

REPORT TO CONGRESS

on the initial finding, required under the Marine Mammal Protection Act of 1972 as amended by the International Dolphin Conservation Program Act of 1997, regarding whether the intentional deployment on or encirclement of dolphins with purse seine nets is having a significant adverse impact on any depleted dolphin stock in the eastern tropical Pacific Ocean.

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PRIMARY RESEARCH DOCUMENTS PREPARED FOR THIS REPORT

- Curry, B. E. 1999. Stress in Mammals: The Potential Influence of Fishery-Induced Stress on Dolphins in the Eastern Tropical Pacific Ocean. Southwest Fisheries Science Center Draft Report dated March 1999. 121 pp.
- Fiedler, P. C. 1999. Eastern tropical Pacific dolphin habitat variability. Southwest Fisheries Science Center Draft Report dated February 22, 1999. 11 pp.
- Gerrodette, T. 1999. Preliminary estimates of 1998 abundance of four dolphin stocks in the eastern tropical Pacific. Southwest Fisheries Science Center Unpublished Report dated March 18, 1999. 20 pp.
- Goodman, D. 1999. Decision framework for assessing the status of the eastern tropical Pacific dolphin stocks. Contract report to the Southwest Fisheries Science Center dated January 24, 1999. 12 pp.

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EXECUTIVE SUMMARY

The International Dolphin Conservation Program Act of 1997 (IDCPA) directed the National Marine Fisheries Service (NMFS) to conduct a program of research to address the question of whether intentional deployment on or encirclement of dolphins with purse seine nets is having a significant adverse impact on any depleted dolphin stock in the eastern tropical Pacific Ocean (ETP).

The research program was specified in Section 304(a) of the Marine Mammal Protection Act (MMPA) to include population abundance surveys and stress studies. The Secretary of Commerce was directed to make an initial finding on this question for any depleted dolphin stock between March 1 and March 31, 1999, on the basis of results of these studies and any other relevant information. The other relevant information considered in this report includes research vessel estimates of absolute abundance for previous years, fishery mortality estimates and relative abundance estimates produced from tuna vessel observer data (TVOD), and oceanographic data for the ETP. The research program also conducted population modeling and began development of a decision analysis framework within which to evaluate all the above information sources to address the question posed by Congress in the International Dolphin Conservation Program Act (IDCPA).

Three dolphin stocks are recognized as depleted under the MMPA: the northeastern offshore spotted dolphin, eastern spinner dolphin and the coastal spotted dolphin. The biological status of the coastal spotted dolphin is unclear and information to re-evaluate this stock is limited.

The 1998 research vessel abundance survey, called *Stenella* Population Abundance Monitoring (SPAM), and subsequent data analyses produced the following abundance estimates: northeastern offshore spotted dolphins - 1,011,104 (Coefficient of Variation = 0.264); eastern spinner dolphins - 1,157,746 (CV=0.336). Taken alone, these estimates are insufficient to determine if these populations are recovering. These estimates are not statistically different from estimates based on research vessel surveys conducted during the 1986-1990 Monitoring of Porpoise Stocks (MOPS) and require the context of a population model to determine if recovery is taking place.

The 1998 estimate for coastal spotted dolphins (108,289, CV=0.405) is considered the best available. The most recent previous estimate from the 1986-1990 MOPS program (29,800, CV=0.346) is too different in size to be solely attributable to population growth, even considering the CVs of the estimates. It is suspected this is due to inadequate spatial coverage of the stocks' range during the MOPS surveys.

Regarding the stress studies, the review of literature on stress-related research concluded that it is plausible that stress resulting from chase and capture in the ETP yellowfin tuna fishery could have a population level effect (increased mortality and/or decreased reproduction) on one or more depleted dolphin stocks. The program of necropsy sampling from dolphins killed in the fishery has completed planning and training. Of the nations that fish on dolphins only Mexico has agreed to participate in the necropsy sampling program. The necropsy program has not yet collected any data, because the NMFS is still awaiting a first opportunity from Mexico to place a technician on a fishing trip.

Examination of historical samples and data are focusing on molecular means for detecting chronic stress and evidence relating the effect of chase and encirclement on the cow/calf bond. Both of these studies appear sufficiently promising to be continued and included in the final finding.

An analysis of oceanographic data looked at (1) physical oceanographic data publicly available in NOAA databases, (2) biological data collected on NMFS dolphin abundance surveys (MOPS 1986-1990 and SPAM 1998), and (3) indices of dolphin habitat suitability for each stock. The time series of El Niño-Southern Oscillation (ENSO) indices, mean habitat suitability, and the other environmental variables examined show no evidence of a recent regime shift or other long-term change that might affect population growth rates for depleted dolphin stocks.

The decision analysis framework reformulated the question from the IDCPA in the following terms which are addressable by scientific information: "In the period since 1991, has there been for any depleted ETP dolphin stock a failure, attributable to fishery activities, to grow at the expected rate?" This in turn was separated into a series of more specific sub-questions, the first relating only to whether there has been a failure to recover, the rest dealing with attributing causality for any observed failure to recover. It was possible to address only the first sub-question quantitatively for this initial finding.

To answer the first specific sub-question, "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," a Bayesian assessment model was used to evaluate the available estimates of relative and absolute abundance and observed fishery mortality. Results of the assessment indicated that

the currently depleted populations of both northeastern offshore spotted dolphins ($p = 0.99$) and eastern spinner dolphins ($p = 0.44$) are not increasing at the rate expected based on the low rate of reported mortalities from the fishery since 1991 and the reproductive potential for these populations.

Reproductive potential, termed " r_{max} ," was estimated directly from the data for these stocks, rather than by analogy with other species and populations.

These results are affected substantially by patterns in the TVOD abundance indices. Very recent, unpublished concerns about these indices (noted in a series of personal communications)¹ identified possible changing biases, and other potential effects of fishing operations on the annual indices. However, as indicated by an congressionally directed independent peer review, in the absence of a thorough, peer-reviewed analysis confirming these possible problems, the NMFS is compelled to include in this initial finding the peer-reviewed published abundance indices. The NMFS will pursue a careful evaluation of the TVOD abundance indices, focusing on the recently-identified concerns for the final finding in 2002.

¹Letters from R. Allen, IATTC, to M. F. Tillman, SWFSC, dated 1/14/99, 2/17/99 and 3/5/99

Attributing causality is far more difficult than interpreting abundance and trend data. It has only been possible to address in a brief and preliminary way the two primary sources identified as possible causes for such failures to recover: changing environmental conditions, and indirect or unobserved effects of the fishery. The environmental data examined to date show no evidence of a recent regime shift or other long-term change that might affect population growth rates for depleted ETP dolphin stocks. In addition, although the review of stress-related literature itself can lead to no firm conclusions, for the present the NMFS concludes that it is not appropriate to dismiss fishery-related stress as a possible source of the observed depression in population growth rates.

Stress is only one possible fishery-related source of the apparent lack of recovery. Other plausible sources include separation of cows and calves (with subsequent calf mortality) and under-reporting of direct kills. It must also be noted that none of the possible causes mentioned are necessarily exclusive of the others. We will address these and related issues for the 2002 finding.

Much essential information is lacking for coastal spotted dolphins, especially from the early years of the fishery when the effect on coastal stocks was most likely at its peak. *Consequently, it is not possible at this time to determine if chase and encirclement by the purse seine fishery is having a significant adverse impact on the coastal stock of spotted dolphins.*

REPORT TO CONGRESS

Initial finding prepared by the Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Department of Commerce as required under the Marine Mammal Protection Act of 1972 as amended by the International Dolphin Program Conservation Act of 1997, regarding whether the intentional deployment on or encirclement of dolphins with purse seine nets is having a significant adverse impact on any depleted dolphin stock in the eastern tropical Pacific Ocean.

1 INTRODUCTORY COMMENTS

The International Dolphin Conservation Program Act of 1997 (IDCPA) established in section 304(a) of the Marine Mammal Protection Act of 1972 (MMPA) a research program within the National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce (DOC) to address the following.

“The Secretary shall, in consultation with the Marine Mammal Commission and the Inter-American Tropical Tuna Commission, conduct a study of the effect of intentional encirclement (including chase) on dolphins and dolphin stocks incidentally taken in the course of purse seine fishing for yellowfin tuna in the eastern tropical Pacific Ocean. The study, which shall commence on October 1, 1997, shall consist of abundance surveys... and stress studies...and shall address the question of whether such encirclement is having a significant adverse impact on any depleted dolphin stock in the eastern tropical Pacific Ocean.”

Further, the IDCPA states the following in section 5(g).

“Secretarial Findings. (1) Between March 1, 1999, and March 31, 1999, the Secretary shall, on the basis of the research conducted before March 1, 1999, under section 304(a) of the Marine Mammal Protection Act of 1972, information obtained under the International Dolphin Conservation Program Act, and any other relevant information, make an initial finding regarding whether the intentional deployment on or encirclement of dolphins with purse seine nets is having a significant adverse impact on any depleted dolphin stock in the eastern tropical Pacific Ocean. The initial finding shall be published immediately in the Federal Register and shall become effective upon a subsequent date determined by the Secretary.”

This report provides the results of research conducted and contracted by the Southwest Fisheries Science Center (SWFSC), NMFS, NOAA, DOC, between October 1, 1997 and March 1, 1999 to address the question posed by the IDCPA of whether chase and encirclement by tuna purse seine fishing vessels is having a significant adverse impact on any depleted dolphin stock in the eastern tropical Pacific Ocean (ETP).

1.1 STRUCTURE OF REPORT

This report summarizes the results to date of the research projects mandated by the IDCPA, namely the stress studies and the research vessel abundance surveys (sections 3 and 4), and describes the additional relevant information (section 5) used in this finding. The analyses performed to integrate these various sources of information into a determination of whether or not intentional deployment on or encirclement of dolphins is having a significant adverse impact on any depleted dolphin stock in the ETP are described in section 6. The conclusions presented in this report draw primarily on the four research documents prepared under the IDCPA research program to date (see page iv) and the assessment model described in Appendix 2.

