DECISION FRAMEWORK FOR ASSESSING THE STATUS OF THE EASTERN TROPICAL PACIFIC DOLPHIN STOCKS

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I. BACKGROUND

During the 1980's, reported ETP dolphin kills incidental to the tuna fishery were relatively numerous, imposing an annual mortality rate that was thought to be in the neighborhood of 3 or 4% for some stocks. Since this mortality rate is greater than or equal to recent estimates of the maximum growth rate of the dolphin populations, these high incidental mortality rates almost certainly did not let these populations recover from a depleted status.

During the 1990's the fishery practices changed, setting on dolphin was less frequent, and by-vessel quotas were instituted for dolphin kills. The number of reported kills dropped appreciably, and the resulting incidental mortality rate was thought to be around 0.5% per year or less for all stocks of ETP dolphin that interacted with the fishery.

For at least two stocks of ETP dolphins (Northeastern Offshore Spotted and Eastern Spinner dolphin), populations were well below historic carrying capacity (e.g., less than 30% of carrying capacity), owing to periods of high mortality incidental to the purse seine fishery for yellowfin tuna prior to and during the 1970's. It was therefore expected that the populations would show a recovery in numbers when the number of kills incidental to the tuna fishery dropped greatly in the 1990's. However, this apparently has not been the case. The estimates of relative abundance for NE Offshore Spotted dolphins calculated by the IATTC from tuna vessel observer data (TVOD) records up to and including 1997 do not show a recovery. The NE Offshore Spotted dolphin has been, and remains, the stock most frequently set upon in the purse seine fishery.

In contrast, the TVOD abundance index for Eastern Spinner dolphins has shown some signs of population growth during the 1990's. Setting on pure schools of Eastern Spinner dolphins was prohibited for US vessels starting in 1984. This contrast between the circumstances of the Eastern Spinner dolphins and the NE Offshore stock of spotted dolphins is consistent with a qualitative conclusion that the process of "fishing on dolphins" to catch tunas in the ETP (i.e., chase and encirclement) is detrimental to the populations of those dolphin stocks that are frequently set on. For these reasons, failure to detect the expected population growth for NE Offshore Spotted dolphins has prompted speculation as to possible causes that might have prevented growth. Possible causes include:

* High incidental mortality on unobserved vessels.

* Misreporting or under reporting of kill on observed vessels.

* Stress effects owing to repeated chase and encirclement causing delayed mortality, or reduction of reproduction, which would not be detected as direct kills reported by observers on the tuna vessels.

* Changes in ocean conditions, unrelated to the tuna fishery, possibly reducing the productivity of the ecosystem for dolphins coincidental with the reduction of fishery mortality in the 1990's.

* Time lags in the response of the population dynamics of dolphin populations to changes in the level of incidental mortality.

These possible causes are not mutually exclusive, and could be operating in combination.

The present NMFS research vessel surveys, called *Stenella* population abundance monitoring (SPAM) are intended to confirm or refute the apparent failure of the populations to grow after the reduction of the kill; and the larger IDCPA program is further intended to provide information that bears on the possible causes, if the conclusion from SPAM is that there has been a failure of any of the populations to grow at the expected rate.

II. KINDS OF EVIDENCE THAT WILL BE AVAILABLE FOR THE DETERMINATION OF TRENDS AND DETERMINATION OF CAUSES

a. New data and the past data with which they can be compared

Abundance

In March of 1999, new estimates of absolute abundance for depleted ETP dolphin stocks will be available from the new survey. These abundance estimates can be compared to the five 1986-90 Monitoring of Porpoise Stocks (MOPS) survey estimates. The study area in the new survey is not identical to the MOPS study area, but the differences are in the southern boundary of the area, and therefore are not a potential issue for either the NE Offshore Spotted or E Spinner stocks. Further, for affected stocks these differences can be corrected for, since the raw MOPS data have been archived. In subsequent years of the present survey, additional data on abundance will be obtained, increasing the sample size and the precision for the estimate of "present" abundance. However, for the March 1999 congressional finding, only 1998 abundance data will be available. It is expected that abundance estimates based on only a single year's effort will have relatively large coefficients of variation, compared to the pooled estimate from the 5 MOPS cruises, or the smoothed estimates from the time series of TVOD estimates.

