered valid, minimum estimate of abundance (N_{min}), maximum intrinsic net rate of increase (r_{max}), recovery factor (F_R), and basis for setting F_R, for major eastern tropical Pacific dolphin stocks. See text for references and further explanation.

Dolphin stock	N	CV	**valid period**	N_{min}	r_{max}	F_R	**Basis for setting F_R**[1]
Northeastern spotted	730,900	0.142	1988-1996	648,920	0.038	0.5	Depleted
Western/southern spotted	1,298,400	0.150	1988-1996	1,145,149	0.04	0.75	Reduced
Eastern spinner	631,800	0.238	1988-1996	518,495	0.022	0.5	Depleted
Whitebelly spinner	1,019,300	0.187	1988-1996	871,982	0.04	0.75	Reduced
Northern common	713,700	0.288	1993-2001	562,719	0.04	0.75	Reduced
Central common	239,350	0.172	1992-2000	207,298	0.04	0.75	Reduced
Southern common	2,210,900	0.217	1988-1996	1,845,561	0.04	1.0	Not reduced

[1] Depleted = designated as a depleted stock under the MMPA; Reduced = above OSP, but reduced to 65%-80% of former abundance; Not reduced = at or near former abundance.

Table 2. Mortality limits for major eastern tropical Pacific dolphin stocks as calculated under the U.S. PBR scheme for 1996-2001 assuming no new estimates of abundance, and under the Declaration of Panama for the same time period. The last column shows reported mortality for 1995 (Hall and Lennert 1996). U means PBR is undefined because the estimate of abundance on which the PBR calculation is based is not current (more than 8 years old).

	Potential Biological Removal (PBR)						Declaration of Panama		
Dolphin stock	**PBR 1996**	**PBR 1997**	**PBR 1998**	**PBR 1999**	**PBR 2000**	**PBR 2001**	**0.2% N_{min} 1996-00**	**0.1% N_{min} 2001**	**1995 mortality**
Northeastern spotted	6,165	U	U	U	U	U	1,298	649	1,060
Western/southern spotted	17,177	U	U	U	U	U	2,290	1,145	708
Eastern spinner	2,852	U	U	U	U	U	1,037	518	664
Whitebelly spinner	13,080	U	U	U	U	U	1,744	872	422
Northern common	8,441	8,441	8,441	8,441	8,441	8,441	1,125	563	9
Central common	3,109	3,109	3,109	3,109	3,109	U	415	207	192
Southern common	36,911	U	U	U	U	U	3,691	1,846	0

[1] The Declaration of Panama sets a total mortality limit of 5,000 for all cetaceans. The total may include mortalities from species and stocks other than the major ones listed.