1.2 CONSULTATIONS AND PEER REVIEWS

As mandated by the IDCPA, the research projects and analyses were conducted in consultation with the Marine Mammal Commission (MMC) and Inter-American Tropical Tuna Commission (IATTC). The consultation with the Commissions, as well as with scientific experts selected by the SWFSC to comment on specific technical topics, took place in preliminary planning meetings for both the stress studies (Curry and Edwards 1998) and the research vessel abundance surveys (Gerrodette et al. 1998), and in a December 1998 meeting to discuss how the various sources of data would be integrated and evaluated in the context of a decision analysis framework to arrive at an overall conclusion regarding adverse impact. In addition to these consultations, the NMFS solicited written peer reviews of the primary research documents associated with this report and incorporated those recommendations where appropriate into those documents. Finally, in response to letters from the U.S. Congress received in January 1999, an independent panel of experts was established by the Center of Independent Experts, University of Miami, under contract with the NMFS to review this report and its scientific basis. This panel reviewed the scientific research and findings presented in this report and its four associated research documents from 8 - 11 March 1999. The NMFS scientific staff incorporated the panel's recommendations where appropriate into this report and the associated research documents.

2 IDENTIFICATION OF DEPLETED STOCKS

In the region known generally as the ETP there are 20 stocks of 14 species of small cetaceans known to have suffered at least some mortality in the ETP purse seine fishery for tuna (IATTC 1998). The primary dolphin species involved in the ETP yellowfin tuna purse seine fishery are classified into stocks, or management units, based on a large body of distributional, demographic, phenotypic and genotypic data (see Dizon *et al.* 1994 and Perrin *et al.* 1985). The stocks addressed specifically in this report include the northeastern offshore spotted, eastern spinner, and coastal spotted dolphin stocks.

2.1 NORTHEASTERN OFFSHORE SPOTTED AND EASTERN SPINNER DOLPHIN STOCKS

Two stocks, the eastern stock of spinner dolphins (*Stenella longirostris orientalis*) and the northeastern stock of offshore spotted dolphins (*Stenella attenuata*) have been the primary targets of “dolphin fishing.” The eastern spinner dolphin and the northeastern offshore spotted dolphin were deemed depleted under the MMPA most recently since 26 August 1993 (58 FR 45066) and 1 November 1993 (58 FR 58285), respectively. At that time the eastern spinner dolphin was estimated at approximately 44% of its pre-exploitation population size (Wade 1993a). The northeastern offshore spotted dolphin was estimated to be between 19% and 28% of its pre-exploitation population size (Wade 1993b). Because these two stocks are clearly considered depleted under the MMPA they are addressed specifically in this report.

2.2 COASTAL SPOTTED DOLPHIN STOCK

There is some ambiguity regarding the status of one other stock, the coastal stock of spotted dolphins. This stock is found within 100 nm of the coast in the ETP. It is sufficiently distinct to be described as a separate subspecies, *Stenella attenuata graffmani* (Perrin 1975). Dolphins from this stock are among those killed incidentally in the fishery, but the extent to which this mortality has affected the population is unknown. During the early years of the purse seine fishery, fishing effort was concentrated near the coast. Therefore, coastal dolphin stocks such as this one that associate with tunas may have experienced high mortality. In a 1980 Federal Register notice NMFS declared that the 1979 population size was estimated to be 193,200 (45 FR 72178-72196). This was stated to represent 42% of its pre-exploitation population size and was therefore considered depleted under the MMPA. A lawsuit challenging this determination resulted in a ruling requiring the NMFS to recalculate ETP dolphin abundance estimates to include tuna vessel observer and employee data and to revise the statuses of stocks accordingly (*American Tunaboat Association v. Baldrige*, No. 80-1952-G [S. D. Cal. Mar. 10, 1982]). However, these recalculations were not published in the Federal Register or elsewhere.

There has not been a reassessment of the status of coastal spotted dolphins since that time. Reevaluations of the status of northeastern offshore spotted and eastern spinner dolphin stocks resulting from the court case mentioned above used three types of information: time series of fishery mortality estimates and of relative abundance estimates from tuna vessel observer data (TVOD), and absolute abundance estimates from research vessel surveys. These types of information are considerably less abundant for coastal spotted dolphins, especially for the early years of the fishery when mortality was most likely highest. For this initial finding, the NMFS has taken a conservative approach, treating coastal spotted dolphins as depleted, and has given the stock consideration in this report. The limited information available for this stock is presented and evaluated to the extent possible in sections 5 and 6 of this report.

3 STRESS STUDIES

Although observed fishery-related mortality of dolphins in the ETP has diminished since 1992 to levels that are unlikely to affect population dynamics in any significant way, the rate at which sets are made on dolphin schools has not diminished substantially. There are still

approximately 8,000 sets made on dolphins each year in the ETP. Considerable concern about the potential effects of stress caused by this procedure led to inclusion in the IDCPA of research projects directed toward assessing the prevalence and magnitude of fishery-induced stress in the dolphins targeted by this fishery.

The IDCPA mandates the following four projects under three subheadings within its stress research component.

- “(A) a review of relevant stress-related research [i.e. stress literature review] and a 3-year series of necropsy samples from dolphins obtained by commercial vessels;
- (B) a 1-year review of relevant historical demographic and biological data related to dolphins and dolphin stocks referred to in paragraph (1) [i.e. depleted stocks]; and
- (C) an experiment involving the repeated chasing and capturing of dolphins by means of intentional encirclement.”

Research has commenced under subheadings (A) and (B). Preliminary planning has commenced on subheading (C); the actual research will occur during 2001.

3.1 STRESS LITERATURE REVIEW

The review of relevant stress-related research has been completed (Curry 1999). This review provides a context for the NMFS’s scientific results by describing what is known about physiological and behavioral stress in mammals, and by relating this knowledge to the chase and encirclement of dolphins in the ETP tuna purse seine fishery. The review includes information regarding stress theory and the physiology of stress. The review examines literature from studies of physiological and behavioral responses to stress that may be relevant to dolphins involved in the purse seine fishery.

Potential stress effects of specific fisheries operations (search, chase, and capture) on the dolphins involved in the ETP fishery are identified. Search operations may disrupt habitat utilization, foraging activities, and social activities. Capture and pursuit have been documented to cause stress, assessed by adrenocortical activity, in terrestrial mammals and cetaceans. Chase and capture operations of the fishery are likely to cause immediate or short-term physiological responses such as activation of the hypothalamic-pituitary-adrenal axis in response to psychological or social stressors associated with these operations. Psycho-social stressors that are likely to affect the dolphins include separation of mother and young, separation from social groups, social aggression during net confinement, and novelty. Other potential short-term responses of dolphins to chase and capture include severe muscle damage, resulting in a condition known as capture myopathy and hyperthermia. Both of these conditions could cause unobserved mortality.

The potential effects of long-term stress include stress-induced pathologies, impairment to the immune system, and impaired reproduction, growth, and metabolism. Based on information from other mammals it seems likely that the reproductive cycle for some female dolphins will be disrupted, either as a result of the hypothalamic-pituitary-adrenal response to stress or through the development of pathologies resulting from chronic stress. Cow-calf

separation can occur as the result of chase and capture, and it is likely that this separation will result in the calf's death, at least for younger calves. Further, it appears that young animals may be particularly vulnerable to impacts of fisheries operations. Maternal separation and novelty are likely to induce significant hypothalamic-pituitary-adrenal responses in young animals, and this can result in impaired growth.

Although this review of existing literature regarding stress in mammals cannot provide a quantitative or definitive answer to the question of whether the tuna fishery is causing stress to affected dolphin populations, the available information and evidence point to the likelihood that physiological stress is induced by fisheries activities. It is therefore plausible that stress resulting from chase and capture in the ETP tuna purse-seine fishery could have a population level effect on one or more dolphin stocks.

3.2 NECROPSY SAMPLING OF DOLPHINS KILLED BY PURSE SEINE FISHING

The necropsy program involves placing trained necropsy technicians onboard commercial tuna vessels to collect tissue samples from dolphins killed in the ETP fishery. These samples will include a wide variety of histological and morphological tissue samples (Curry et al., in prep.).

This necropsy sampling will specifically include collection and analysis of adrenal glands, under carefully controlled, recorded and standardized conditions. Although information is available from a previous study of adrenal glands from dolphins killed by the purse seine fishery (Myrick and Perkins 1995), the conditions under which those samples were collected, stored and analyzed are largely unknown and unverifiable. The observed results may have been produced or affected by any or all of a number of confounding or interfering factors, none of which were measured or accounted for during data collection, storage or analysis. Thus the results from this study are equivocal at best. Nonetheless, the questions addressed by the study remain very important and will be included as a specific focus of the necropsy program.

Collection of these tissue samples requires that technicians be placed onboard non-U.S. tuna vessels fishing on dolphins because U.S. vessels currently do not fish on dolphins in the ETP. To initiate necropsy sampling, the NMFS solicited cooperation from the fishing nations attending both the 1997 and 1998 IATTC annual meetings and conveyed its need to place technicians aboard member fishing vessels. In September of 1998, at the annual MEXUS-Pacifico meeting in Ensenada Mexico, the Instituto Nacional de la Pesca (INP) of Mexico agreed to work with the NMFS under the auspices of the MEXUS-Pacifico bilateral agreement to conduct a pilot necropsy study. A necropsy technician training course was held by the SWFSC from 19 to 21 January, 1999, to train observers from both the Mexican national and IATTC observer programs, for the pilot necropsy program. Since that time, no fishing vessels have been made available to host any of the trained technicians. No other country that fishes on dolphins has agreed to participate in the necropsy sampling program.

3.3 REVIEW OF RELEVANT HISTORICAL AND DEMOGRAPHIC DATA

The intent of the historical and demographic data project is to assess the potential of existing archived samples from the fishery for determining fishery-related stress in ETP dolphins

and to proceed with the most promising apparent avenues of research utilizing the samples. These samples, while not necessarily ideal for all purposes, represent a readily available source of material for examination.

Most of these samples were collected between approximately 1975 and 1990, when the dolphin fishery made about 10,000 sets per year and killed approximately 20,000-130,000 dolphins per year. The archive includes several thousand samples for each year and consists of reproductive organs, teeth, blood stains, and skin. In addition, over 500 biopsy samples (skin samples taken by retrievable dart) were taken during the 1998 abundance survey in the ETP.

Two lines of investigation are currently underway; the first involves molecular genetic methodologies and the other involves investigating the cow/calf relationships in samples from individual sets.