Oceanography

The new research vessel survey will provide oceanographic data that can be analyzed to produce maps of environmental conditions thought to indicate favorable dolphin habitats. The habitat preferences of dolphins were estimated from past research vessel dolphin encounter rates analyzed in relation to oceanographic variables, primarily from the 1986-90 MOPS expedition. The spatial patterns and total amounts of dolphin habitats in the study area during the 1998 survey can be compared to annual amounts and patterns observed during the five MOPS years. This comparison is intended to address the possibility that NE Offshore Spotted dolphins in particular might shift their distribution in some years so that the population would not be entirely within the study area at the time of the surveys. If the 1998 total amounts and spatial patterns of favorable habitat conditions are within the ranges observed during the 1986-1990 MOPS surveys then the abundance estimates from the two periods should be otherwise comparable.

A second, related analysis of ETP oceanographic conditions will be prepared for the March 1999 finding. In this analysis, annual indices of El Nino/La Nina conditions (computed from large, publicly available data bases), and annual indices of amount of favorable dolphin habitat in the ETP will be examined as a time-series, for all years from 1970 to 1998. A major focus of this larger-scale analysis will be to look for indications of a so-called regime shift in the ETP during the past decade. A regime shift could potentially cause or contribute to a lack of recovery of a dolphin stock.

The new research vessel surveys also are collecting a substantial amount of information on other taxa, such as sea birds and dolphin prey. An analysis will be prepared at the completion of the program that includes consideration of variability in these related biological populations. However, this will not be possible for the initial finding in March 1999.

Stress

Other than a review of relevant literature, no results from stress studies will be available for the March 1999 finding.

Stress studies will be conducted later in the research program are intended to obtain samples from dolphins killed in the purse seine fishery, so that these can be examined for physiological evidence of stress. Depending on experimental design issues and permits, these results may be calibrated from data on encircled and released animals. There are no past measurements of this kind on ETP dolphin for comparison. Results of these stress studies will not be available until the completion of the program.

b. Existing sources of population and demographic data

Absolute Abundance

Past research vessel cruises provide estimates of past abundance. There was concerted effort in 5 years of such cruises for the MOPS estimates in 1986-1990. There were scattered research vessel

cruises in some earlier years.

Relative Abundance

Published TVOD measurements, from about 1975 through the present, provide estimates of relative abundance as calculated by the IATTC. It is this time series of relative abundance estimates that has formed the basis for recent concerns that the NE Offshore Spotted dolphin population has not been recovering in the 1990's. In one comparison of research vessel estimates with tuna vessel estimates for the same years, the TVOD indices agreed in general with research vessel data, except for an aberration in the 1983 estimates, so that it is not unrealistic to expect that the IATTC's trend estimates reflect actual trends in dolphin abundance.

As part of her research while a Ph.D. student at SIO, Debbie Palka did a model simulation to investigate the statistical properties of the estimation process that the IATTC employed to calculate a time series of relative abundance estimates from the TVOD. This study also concluded that the relative abundance estimation process then in use is relatively robust for purposes of estimating population trends.

Peter Perkins is now reviewing the general statistical methodology that converts raw tuna vessel observer data into the indices of population abundance published by the IATTC. Some essential details of the IATTC calculations are not made explicit in the literature, and are therefore not known to the NMFS personnel participating in the present ETP Dolphin Safe Evaluation Program. It is planned to continue this review and evaluation in the coming year, but for the purposes of the March 1999 finding the TVOD trend estimates provided by IATTC will be accepted directly as input for the analysis.

Reproductive Rates

There are historic data on pregnancy rates and fraction lactating and fraction mature in the kill. These data for the period 1971 through 1984 were reviewed and analysed by Reilly and Barlow in a 1986 paper. In more recent years these data collections from the kill ceased to obtain meaningful sample sizes.

Population Growth Rates

A modeling analysis of the time series of relative abundance estimates from the TVOD, in conjunction with the reported kill, was the basis for the estimate that during the period 1975-1990 the intrinsic growth rate of the dolphin population was around 3%. Paul Wade is updating this analysis for input to the March 1999 finding. Carlos Alvarez (UW graduate student) is conducting a similar analysis that attempts to include covariates for explicit estimation of cryptic kill, but this study is still in its early stages and will not be completed in time to be used in the March 1999 decision.

III. ANTICIPATING A FORMAL ANALYSIS

a. Abundance Trends

It is expected that the estimate of trend obtained from comparing the new abundance survey results with the MOPS data will have less power than the trend estimate from the relative abundance time series based on TVOD, because the TVOD estimates are based on large numbers of sightings every year, and have relatively small variances. The time series of TVOD relative abundance estimates is already established for the period 1975-1997. This time series is likely to dominate the information bearing on abundance trends for the stocks of interest.