3.3.1 Molecular Indices of Stress . This investigation focuses on the feasibility of using molecular means to observe the effects of stress. Skin samples are available from animals biopsied from areas that are heavily fished as well as areas that are not heavily fished. The samples from areas of low fishing effort provide presumably unstressed control samples with which the presumably stressed samples from the heavily fished areas can be compared.

Three different indices of stress are under investigation: (1) changes in composition of skin microflora (e.g. fungus), (2) production of unique extra-nuclear DNA known to occur in response to cellular stress, and (3) increases of messenger RNA of various receptors indicative of neuroimmunological stress.

This research and an investigation of methods to relate these results from individual animals to population level effects are underway. Final results will not be available until the final finding in 2002.

3.3.2 Cow-Calf Bond . This non-molecular study is a comprehensive examination of the age-sex composition of the historical kill focusing on potential effects of chase and encirclement on the cow-calf bond. This is conceptually simple, but a variety of sample biases have to be dealt with. One would expect that for every lactating female killed, a high proportion of their calves should also be observed killed because the cow-calf bond is very strong. If calves are not observed killed with their mothers, the mortality count is biased downwards by some unknown but estimable degree. The assumption is that calves, by and large, will not survive on their own.

If calves are generally not observed killed with their mothers, one explanation is that the chase causes separation. If so, there is another element that would bias the total mortality count downward. Even if the mother is released alive at backdown, the survival of the separated calf can not automatically be assumed. Considering the huge numbers of lactating females encircled on a yearly basis and released alive, even very conservative assumptions about calf mortality during the separation could account for a very high additional number of dead dolphins not included in the reported kill.

This research is currently underway but final results will not be available until the final finding in 2002.

3.4 CHASE-RECAPTURE EXPERIMENT

The IDCPA specifically mandates “. . . an experiment involving the repeated chasing and capturing of dolphins by means of intentional encirclement.” As designed in a planning workshop held in July 1997 (Curry and Edwards 1998), the chase-recapture experiment is intended to provide physiological samples from live dolphins to complement the necropsy program, which will provide tissue and morphological samples from dolphins killed by the fishery. The chase-recapture samples are intended to provide information about dynamic changes in physiological systems affected by chase, capture and release.

The samples to be collected during the chase-recapture experiment (blood sampled from flukes) will provide repeated measures of stress indicators over a time course that will include multiple sets (likely 3-4) for single animals over a period of several days to weeks. The objective is to measure the time course of responses of stress-related blood parameters in individual animals and to evaluate the potential for recovery between sets.

Although the basic approach and preliminary details of this experiment were proposed at the July 1997 workshop, the concept and execution of this project will be especially complex. Thus, the NMFS intends to initiate additional formal research planning in mid-1999, through consultation with experts and workshops, with the proposed experiment to be conducted during the period February-April 2001.

4 RESEARCH VESSEL ESTIMATES OF ABUNDANCE FOR DEPLETED STOCKS FOR 1998

The IDCPA directed that the first of the three annual dolphin population surveys be undertaken in 1998 to obtain a current estimate of abundance for depleted stocks. A planning meeting was held on December 17-18, 1997, to consider methodology and design (Gerrodette *et al.* 1998). The line-transect survey, called *Stenella* Population Abundance Monitoring (SPAM 1998), was carried out in the ETP from July 31 to December 9, 1998, utilizing teams of observers and other scientists aboard three research vessels. Following the cruise, a preliminary analysis of the 1998 abundance data was presented and discussed at a review meeting on January 21, 1999 (Olson and Gerrodette 1999). Meeting participants included line-transect specialists and scientists representing the IATTC. The MMC was invited to send representatives but declined. A full discussion of methods and analysis leading to the estimates of 1998 abundance used in this preliminary finding is reported in Gerrodette (1999). A brief summary of this report follows.

The size of ETP dolphin populations was estimated using distance sampling (Buckland *et al.* 1993). The study area was designed to be certain to include the entire range of coastal spotted, northeastern offshore spotted and eastern spinner dolphins (Figure 1). Within the study area, searching effort was stratified into four areas based on densities of the target dolphin stocks (Gerrodette 1999 and Figure 1). Methods of data collection and analysis closely followed

previous surveys (Wade and Gerrodette 1993, Wade 1994). Searching was carried out by dedicated observers primarily using pedestal-mounted 25x150 binoculars fitted with azimuth rings and reticles for angle and distance measurements. Bias reduction methods developed at the SWFSC based on aerial photography (Gerrodette and Perrin 1991, Gilpatrick 1993, Barlow et al. 1998) were applied to observers' estimates of school size. Estimates of dolphin density and abundance for each stock were made using Distance, version 3.5, Release 4 (Thomas et al. 1998). Variances of abundance estimates were estimated using the bootstrap procedure within Distance, which includes the variance due to model selection at each iteration.

Estimates of abundance were 1,011,104 (CV=0.264) for northeastern offshore spotted, 1,157,746 (CV=0.336) for eastern spinner, and 108,289 (CV=0.405) for coastal spotted dolphin stocks in 1998 (Gerrodette 1999 and Table 1).

The congressionally-directed peer review panel expressed concerns about the magnitude of the CVs of these abundance estimates, and made a series of suggestions for possible improvements to the stratification scheme and variance estimation methods for years two and three of the program. The NMFS will investigate these suggestions carefully to pursue lower CVs for the final finding. The issue of CVs for NMFS' abundance estimates will become an even greater challenge in years two and three, as the current plan and funding allocation is for a reduction in effort down to two ships from the three used in 1998.

5 OTHER RELEVANT INFORMATION

The IDCPA states that findings regarding the depleted dolphins stocks in the ETP will be based on the research conducted under the IDCPA research program and any other relevant information. Additional information relevant to the finding presented here includes data on dolphin abundances and fishery mortalities from observers aboard tuna fishing vessels in the ETP, a variety of data from research vessel surveys of the region, and physical oceanographic data from publicly available databases. A description of these data and how they were incorporated into the initial finding follows.

5.1 TUNA VESSEL OBSERVER DATA ESTIMATES OF FISHERY MORTALITY

A record of dolphin mortality in the purse seine fishery is an important part of the information required for this finding. For northeastern offshore spotted and eastern spinner dolphins fishery mortality estimates are available from TVOD for every year from 1959 through 1997. Wade (1995) reported the most recent estimates of incidental dolphin mortality in the early years of the fishery from 1959 to 1972. For the northeastern offshore spotted dolphin, estimates for 1973-1987 were calculated by the IATTC but are unpublished. For the eastern spinner dolphin, estimates for 1973-1978 were reported in Wahlen (1986), as modified in Wade (1993a). Estimates for 1979-1987 are in IATTC (1989). Table 2 shows estimates of mortality for both stocks for 1973-1987 with sources.

For years since 1987 (the last year included in Wade's (1993b) assessments of northeastern offshore spotted and eastern spinner dolphin) annual mortality estimates have been published by IATTC in a number of sources, with apparent refinements included in later sources

for each year. Because of the lack of clarity in published accounts regarding which numbers are considered the best estimates for each stock for each year, the IATTC was consulted for their best estimates for 1988 through 1997 (Table 3). Assessments reported below under item 6.2 used mortality estimates for 1959-1972 from Wade (1995) (see also Tables A1 and A2 in Appendix 2 of this report) and estimates for 1973-1997 from Tables 2 and 3.

5.2 TUNA VESSEL OBSERVER DATA ESTIMATES OF RELATIVE ABUNDANCE AND TRENDS IN ABUNDANCE

TVOD abundance indices form an essential part of the information available on the depleted dolphin stocks of the ETP. Being produced and published by the IATTC, these estimates are not addressed in a primary document arising from NMFS research under the IDCPA. Because of their importance, the NMFS includes here a synopsis of their attributes for representing abundance trends, as represented in the peer-reviewed scientific literature. A more detailed description of these data can be found in Appendix 1.

In 1979, the IATTC began a program to develop statistical methods for estimating the abundance of dolphin stocks in the ETP using TVOD in order “to obtain information on trends in population abundance in time” (Hammond and Laake 1983) and “in a way that allows trend estimates to be used for management purposes” (Buckland et al. 1992). From the beginning of the program, it was recognized that the data “include potential violations of the assumptions necessary for a random sample and for the use of line transect sampling techniques,” and that the resulting “biases in the estimates . . . dictate that the results [should be] investigated for trends over time and not taken as indicators of actual abundance” (Hammond and Laake 1983). Modifications to a standard line transect analysis, designed to account for these biases, are described briefly below. Provided that “bias arising from the failure of an assumption [in the statistical model] is consistent across time” or “that bias shows no trend with time,” the estimates may be used “solely as indices of relative abundance” (Buckland et al. 1992).

Neither tuna vessel search effort nor dolphin schools are spatially uniformly random within each stock range. In addition, different fishing modes predominate in different areas, and mean school size varies spatially as well. A post-stratification scheme, intended to account for potential biases resulting from spatial correlations between search effort and the three components of the abundance estimates (encounter rate, effective strip width, and mean school size) is used, allowing estimates to be made over more homogeneous regions (Buckland and Anganuzzi 1988; Anganuzzi and Buckland 1989, 1993). This post-stratification scheme violates the assumptions necessary for the usual analytic variance approximations, and bootstrap confidence interval estimators are used instead (Buckland et al. 1993).

Range and bearing to a dolphin school sighting are difficult to measure accurately and, in particular, observers tend to round bearings to convenient values. Along with an appropriate binning of perpendicular distances, a data smearing algorithm is used to account for rounding errors (Hammond and Laake 1983, Buckland and Anganuzzi 1988, Buckland et al. 1992).

Because many sightings are seen only by the crew, a correction is used to calibrate crew

school size estimates with respect to observer estimates. To control bias due to school size-dependent probability of detection, mean school size is estimated based on sightings within a limited perpendicular distance range (Buckland and Anganuzzi 1988).

As new technologies and fishing methods are introduced to the fishery (helicopters, bird radar, dolphin-safe fishing), the encounter rate for dolphin schools can be expected to change. However, the effective strip width parameters, estimated using the line transect model, in theory accounts for some of these changes, leading to stable relative abundance estimates. Analyses of the data have found little evidence that abundance estimates have been affected by changes in the fishery (Buckland and Anganuzzi 1988, Anganuzzi and Buckland 1989, Anganuzzi et al. 1991, Buckland et al. 1992, Anganuzzi 1993, Anganuzzi and Buckland 1994) .

Fluctuating environmental conditions can lead to different biases in abundance estimates for different years with particularly unusual years leading to abundance estimates, which are effectively outliers. A non-parametric smoothing algorithm is applied to the time series of annual abundance estimates to produce estimates of trends which are biologically more plausible than the individual annual estimates (Buckland et al. 1992, Anganuzzi 1993). A simulation study indicated that when such fluctuations do not have a temporal trend, the smoothing algorithm produces valid trend data when a suitably long time series is used (Buckland et al. 1992).

As with any set of estimates based on fishery-dependent data, continuing vigilance is required to maintain their validity. One particular source of concern is that the fishery is not static but continues to change its mode of operation. Very recent, unpublished concerns about these indices (noted in a series of personal communications)¹ identified possible changing biases, and other potential effects of fishing operations on the annual indices. The NMFS is aware that these concerns, if proven valid by subsequent research, may have an effect on the results of the assessment modeling conducted as part of this report. However, as noted by the independent peer review (conducted in response to a request by congress), in the absence of a thorough, peer-reviewed analysis confirming these possible problems, the NMFS is compelled to include in this initial finding the peer-reviewed published abundance indices. Further, given the substantial body of peer-reviewed work cited above which supports the validity of these indices to track abundance trends, and in particular the analyses that found little evidence that abundance estimates have been affected by major changes in the fishery (such as the use of helicopters for searching), the NMFS accepts the assertions in these publications and has used TVOD abundance indices as measures of relative abundance in the assessments. The NMFS will pursue a careful evaluation of the TVOD abundance indices, including but not limited to the recently-identified concerns, for the final finding in 2002. Additional comments on the possible effects of uncertainty regarding biases in the TVOD abundance indices are made below in section 7.

5.3 OCEANOGRAPHY

Environmental variability can cause perceived changes in abundance of dolphin stocks in two fundamentally different ways: (1) by causing changes in distribution that result in variable

¹Letters from R. Allen, IATTC, to M. Tillman, SWFSC, dated 1/14/99, 2/17/99 and 3/5/99

biases in survey estimates (e.g. if animals move into or out of the survey area or if group size or sighting conditions change enough to affect detectability), or (2) by causing habitat changes that affect population growth rates and over time result in real changes in abundance. Variable biases are very unlikely to affect the NMFS's absolute abundance estimates of the two depleted stocks because the survey area is large enough to encompass interannual shifts in distribution, and changes in detectability are accounted for by adjusting the effective strip width (Wade 1994, Gerrodette et al. 1998).

Environmental variability and its potential effect on dolphin habitat and abundance were examined by Fiedler (1999). Variability of spatial patterns and time series of spatial means were examined for three types of environmental variables: (1) physical oceanographic data publicly available in NOAA databases, (2) biological data collected during the NMFS's dolphin abundance surveys called Monitoring of Porpoise Stocks (MOPS) from 1986-1990 and SPAM 1998, and (3) indices of dolphin habitat suitability for each stock. Habitat suitability was calculated from the results of an analysis of MOPS environmental and sighting data (Reilly and Fiedler 1994), using a nonlinear multivariate model predicting relative encounter rate of schools as a function of environmental variables from data sources (1) and (2).

El Niño-Southern Oscillation (ENSO) variability is the most important component of interannual variability in the ETP. The amplitude of ENSO variability of surface temperature and thermocline depth in the "core area" (Figure 1) occupied by the northeastern offshore spotted and eastern spinner dolphin stocks is about one-half that of ENSO variability in the eastern equatorial Pacific to the south of the core area. ENSO variability in 1997-1998 was similar to that observed before and during the 1986-1990 MOPS surveys and during the intervening years.

Comparisons of recent to earlier data indicated that spatial fields of dolphin habitat suitabilities and phytoplankton biomass (chlorophyll concentration, an index of ecosystem productivity) for 1998 were within the range of variation observed during and since MOPS. The large-scale spatial pattern of these variables has not changed from year to year, only the amplitude of the pattern. This indicates that changes in the basic structure of the environment have not occurred over the last decade. *Time series of ENSO indices, mean habitat suitability, and the other environmental variables examined show no evidence of a recent regime shift or other long-term change that might decrease population growth rates for depleted dolphin stocks.*

5.4 ABSOLUTE ABUNDANCE ESTIMATES FROM NMFS RESEARCH VESSEL SURVEYS, 1979-1990

The SWFSC began research cruises to survey dolphin abundance in the ETP in 1974. Data suitable for line-transect analyses have been collected since 1979. Data were analyzed by methods similar to those used for the 1998 analysis, as discussed above. There was insufficient search effort and sightings to produce estimates of abundance of coastal spotted dolphins on each survey, but estimates of abundance for northeastern offshore spotted and eastern spinner are shown in Table 4, taken from Wade (1994, Table 6.3). Estimates of absolute abundance and their accompanying dispersion statistics from Table 4 were used in the assessments below.

Variability in abundance estimates can be the result of (1) real changes in abundance and/or (2) imprecision or variable bias in the estimates. Year-to-year variability that cannot be attributed solely to biological change (reproduction, mortality or migration) has been a concern for both RVOD and TVOD abundance estimates (e.g the 1987-1988 increases in Fig. 2). Much of this variability may be attributed to imprecision in the estimates: the error bars on the RVOD estimates in Figure 2 all overlap for eastern spinner dolphins, and all but the 1986 and 1989 estimates overlap for northeast offshore spotted dolphins. However, this one significant difference points to the probable existence of additional, unmeasured variability in these abundance estimates.

Variable bias is also possible: Fiedler and Reilly (1994) showed that when favorable habitat expands in good years, TVOD estimates for some stocks may be biased if animals follow favorable habitat beyond nominal stock boundaries. The survey area for the RVOD estimates extends well beyond the nominal stock boundaries, and favorable habitat (Fiedler, 1999), for eastern spinner and NE offshore spotted dolphins. Therefore, migration of animals out of the survey area is very unlikely to explain variability in these research vessel abundance estimates.

Figure 2 illustrates time series of TVOD and RVOD abundance estimates for eastern spinner and northeastern offshore spotted dolphins, plotted along with estimated habitat availability, a measure of the relative extent of favorable habitat for each stock within the RVOD survey area (Reilly and Fiedler, 1994; Fiedler, 1999). The year-to-year changes in habitat availability are strongly correlated with the state of the ocean in the eastern tropical Pacific known as the El Niño-Southern Oscillation (ENSO). The 1982-83, 1986-87, and 1997-98 El Niño events appear to be associated with some low estimates and the 1988-89 and 1999- La Niña events appear to be associated with some high estimates. However, even without considering the imprecision of the estimates, overall relationships between mean habitat availability throughout the region and the various abundance estimates are not statistically significant. Continued research vessel surveys of the dolphin stocks and their environment are needed to explain and perhaps reduce year-to-year variability in abundance estimates.

6 SIGNIFICANT ADVERSE IMPACT DETERMINATION

Because there are several types of information that are relevant to the finding on whether purse-seine fishing activities are having an adverse impact on depleted dolphin stocks in the ETP, a formal objective strategy for combining various types of research results and their associated levels of uncertainty was sought. Consequently, a decision analysis framework is being used to quantitatively evaluate these various types of information in order to make the significant adverse impact determination required by the IDCPA. This section describes the decision analysis framework and how each component (i.e. the various types of information and research results) will be incorporated into the overall determination.

6.1 DECISION ANALYSIS FRAMEWORK

This framework is being developed for the SWFSC under contract by D. Goodman of Montana State University. The basic elements of the framework are in place and are used in this

initial finding, with the entire framework to be in place for the final finding in 2002. Details of the framework as developed for the 1999 initial finding are given in Goodman (1999). One basic aspect of this system is reformulating the question posed by the IDCPA regarding significant adverse impact in terms that can be addressed by scientific information. The reformulated overall question for the research program follows.

Question 1. “In the period since 1991, has there been for any depleted ETP dolphin stock a failure, attributable to fishery activities, to grow at the expected rate?”

Two key elements are needed to turn this question into a decision rule: (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 one needs to be that such a depression of population growth rate has or has not occurred, in light of the imperfect information that is available.

Goodman (1999) further noted that 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. The methods used here for detection of the effect, “failure to grow at the expected rate,” for purposes of the 1999 initial finding are described below (question 2 in this section, and section 6.2). For purposes of the 2002 determination, the process by which failure to recover is or is not attributed to fishery activities 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.

The series of questions needed to completely specify the decision tree has not been 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 developments of the decision framework 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.

Given the limited information now available it is not possible to address in a formal sense the second definition required for question 1, regarding attribution of cause. Rather, it is only possible to obtain indirect, qualitative information from two possible causes for any observed “failure to grow at the expected rate”: changes in oceanography of the ETP and/or physiological stress to dolphins resulting from the fishery. The NMFS has used the limited information available to answer a sub-set of the questions posed below regarding these two causes.

6.1.1 Trend and Abundance Component of the Determination

Question 2. “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 absolute abundance estimates?”

An analysis to answer the trends and abundance question has been conducted (reported below under section 6.2) using the existing time series of kill estimates as well as absolute and relative abundance estimates including the 1998 SPAM survey results. 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 below.

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 three or four years of TVOD abundance estimates and kill data, and two more years of research vessel abundance estimates.

6.1.2 Stress Component of Attribution of Cause

- Question 3a. “Is chase and encirclement a generally plausible cause of stress?”
- Question 3b. “Is stress a generally plausible cause of depression in population growth?”
- Question 3c. “Is there physiological evidence of stress in individuals from the affected dolphin populations?”

An affirmative answer to question 3a, based on a literature review, is given in section 4.1 of this report. Question 3b was partially but not definitively answered affirmatively by the stress literature review. Answers to question 3c are not yet available but may be so at the completion of the necropsy sampling program. However, it must be emphasized that there is no methodology at present for quantitatively relating observed measures of stress in individual animals to an expected magnitude of depression of survival or reproductive rates.

6.1.3 Oceanographic Component of Attribution of Cause

- Question 4a. “Is the present magnitude or extent of preferred dolphin habitat, in the area of the affected stocks, within the range of variation observed during 1986-1990?”
- Question 4b. “Are the present indices of ecosystem productivity, in the area of the affected stocks, within the range of variation observed during 1986-1990?”
- Question 4c. “Do the time series of annual indices of El Niño/La Niña 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?”
- Question 4d. “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?”