If the research vessel and TVOD data sources are combined, it is possible that the resulting trend estimate for NE Offshore Spotted dolphins may indicate, with some defined statistical confidence, that the population is not growing at the expected rate. If such a trend analysis does conclude that there is a failure to grow at the expected rate, this will not in itself indicate the cause of the failure.

b. Oceanographic Analysis

If the analysis of SPAM oceanographic data concludes that the amount of preferred dolphin habitat available in the ETP during the 1998 research vessel survey was within the range observed during the five year MOPS program of the late 1980s, this would largely dismiss hypotheses that the 1998 estimate is biased downward due to movement out of the study zone in response to habitat changes. This potential concern applies primarily to NE Offshore Spotted dolphins (of the three stocks addressed in the March 1999 initial finding).

If the time series analysis of large-scale oceanographic conditions concludes that a regime shift has occurred in the ETP, this potentially could confound interpretation of trends in dolphin abundance. If no evidence exists of a regime shift, then current abundance estimates should be otherwise comparable to earlier ones, and any apparent lack of recovery is likely due to causes other than those related to oceanography or the environment.

The ambiguity in quantifying effects of environmental variability on dolphin populations might be removed if the amount of favorable habitat could be combined with assessments of food chain elements (prey and competitors of the dolphins) to quantify a term like "carrying capacity" in a density dependent growth model. Then the magnitude of the expected effect on the dolphin population could be computed, allowing quantification of the fraction of the depression in dolphin growth rate that can be accounted for by oceanographic conditions versus effects attributable to the tuna fishery. Present knowledge is not sufficient for such a quantification and prospects for obtaining the required information are remote.

Other more complicated food chain changes could affect the dolphin populations. Either El Nino environmental effects starting at the bottom of the food chain, or fisheries reduction of population sizes of predators operating near the top of the food chain might affect prey

availability for dolphins, and these effects could involve some time lag to work their way through the system. These food chain effects will not be evaluated in the March 99 decision, but they will be considered, to the extent that our scientific information permits, in 2002.

c. Stress Studies

For the March 1999 finding, the stress literature review will conclude whether stress resulting from chase and capture is or is not a plausible source of mortality or cause of reduced reproduction for ETP dolphins. For the final finding, the stress studies will result in a determination whether physiological evidence of stress is or is not detectable. If stress is detected this will add plausibility to the hypothesis that fishery practices are contributing to the depression of the dolphin population growth rate. Inability to detect stress would detract from the plausibility of that hypothesis. But the result will not be conclusive in either case, since we do not have a way to quantify an expected relation between these measures of stress and depression of population growth rate.

IV. FORMAL DECISION FRAMEWORK

NMFS participants met on 9/15/98 and 11/10/98 to discuss a formal decision framework specifically for the March 99 decision, but also with an eye on the final determination in 2002. A third meeting was held, 12/16-12/17/1998, with the added participation of representatives from the Marine Mammal Commission and the IATTC.

These meetings culminated in the drafting of a set of questions, bearing on the issues that motivated the present NMFS ETP dolphin program (International Dolphin Conservation Program, IDCPA), for which it is reasonable to expect scientific answers by 2002. The third meeting further refined a small subset of the questions into a proposed decision rule for the March 99 decision.

The larger set of questions is as follows:

1.0 Overall Question for the Program

"In the period since 1991, has there been for any depleted ETP dolphin stock, a failure, attributable to fishery activities, of the population to grow at the expected rate?"

It was noted that two key elements are needed to turn this into a decision rule, namely (1) a specification of how great a magnitude of depression of population growth rate is sufficient for concern, and (2) a specification of how certain we need to be that such a depression of population growth rate has or has not occurred, in light of the imperfect information that will be available. These elements of "How much?" and "How certain?" are specified quantitatively in the next section (V), only with respect to a proposed decision rule for a finding in March 99 on trends and abundance. The two elements of "How much?" and "How certain?" have not yet been specified

for other components of the overall decision that will be made in 2002.

It was further noted that to operationalize the 2002 determination, two key definitions are needed for (1) how the effect, "failure to grow at the expected rate," will be detected, and (2) how the causation, "attributable to fishery activities," will be ascribed.