The review of oceanographic conditions in the ETP summarized briefly in section 5.3 above concludes that the answer to question 4a is affirmative. That review and analysis is not fully conclusive on question 4b, but the information available supports an affirmative answer. The answer to question 4c is negative; the time series examined do not reflect an oceanographic regime shift in the ETP in the period since 1970. It was not possible to address question 4d for the initial finding. Work is underway to do so for the final finding.

6.1.4 Proposed Decision Rules

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 before 1991.”

The failure of the population to grow at the expected rate can be measured as a probability distribution on the amount by which the rate of population growth, estimated for the period up to and including 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 the entire time series, in an age-structured model.

The analysis of the data for the trends and abundance can be conducted in terms of estimating a depression in the population growth rate after 1991 compared to the period up to and including 1991. The decision quantity will be the size of the sum of the estimate of growth rate depression and the reported kill rate, relative to the estimate of r_{max} . The r_{max} will be estimated from fitting the time series data for the period up to and including 1991 and back-calculating a population trajectory to the year at the start of the fishery (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 r_{max} will be Bayesian, and the estimate will be conveyed as a posterior distribution.

The decision framework proposes that multiple thresholds 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, whereas 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 growth rate depression exceeds the r_{max} 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 growth rate depression exceeds half the r_{max} 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 growth rate depression exceeds one quarter the r_{max} from the period up to and including 1991.”

It is noted that these criteria drew on the rationale from technical discussions leading to the interim Panama agreement and the PBR criteria. It is important to note that criterion 2 is less restrictive than a PBR limit in that it does not include the additional “recovery factor” of the PBR approach, which in effect scales down the potential biological removal by a factor which depends on the extent to which the stock is depleted. The discussion of criterion number 3 also considered the value one tenth the r_{max} estimate in place of one quarter, as possibly appropriate.

The technical statistical estimates have been carried out by modification of Wade's (1994) Bayesian population model for ETP dolphins, as described below.

6.2 POPULATION ASSESSMENT MODEL USED FOR NORTHEASTERN OFFSHORE SPOTTED AND EASTERN SPINNER DOLPHIN STOCKS

6.2.1 Methods

The methods used are similar to other previous analyses (Wade 1994, in press) and are documented in more detail in Appendix 2. Wade (1994) used an identical population model and nearly identical Bayesian methods to estimate depletion levels of both northeastern offshore spotted dolphins and eastern spinner dolphins. Wade (in press) contains a similar analysis of northeastern offshore spotted dolphins using identical statistical methods, but with a non-age-structured model. A summary of the methods used here follows.

A population model was fit to available abundance data. Abundance estimates are available from research vessel surveys in ten years from 1979 to 1998 (Tables 1 and 4). Indices of abundance from data collected on tuna vessels (TVOD) are available for 23 years from 1975 to 1997 (Tables 2 and 3).

Fisheries mortality estimates are available for every year from 1959 to 1997 (Tables A1 and A2 in Appendix 2, and Tables 2 and 3 of this report). Estimates of fisheries mortality for 1998 are not yet available; therefore, mortality in 1998 was assumed to be equal to mortality in 1997, with a small amount of variability (CV=0.10) specified in this assumed 1998 mortality to account for uncertainty in its actual level. The sampling errors of the mortality estimates was assumed to be log-normal. Additionally, the sampling errors of the mortality estimates from 1959-72 were assumed to be correlated because mortality-per-set rates were pooled across that time period (Wade 1995).

A population model was fit to available abundance data from 1975 through 1991. The model used was an age-structured density-dependent model in the form of a Leslie matrix (Breiwick et al. 1984). Parameters of the model were juvenile survival (s_j), adult survival (s_a), maximum fecundity rate (f_{max}), age of sexual maturity (asm), age of transition to adult survival (ia), maximum age (iw), and equilibrium population size (N_{eq}). In this model, density-dependence acts on fecundity, and the amount of non-linearity in the density dependent response is in the form of the generalized logistic, with a shape parameter (z), which determines the maximum net productivity level. The maximum population growth rate (r_{max}) was calculated as $\lambda_{max}-1$, where λ_{max} was the λ (finite rate of increase) associated with the Leslie matrix with fecundity equal to f_{max} . The estimate of r_{max} essentially comes from the realized growth rate estimated from the 1975-1991 abundance data, in concert with the estimate of where the population was relative to N_{eq} .

The population size was assumed to be equal to N_{eq} in 1958 and to be in the stable age distribution associated with the equilibrium Leslie matrix (where the fecundity rate was equal to f_0 , the fecundity rate at equilibrium or zero population growth). In each year, (1) the population was projected using the model, (2) the additional mortality was subtracted (where additional mortality was simply the estimated fisheries mortality 1959-1991), and (3) the model population size was compared to the abundance data (if available in that year). Age-specific selectivities were calculated using an iterative convergence routine, such that the age structure of the fisheries mortality in 1984 was equal to the smoothed observed age distribution of the kill from 1974-1992 presented in Wade (1994, Fig. 6.3).

After estimating r_{max} from the abundance data from 1975-1991, the population was then projected through 1998 with the expected realized growth rate, given the estimated model parameters and estimated depletion level (population level relative to N_{eq}). Any difference between the expected model trajectory and the estimated 1992-1998 population trajectory (as fit to the 1992-1998 abundance data) represents an estimate of a change in the population growth rate. An additional parameter (μ) was specified to represent this potential change from the expected population growth rate from 1992 to 1998, acting through additional mortality (mortality in addition to the natural mortality accounted for by parameters s_j and s_a). In the model trajectory, prior to 1992, additional mortality was from only the estimated fisheries mortality. In 1992 and later years, additional mortality was equal to $M_t + \mu N_t$, where M_t was the observed estimated mortality in year t , and N_t was the model population size in year t . Therefore, μ represents an estimate of the difference between the expected population growth rate and the observed population growth rate in the years 1992-1998. A total additional mortality rate was calculated as $\mu_{tot} = (M_t + \mu N_t)/N_t = (M_t/N_t) + \mu$.

The estimation of r_{max} from the abundance data from 1975-1991, and then the estimation of μ conditioned on that estimate of r_{max} , could be done sequentially in two separate steps. However, it was simpler to estimate both in a single analysis, by projecting the population model through 1998, and including the contributions to the likelihood from the 1992-1998 abundance data to the total likelihood. Because there was probably some level of unobserved mortality during 1975-1991 and this is not accounted for in our estimation of r_{max} , we are probably underestimating r_{max} by some unknown amount.

The model parameters were estimated using Bayesian statistical methods. The Bayesian joint posterior distribution was approximated using the SIR routine (Smith and Gelfand 1992). Log-normal likelihoods were used for both series of abundance estimates. The TVOD data were scaled to absolute abundance using a scale parameter, a . Prior distributions were specified for the eight parameters N_{eq} , s_a , s_j , f_{max} , z , asm , a , and μ . The parameters ia and iw were set to fixed values. Marginal probability distributions were calculated for all the estimated parameters. In particular, a probability distribution for the decision quantity, the ratio μ/r_{max} , was calculated. The cumulative probability this ratio was greater than 1.0, 0.5, 0.25, and 0.1 was also calculated. These values were the decision criteria thresholds that were specified under section 6.4, namely, (1) $\text{Prob}(\mu_{tot} > r_{max}) > 0.010$, (2) $\text{Prob}(\mu_{tot} > 0.5*r_{max}) > 0.050$, and (3) $\text{Prob}(\mu_{tot} > 0.25*r_{max}) > 0.500$ (Table 5).

6.2.2 Results

6.2.2.1 Northeastern Offshore Spotted Dolphin

Estimates of the eight parameters from the analysis of northeastern offshore spotted are in Table 6. Estimates of the output quantities of interest, which are functions of the eight parameters, are also presented in Table 6. The point estimate of r_{max} is 0.015 or about 1.5% population growth per year. The point estimate of μ is 0.038 or 3.8% of the population per year. The quantity μ_{tot} , which includes the estimated observed fisheries mortality, is slightly higher at 4.1%. Because μ is greater than r_{max} , this implies that the population declined from 1991 to 1998, which can be seen from a comparison of the posterior means for population size in those years (722. versus 582.). This decline is consistent with the TVOD trend data over this time period.

For the northeastern offshore spotted dolphin, each of decision criteria probabilities exceeds the specified acceptable levels of 0.01, 0.05, and 0.50 (Table 7). Therefore, the difference between the expected and observed population growth rate from 1992-1998 is considered to be too high (Figure 3). *That is, for northeastern offshore spotted dolphins all three decision rules are violated: (1) $\text{Prob}(\mu > r_{max})$ equals 0.996, (2) $\text{Prob}(\mu > 0.5*r_{max})$ equals 0.9988, and (3) $\text{Prob}(\mu > 0.25*r_{max})$ equals 0.9994.*