Discussion among the NMFS participants reached a consensus on operationalizing detection of the effect, "failure to grow at the expected rate," for purposes of the March 99 decision, as described below (question 2 in this section). The process by which failure to recover is attributed to a specific fishery for purposes of the 2002 determination will be based on a series of `yes' and `no' answers to a predetermined set of questions. The questions will be arrayed in a logical structure, called a `decision tree.' Each `branch point' in the tree corresponds to a narrowly defined question, whose answer determines which branch is taken. All paths through the branches in the tree culminate in one or the other of the basic conclusions that the decision tree is intended to resolve.

At the 16-17 December 1998 meeting, the series of questions needed to fully specify the decision tree was not fully developed, but a number of operational sub-questions were identified as described below (questions 3 and 4 in this section). It is anticipated that future discussions will link these in a more comprehensive decision tree. Discussions to date point in the direction of a "process of elimination" logic for the decision on the attribution of cause.

2.0 Trend and abundance component of the determination

"In the period since 1991, has there been for any depleted ETP dolphin stock, a failure of the population to grow at the rate expected from the dynamics in the period 1975-1991, in light of the reported time series of kill, TVOD relative abundance estimates, and research vessel (RV) absolute abundance estimates."

The analysis to address this question will assume that the population size over the period 1975 to present has not changed enough relative to historic carrying capacity for there to be significant density dependent changes in the growth rate during this time. Therefore, the analysis will simply fit two separate, constant, growth rates R to the data time series, one for the period 1975-1991, and one for the period since 1991, where the fit takes into account reported kill, but does not explicitly represent cryptic kill, reproductive effects of chase and encirclement, or misreporting or mis-estimation of kill. And the question, whether the post 1991 growth has been as large as expected, will be answered by comparing the two estimates of intrinsic growth rate, R(1975-1991) and R(1991-1998). The breakpoint in 1991 was selected because observed kills decreased substantially about that time.

Since the effects of cryptic kill, reproductive effects of chase and encirclement, and misreporting or mis-estimation of kill are not accorded distinct terms in the fitting, these effects will be absorbed into the respective estimates of growth rate R for the two time periods. Then, if it is

assumed that environmental effects have not changed significantly between the two periods, the differences between the estimates of growth rate for the two periods may be interpreted as changes in cryptic kill, reproductive effects of chase and encirclement, or misreporting or mis-estimation of kill. Using the period 1975-1991 as the baseline for defining the expected growth rate, assumes that the effects of cryptic kill, reproductive effects of chase and encirclement, or misreporting or mis-estimation of kill were small enough, at the population level, during that period, that these effects were not of management concern. But if effects of cryptic kill, reproductive effects of chase and encirclement, or misreporting mis-estimation of kill in the period of since 1991 are larger, that could be of management concern.

An analysis to answer the trends and abundance question will be conducted, using the existing time series of kill estimates and absolute and relative abundances estimates including the 1998 SPAM cruise, for incorporation in the March 1999 report to Congress. The proposed decision rule specifying the statistical details (e.g., magnitudes of difference in observed and expected rate of growth that are biologically relevant and tolerances for uncertainty in the determination) is given in the next section (V).

The trend and abundance component of the decision will be repeated in 2002, when the analysis can be done on a time series of TVOD and research vessel abundance estimates that includes an additional 4 or 5 years of TVOD and kill data, and two more years of research vessel data.

3.0 Stress Component of Attribution of Cause

3.1 "Is chase and encirclement a generally plausible cause of stress?"

3.2 "Is stress a generally plausible cause of depression in population growth?"

3.3 "Is there physiological evidence of stress in individuals from the affected dolphin populations?"

An answer to question 3.1, based on a literature review and consultation with experts, will be available in time for the March 99 decision. Question 3.2 should be partially but not definitively answered by the literature review. Answers to question 3.3 will not be available in that time frame.

It was noted that the literature survey on stress has the potential to confirm or refute the plausibility of stress as a possible factor in failure of the population to grow at the expected rate. A new sampling program for physiological indicators of stress has the potential to provide evidence on whether stress is detectable in these populations, but there is no methodology at present for quantitatively relating observed measures of stress to an expected magnitude of depression of survival or reproductive rates.

4.0 Oceanographic Component of Attribution of Cause

4.1 "Is the present abundance of preferred dolphin habitat, in the area of the affected stocks, within the range of variation observed during 1986-1990?"

4.2 "Are the present indices of ecosystem productivity, in the area of the affected stocks, within the range of variation observed during 1986-1990?"

4.3 "Do the time series of annual indices of El Nino/La Nina conditions and abundance of preferred dolphin habitat in the ETP for the period since 1970 indicate a regime shift in the ETP during that period?"

4.4 "Do the analyses of abundances of sea birds, dolphin prey, and dolphin competitors in the ETP indicate a reduced availability of prey for dolphins in the period since 1991?"

It was noted that the oceanographic survey will have the potential to dismiss the hypothesis that ocean conditions have caused the failure of the dolphin populations to grow at the expected rate, if the results of the oceanographic survey and data review are that the amount of preferred dolphin habitat and prey availability during the 1990's was not appreciably smaller than previously. But if the oceanographic survey shows a decline in preferred dolphin habitat and prey, or the data review finds indications of a regime shift, the implication for attribution of causes for failure of the dolphin populations to grow at the expected rate will be less conclusive. Methodology at present is lacking for quantification of the predicted magnitude of the oceanographic effect on dolphin populations.

V. PROPOSED DECISION RULE FOR EVALUATING THE POTENTIAL ADVERSE IMPACT OF CHASE AND ENCIRCLEMENT ON ETP DOLPHIN POPULATIONS

The determination is: "Whether, in the period since 1991, there has been for any depleted ETP dolphin stock, a failure of the population to grow at the expected rate, where the expected rate, as stated is defined by the rate of population growth R in the period 1975-1991."

The failure of the population to grow at the expected rate will be measured as a probability distribution on the amount by which the rate of population growth, estimated for the period 1975-1991 exceeds the estimated rate of population growth after 1991, where both inferences are in the form of a joint posterior distribution in a Bayesian analysis of all the research vessel and TVOD annual population estimates, and the reported kill for 1975-present, in an age-structured model.

The analysis of the data for the trends and abundance determination in March 1999 will be conducted in terms of estimating a depression in the population growth rate after 1991 compared to the period 1975-1991. This can equivalently be expressed in units of per capita unreported additional mortality operating in the period since 1991, but assumed not operating in the period 1975-1991, that would account for the difference in estimated growth rates between the two periods. Expressing the depression in growth rate as a "mortality" is convenient for comparison to

PBR criteria as a policy yardstick on how large such a mortality would be permitted, in conjunction with estimated direct kill, if it were attributed to the fishery.

For purposes of the March 1999 and the 2002 decisions, the depression of the estimated rate of population growth in the period after 1991, relative to the base period 1975-1991, will be expressed in units of unreported mortality. The decision quantity will be the size of the sum of the estimate of unreported mortality and the reported kill rate, relative to the estimate of Rmax. Rmax will be estimated from fitting the time series data for the 1975-1991 period and back-calculating a population trajectory to 1958 using the estimates of the kills back to 1958. The population size estimated for 1958 will be taken to represent the historic carrying capacity. The estimation procedure for Rmax will be Bayesian, and the estimate will be conveyed as a posterior distribution. The prior distribution for Rmax in this analysis will be truncated at a value 0.04, consistent with maximum plausible values that have been used implicitly as defaults in other settings (such as interpreting the initial Panama/IDCPA maximum allowable kill rate of 0.002 as a PBR criterion of ½ Rmax times a recovery factor of 0.1).

It was agreed at the 16-17 December 1998 meeting that multiple thresholds will be used for the decision that some aspect of setting on dolphins adversely impacts dolphins; and the degree of certainty that a particular criterion has been met will differ by threshold. That is, there will be a very low tolerance for a high potential impact such as potential extinction, while there will be a moderate tolerance for less severe effects, such as delay in time to recover from depleted status. The following criteria are proposed:

(1) A criterion based on risk of extinction of an endangered stock

"There must be less than 1% probability that the sum of the reported post-1991 kill rate and the estimate of post-1991 unreported mortality rate exceeds the Rmax estimate."

(2) A criterion based on risk of exceeding PBR for a depleted stock

"There must be less than 5% probability that the sum of the reported post-1991 kill rate and the estimate of post-1991 unreported mortality rate exceeds half the Rmax estimate."

(3) A criterion based on risk of delaying recovery of a depleted stock

"There must be less than 50% probability that the sum of the reported post-1991 kill rate and the estimate of post-1991 unreported mortality rate exceeds one quarter the Rmax from the period 1975-1991."

It was noted that these criteria drew on the rationale from technical discussion leading to the interim Panama agreement and the PBR criteria. The discussion of criterion (3) also considered the value one tenth the Rmax estimate in place of one quarter, as possibly appropriate.

The technical statistical estimates will be carried out by modification of Paul Wade's Bayesian population model for ETP dolphins.