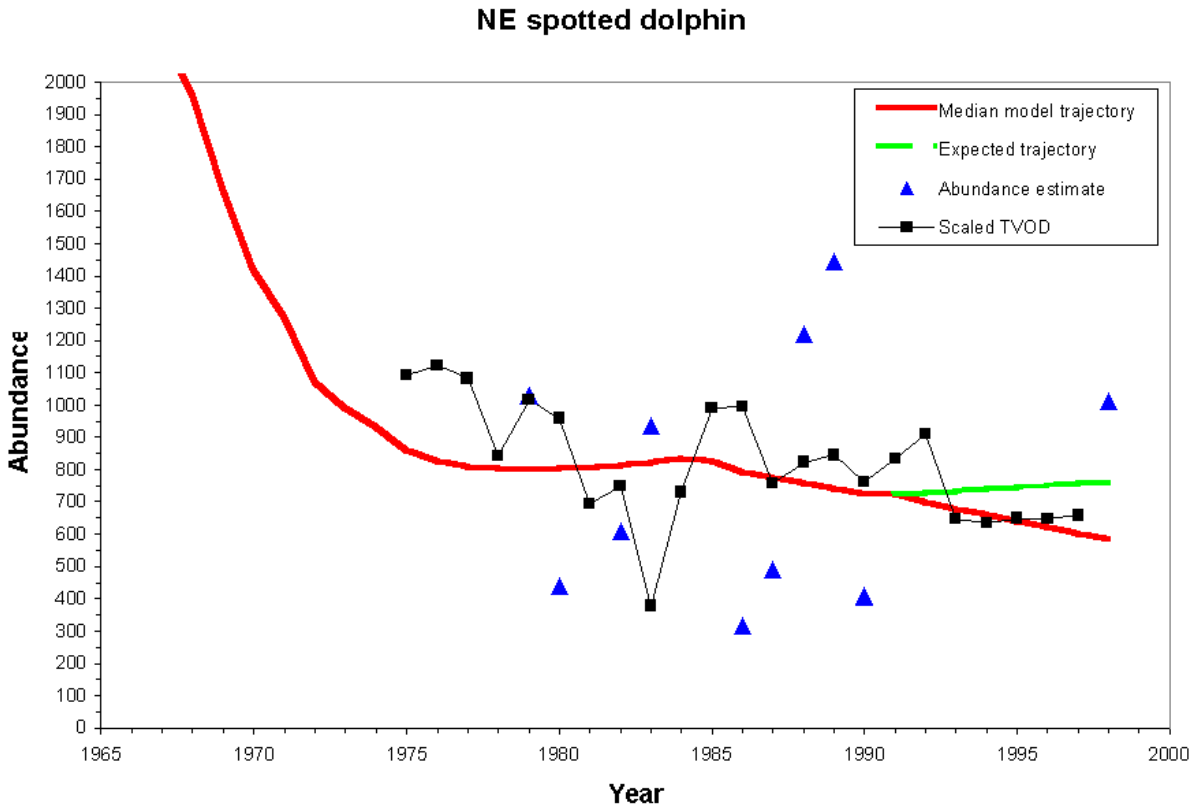


Figure 3. Model population trajectory and abundance data for the northeastern offshore spotted dolphin. Median model trajectory is the median model population size in each year from the posterior distribution. Expected trajectory is the expected model trajectory using r_{max} estimated from 1975-91 data, with μ set to 0.0. Abundance estimates are the research vessel abundance estimates. Scaled TVOD are the Tuna Vessel Observer Data trend estimates, scaled to absolute abundance by the estimated parameter a .

6.2.2.2 Eastern Spinner Dolphin

Estimates of the eight parameters and output quantities from the analysis of the eastern spinner dolphin are in Table 8. The point estimate of r_{max} and μ are nearly the same (0.017 versus 0.016). The point estimate of the quantity μ_{tot} (0.017), which includes the estimated observed fisheries mortality, is identical to the estimate of r_{max} . However, the distribution for μ_{tot} has a longer tail at the upper end, meaning that there is substantial probability that μ_{tot} is greater than r_{max} . Because estimated values of μ_{tot} are similar to estimated values for r_{max} , this implies that the population was nearly stable or declined slightly from 1991 to 1998, which can be seen from a comparison of the posterior means for population size in those years (636. versus 623.). Again, this result is consistent with the TVOD trend data over this time period.

For the eastern spinner dolphin, each of the decision criteria probabilities exceeds the specified acceptable levels of 0.01, 0.05, and 0.50 (Table 9). Therefore, the difference between the expected and observed population growth rate from 1992-1998 is considered to be too high (Figure 4). *That is, for eastern spinner dolphins all three decision rules are violated: (1) $Prob(\mu > r_{max})$ equals 0.440, (2) $Prob(\mu > 0.5 * r_{max})$ equals 0.690, and (3) $Prob(\mu > 0.25 * r_{max})$ equals 0.848.*

Eastern spinner

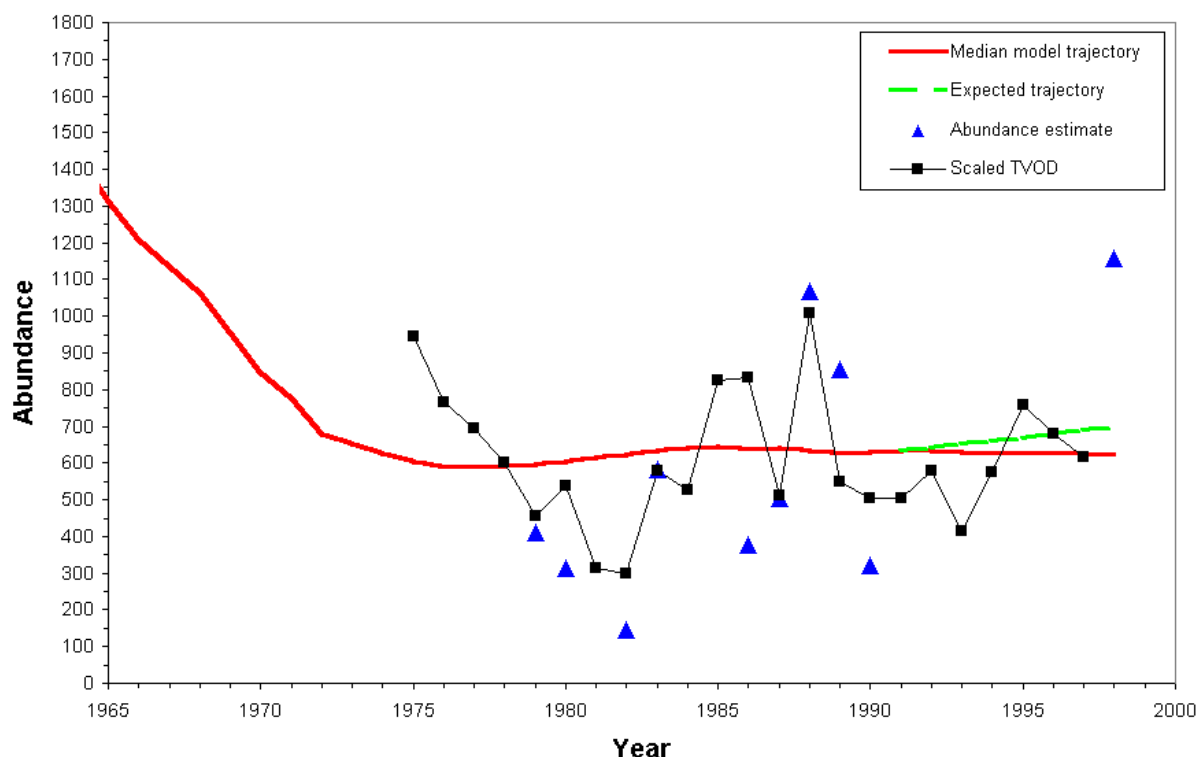


Figure 4. Model population trajectory and abundance data for the eastern spinner dolphin. Median model trajectory is the median model population size in each year from the posterior distribution. Expected trajectory is the expected model trajectory using r_{max} estimated from 1975-91 data, with μ set to 0.0. Abundance estimates are the research vessel abundance estimates. Scaled TVOD are the Tuna Vessel Observer Data trend estimates, scaled to absolute abundance by the estimated parameter a .

6.3 COASTAL SPOTTED DOLPHIN STOCK

The information available to evaluate the status of the coastal spotted dolphin stock includes TVOD estimates of fishery mortality for 1973-1997, TVOD estimates of relative abundance for 1987-1997 and research vessel estimates of absolute abundance for 1988 and 1998 (Table 10). Other information potentially relevant here includes earlier estimates of abundance from pre-MOPS surveys and records of the frequency of net sets on dolphins within 100 nm of the coast by year.

Observed fishery mortality is quite variable but low overall as an annual fraction of absolute abundance. The largest annual mortality was estimated for 1973, the first year when those figures were available, when 3,197 animals were estimated to have been killed. In comparison to the 1998 estimate of absolute abundance (perhaps the only reliable estimate of absolute abundance for this stock) this was about 3% and may not have been sustainable. However, annual mortality dropped to just 76 animals the following year and varied between single digit values and highs of 200-300 for most years thereafter. A subsequent high kill year was recorded for 1990 when the estimate was 716 or 0.7% of current abundance. In conclusion, since 1974 observed fishery mortality has been relatively low for this stock and would not alone be expected to deplete the stock or substantially delay its recovery, should it have been depleted in years before 1974.

The TVOD time series for 1987-1997 may not be sufficiently precise to represent small interannual changes (standard errors are in the range of 27% to 100% of annual estimates) but overall the estimates are not inconsistent with stability during that period. This observation obviously carries little statistical power, however, and is not in itself a basis for an evaluation of fishery effects.

The 1998 estimate of 108,289 (CV=0.4) is considerably higher than the 1988 estimate of 29,800 (CV=0.346). However, a direct comparison of the two estimates is of questionable value. Although the CV estimates are moderately large, the difference is still too large to be attributed to population growth alone. Because similar analytic methods were used for both estimates, it is likely that some kind of sampling problem is present. Of the two estimates, the 1998 estimate should be considered more reliable because this survey included a planned sampling of the range of the coastal spotted dolphin. The 1988 estimate was based on data pooled over five years and did not include any designed sampling in the stock's range. Most sampling during the 1986-1990 MOPS surveys occurred as the vessels came into or left from the same ports each year, so the sampling was not geographically random.

An evaluation of all relevant information including pre-MOPS absolute abundance estimates and frequency of purse seine fishing within the stock's range will not be available for this initial finding. *In conclusion, it is not possible at this time to determine if chase and encirclement by the purse seine fishery is having a significant adverse impact on the coastal stock of spotted dolphins.*

6.4 ADDITIONAL ANALYSES REQUESTED BY THE PEER-REVIEW PANEL

The peer-review panel expressed concerns about the definition and estimation of μ in the assessment modeling reported above. As the panel suggested NMFS will pursue alternate modeling structures for the 2002 finding. For the present, initial finding a simple alternate model was fit to the data without an explicit parameter such as μ . Rather, this effort fit exponential growth models to the time series for 1975-1991 and 1992-1998. As before, the break was made at 1992 to reflect the large reduction in reported mortalities at that time. Results of a maximum likelihood analysis were: $r_{75-91} = 0.017$ (exactly as before), and $r_{92-98} = -0.30$. The difference between these is 0.047 or 4.7%. Similarly, a Bayesian estimation gave $r_{75-91} = 0.017$ (0.000, 0.035) and $r_{92-98} = -0.26$ (-0.068, 0.019) with a difference in growth rates of 0.043 or 4.3%. These estimates are close but slightly larger than the full age structured Bayesian analysis which estimated $\mu = 0.038$, and as the panel noted indicate that the definition and estimation of μ are not driving the results. Figure 5 presents the fit of the exponential model, which is very close to the fit of the full model (for the common time period covered) shown above in Figure 3.

Another concern expressed by the panel regarding μ was that it was defined as a constant proportion of population size rather than a function of the fishery, such as the number of dolphin sets or the observed fishery kill rate. We continue to regard it as preferable to define μ as a rate of population size, at least for the initial finding, because to define it as a direct function of the fishery would presuppose a direct fishery effect in any observed lack of recovery. As noted

above, such attribution of causality is beyond the scope of the information presently available, and thus would not seem appropriate.

7 DISCUSSION AND CONCLUSIONS

Determining adverse impact, other than observed mortality, to a marine wildlife population is a daunting task. This is made more difficult by any expectation that results from just the first year of a three-year program will prove conclusive; they have not, and this is not surprising. The reporting of the initial results of the research program here has attempted to separate the question of adverse impact into parts that can be addressed scientifically. Some can be answered quantitatively and others only qualitatively. In the following paragraphs the initial results from the research program are first summarized and then followed by an attempt to put those results into a larger context that considers the strengths and weaknesses of the data and some likely interpretations of the observations.

Given the information available from research vessel abundance estimates, tuna vessel abundance indices and observed fishery mortality, the quantitative answers to the question, “In the period since 1991, has there been for any depleted stock a failure to grow at the expected rate. . .” are “yes” for both northeastern offshore spotted and eastern spinner dolphins. The probabilities associated with these answers are quite high, well above the suggested thresholds of 0.01, 0.05 and 0.50 (Tables 7 and 9). When considered with the qualitative answer from oceanographic studies (that it is unlikely that such a failure to grow can be explained by large-scale environmental variability) and the qualitative answer from the literature review (that it is plausible that stress resulting from chase and encirclement could have population level effects) the information suggests but by no means conclusively that the fishery has been the source of significant adverse impact on these two populations.

The data are not entirely conclusive, nor will they ever be so, even with many additional years of information. This analysis has attempted through the use of Bayesian statistics to include explicitly those sources of uncertainty that can and have been measured. Even given this relatively large measured uncertainty the results clearly suggest that growth rates have been significantly depressed for both stocks. However, one must also consider other sources of uncertainty not amenable to explicit inclusion in such an analysis. These include unknown biases in one or more of the data sources. In particular, biases that change non-randomly over time can lead to inappropriate conclusions. Directly pertinent here are the very recent concerns expressed by the IATTC regarding biases in the TVOD abundance indices. One of these concerns raises the possibility that changes in fishery operations in the early 1990s, and therefore related changes in data recording biases, may have resulted in lower-than-appropriate abundance indices in recent years. If subsequent research, evaluated by peer-review, supports this new concern then it will be appropriate to repeat the assessment modeling reported here using a series of TVOD indices with this matter corrected. The numerical change in results of the assessments cannot be predicted, but it is likely that estimates of the apparent failures to recover would be smaller in magnitude. This apparent concern regarding a change in bias, with another recently-expressed concern indicating a possible correlation of the TVOD abundance index with the number of sets on dolphins, strongly indicate the need for an independent evaluation of the entire process of estimating abundance and trends with TVOD. The NMFS will likely pursue such an evaluation, in the spirit

of replication of scientific findings, in order to include less uncertainty in the final finding for 2002.

It is also possible that the time since observed mortality was substantially reduced (circa 1991) is not long enough to allow detection of recovery because of lags resulting from, among other things, the time between birth and age at sexual maturity. If this proves to be the case, the NMFS may be able to detect the recovery by the end of the program. Limitations to the modeling approach must also be considered. In particular, issues surrounding estimating maximum possible growth rates (r_{max}) are notoriously difficult. (Here, the NMFS has estimated r_{max} directly from the data, rather than using a default value obtained by analogy with other populations and species). However, lacking clear scientific evidence of the existence of such changes in biases, time lags in population response or specific model mis-behaviors, the conservative approach, at least for the present, is to accept the apparent failures to recover as real and move to the next decision phase which addresses causality.

Attributing causality is far more difficult than interpreting abundance and trend data. It has only been possible to address in a brief and preliminary way the two primary sources identified as possible causes for such failures to recover: changing environmental conditions and indirect or unobserved effects of the fishery. The review of environmental conditions did not disclose any large-scale oceanographic regime shifts during recent decades, such as have been observed in the North Pacific and linked to conservation problems for salmon and other species (e.g. Francis and Hare 1994). However, the NMFS has not yet investigated possible changes in abundances and associations of the other large pelagic predators of the ETP. For the 2002 finding the NMFS will be investigating possible changes between the late 1980s (for which we have data from the MOPS expedition) and late 1990s in abundance and species mix of bird flocks that associate with dolphins and tunas. The NMFS will also investigate data on tunas and other large predatory fishes that share common prey or potentially could be competitors with dolphins, and selected prey species for evidence of community structure shifts that could contribute to depression of dolphin population growth rates. For the present, however, such possible explanations for the apparent lack of recovery are only hypothetical, and the clear observation of a lack of large-scale oceanographic changes cannot be ignored.

The stress literature review concluded that fishery-related stresses could plausibly affect mortality or reproduction. Such a review can do no more than suggest if such a population-level effect is plausible and point to avenues for research. The NMFS can not yet determine if physical evidence of such stress occurs in dolphins killed in the fishery. To make that determination the NMFS must await results from the necropsy sampling program and the other stress-related research projects now underway. Further, even given such evidence it is not clear how it can be placed in a quantitative population context. Work is being done on these matters for the 2002 finding. For the present, it can only be said that it is not appropriate to dismiss fishery-related stress as a source of the observed depression in population growth rates.

Stress is only one possible fishery-related source of the apparent lack of recovery. Other plausible sources include separation of cows and calves (with subsequent death of calves) and

under-reporting of direct kills. It must also be noted that none of the possible causes mentioned are necessarily exclusive of the others. We will address these and related issues for the 2002 finding.

In summary, evidence from a combination of research vessel estimates of absolute abundance and tuna vessel estimates of relative abundance and fishery mortality indicate that during the past decade there has been a failure to recover as expected by both the northeastern offshore spotted dolphin and eastern spinner dolphin stocks. Our first examination of a large amount of data on the region's oceanography disclosed no indication of a regime shift or other large-scale change that conceivably could contribute to this failure. A review of literature on stress in mammals suggested that fishery-caused stress is a plausible contributor to such a failure. These latter two observations do not provide "proof" that the tuna purse seine fishery is the cause of the failures to recover but neither do they dismiss it as a possible cause.

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Table 1. Estimates of abundance in 1998 for three stocks of dolphins in the eastern tropical Pacific. The coefficient of variation (CV) is also shown for each estimate.

Stock	Estimate	CV
Eastern spinner dolphin	1,157,746	0.336
NE offshore spotted dolphin	1,011,104	0.264
Coastal spotted dolphin	108,289	0.405

Table 2. Estimates of relative abundance (1975-1987) and mortality (1973-1987) from Tuna Vessel Observer Data for northeastern offshore spotted dolphins and eastern spinner dolphins.

Year	<i><u>Northeastern Offshore Spotted</u></i>						<i><u>Eastern Spinner</u></i>					
	Abundance (n)			Mortality (m)			Abundance (n)			Mortality (m)		
	n	SE(n)	source	m	SE(m)	source	n	SE(n)	source	m	SE(m)	source
1973	n/a	n/a	n/a	49928	8899	2	n/a	n/a	n/a	18400	2944	3
1974	n/a	n/a	n/a	37410	4222	2	n/a	n/a	n/a	17800	1958	3
1975	1539000	295000	1	49399	8809	2	670000	285000	1	17100	1881	3
1976	1581000	320000	1	20443	4721	2	544000	182000	1	14700	1764	3
1977	1523000	257000	1	5937	690	2	494000	137000	1	1800	216	3
1978	1187000	227000	1	4226	827	2	428000	153000	1	1100	121	3
1979	1432000	282000	1	4828	817	2	323000	185000	1	1460	357	4
1980	1348000	252000	1	6468	962	2	381000	117000	1	1108	218	4
1981	976000	117000	1	8096	1508	2	222000	120000	1	2261	634	4
1982	1054000	143000	1	9254	1529	2	212000	102000	1	2606	744	4
1983	532000	116000	1	2430	659	2	410000	133000	1	745	285	4
1984	1027000	238000	1	7836	1493	2	375000	139000	1	6033	3124	4
1985	1394000	183000	1	25975	3210	2	587000	136000	1	8853	1382	4
1986	1401000	188000	1	52035	8134	2	590000	118000	1	19526	3652	4
1987	1067000	68000	1	35366	4272	2	363000	100000	1	10358	1243	4

Notes:

n/a = not available. No abundance estimates made for these years.

Sources:

1. Anganuzzi and Buckland (1994) (northeastern spotted dolphin) and personal communication, A. Anganuzzi, IATTC (eastern spinner dolphin).
2. Wade (1994) and letter from Joseph to Tillman, 9/6/1994 (IATTC ref#0539-812).
3. Wahlen (1986) as modified by Wade (1993a).
4. IATTC (1989).

Table 3. Mortality and abundance estimates produced by the Inter-American Tropical Tuna Commission from Tuna Vessel Observer Data for northeastern offshore spotted dolphins and eastern spinner dolphins, 1988-1997.

Year	<u>Northeastern Offshore Spotted*</u>						<u>Eastern Spinner†</u>					
	Abundance (n)			Mortality (m)			Abundance (n)			Mortality (m)		
n	SE(n)	source	m	SE(m)	source	n	SE(n)	source	m	SE(m)	source	
1988	1159000	135000	1	26625	2744	4	717000	110000	2	18793	1749	2
1989	1188000	129000	1	28898	3108	4	389000	71000	2	15245	1674	2
1990	1072000	79000	1	22616	2575	4	358000	76000	8	5378	949	2
1991	1174000	94000	1	9005	956	4	358000	65000	2	5879	771	2
1992	1282000	92000	1	4657	321	2	410000	91000	2	2794	168	2
1993	911000	68000	2	1139	89	2	295000	54000	2	821	98	2
1994	895000	63000	3	935	69	6	408000	85000	3	743	84	6
1995	913000	61000	2	952	n/a	7	538000	83000	2	654	n/a	7
1996	910000	56000	2	818	n/a	2	483000	139000	2	450	n/a	2
1997	927000	54000	5	721	n/a	5	439000	127000	5	391	n/a	5

Notes:

* Includes coastal spotted dolphins in the coastal region north of 5°N.

† Includes unidentified spinner dolphins prorated to the eastern spinner stock.

n/a = not applicable. 100% observer coverage.

Sources:

1. Anganuzzi and Buckland (1994).
2. IATTC Annual Reports.
3. Personal Communication, C. Lennert, IATTC, Dec. 1998.
4. Wade (1994) and letter from Joseph to Tillman, 9/6/1994 (IATTC ref#0539-812).
5. IATTC (In prep).
6. Lennert and Hall (1996).
7. Hall and Lennert (1997).
8. Anganuzzi et al. (1992).

Table 4. Estimates of absolute abundance for northeast offshore spotted and eastern spinner dolphin stocks in the eastern tropical Pacific based on Southwest Fisheries Science Center line-transect surveys. The coefficient of variation (CV) is also shown for each estimate.

Year	NE offshore spotted		Eastern spinner	
	Estimate	CV	Estimate	CV
1979	1,031,400	0.36	408,800	0.43
1980	438,300	0.46	312,100	2.38
1982	608,400	0.34	146,400	0.76
1983	937,400	3.59	582,600	1.61
1986	318,200	0.28	378,200	0.53
1987	489,500	0.22	505,100	0.41
1988	1,220,100	0.31	1,066,500	0.37
1989	1,445,000	0.26	855,100	0.49
1990	406,700	0.46	320,100	0.59

Table 5. Decision criteria thresholds. μ_{tot} is the difference in the observed population growth rate from 1992-1998 from the expected rate as estimated from 1975-1991 abundance data. r_{max} is the maximum population growth rate, estimated from the fit of the model to the 1975-1991 abundance data. μ is considered unacceptable if any of these conditions are met:

1. $\text{Prob}(\mu_{\text{tot}} > r_{\text{max}}) > 0.010$
2. $\text{Prob}(\mu_{\text{tot}} > 0.5 * r_{\text{max}}) > 0.050$
3. $\text{Prob}(\mu_{\text{tot}} > 0.25 * r_{\text{max}}) > 0.500$

Table 6. Parameters and output quantities for the northeastern offshore spotted dolphin. Mean is the mean of the posterior distribution. 2.5th and 97.5th are the respective percentiles of the posterior distribution. N_{eq} , N_{91} , and N_{98} are all in thousands of animals.

Parameter	Mean	2.5 th	97.5 th	Output quantities	Mean	2.5 th	97.5 th
N_{eq}	4039.	3063.	5164.	N_{91}	722.	581.	886.
s_a	0.987	0.962	0.998	N_{98}	582.	468.	729.
s_j	0.868	0.819	0.921	N_{98}/K	0.148	0.108	0.195
f_{max}	0.236	0.170	0.323	r_{max}	0.015	0.004	0.027
z	5.57	1.14	10.87	μ/r_{max}	2.948	1.453	6.102
asm	11.65	11.00	13.00	μ_{tot}	0.041	0.017	0.066
a	1.502	1.224	1.823	$\mu_{\text{tot}}/r_{\text{max}}$	3.152	1.544	6.512
μ	0.038	0.015	0.062				

Table 7. Decision criteria probabilities for the northeastern offshore spotted dolphin.

1. $\text{Prob}(\mu_{\text{tot}} > r_{\text{max}}) = 0.996$
2. $\text{Prob}(\mu_{\text{tot}} > 0.5 * r_{\text{max}}) = 0.9988$
3. $\text{Prob}(\mu_{\text{tot}} > 0.25 * r_{\text{max}}) = 0.9994$

Table 8. Parameters and output quantities for the eastern spinner dolphin. Mean is the mean of the posterior distribution. 2.5th and 97.5th are the respective percentiles of the posterior distribution. N_{eq} , N_{91} , and N_{98} are all in thousands of animals.

Parameter	Mean	2.5 th	97.5 th	Output quantities	Mean	2.5 th	97.5 th
N_{eq}	1913.	1348.	2557.	N_{91}	636.	443.	882.
s_a	0.976	0.947	0.994	N_{98}	623.	420.	891.
s_j	0.848	0.803	0.923	N_{98}/K	0.340	0.215	0.524
f_{max}	0.240	0.170	0.323	r_{max}	0.017	0.003	0.036
z	5.82	1.20	10.91	μ/r_{max}	1.482	0.041	5.155
asm	10.07	8.00	12.00	μ_{tot}	0.017	0.001	0.055
a	0.725	0.517	0.998	μ_{tot}/r_{max}	1.582	0.078	5.463
μ	0.016	0.001	0.052				

Table 9. Decision criteria probabilities for the eastern spinner dolphin.

1. $\text{Prob}(\mu_{tot} > r_{max}) = 0.44$
2. $\text{Prob}(\mu_{tot} > 0.5 * r_{max}) = 0.69$
3. $\text{Prob}(\mu_{tot} > 0.25 * r_{max}) = 0.848$

Table 10. Coastal spotted dolphin estimates of fishery mortality for 1973-1997 and relative abundance for 1987-1997 from Tuna Vessel Observer Data, and research vessel estimates of absolute abundance for 1998.

Year	Tuna Vessel Observer Data*				Research Vessel	
	Abundance (n)	SE(n)	Mortality (m)	SE(m)	Abundance (n)	CV(n)
1973			3197	2295		
1974			76	44		
1975			68	21		
1976			9	7		
1977			208	92		
1978			3	1		
1979			289	123		
1980			7	7		
1981			337	243		
1982			9	8		
1983			16	14		
1984						
1985			43	39		
1986			3	1		
1987	21622	21043	164	82		
1988	36880	12271	199	106	29800 [†]	0.346
1989	79925	22125	134	43		
1990	77570	53649	716	500		
1991	69897	24891	141	43		
1992	74667	23292	120			
1993	54466	15151	166			
1994	133422	44991	55			
1995	65561	27162	43			
1996	74608	23762	5			
1997	67145	30054	26			
1998					108289 [‡]	0.405

Notes:

* Letters to M. F. Tillman from IATTC, 4 December 1999 (relative abundance estimates) and 1 February 1999 (mortality estimates).

† Wade and Gerrodette (1993).

‡ Gerrodette (1999).

Figure 1. *Stenella* Population Abundance Monitoring (SPAM) 1998 research vessel survey study area with sampling strata identified (from Gerrodette 1999).

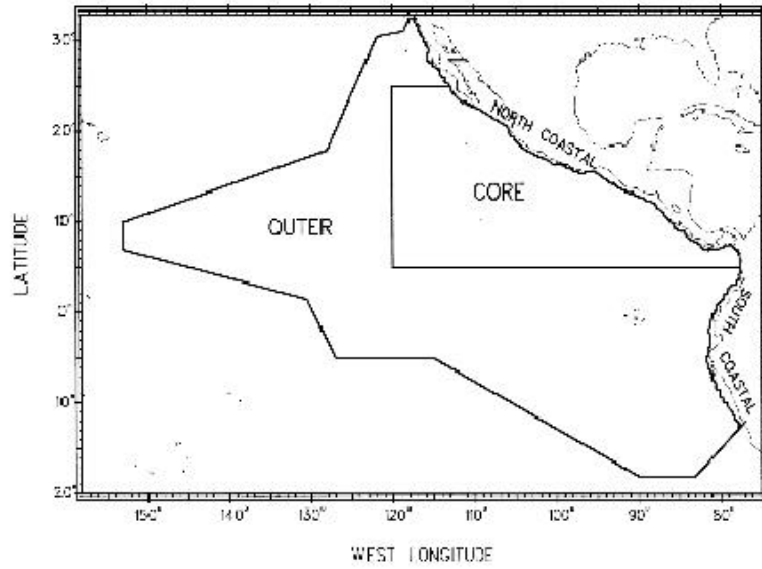


Figure 2. Dolphin habitat availability (H, 13-month running mean, thick line) in the ETP (Fiedler, 1999) and abundance estimates (N, ■ scaled TVOD, ▲ RVOD $\pm 95\%$ CL).

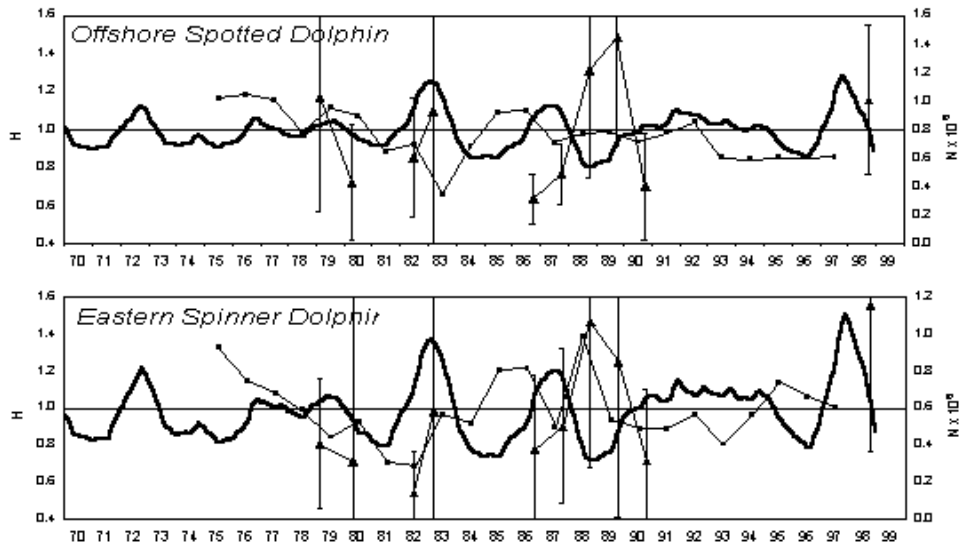


Figure 3. See page 19.

Figure 4. See page 20.

Figure 5. Fit of an exponential growth rate model to data for northeast offshore spotted dolphins, without an explicit parameter to represent a growth rate difference between early and late parts of the series. This was done as a sensitivity test of the definition and estimation of μ in the primary assessment modeling.

