A Review of Ecosystem Research in the Eastern Tropical Pacific During the Monitoring of Porpoise (MOPS) and *Stenella* Abundance Research (STAR) Programs

Prepared for the
UM Independent System for Peer Reviews
University of Miami

by

Dr. John F. Dower
Biology Department and School of Earth & Ocean Sciences
University of Victoria, Victoria, BC, Canada

Executive Summary

This report is based on a review of recent ecosystem research in the Eastern Tropical Pacific (ETP hereafter) conducted by NMFS scientists from the Southwest Fisheries Science Center. This report forms part of a larger review that addresses the status of depleted dolphin stocks in the ETP. The overall management question on which this report is based is: ***Has there been a change in the ecosystem that might affect the recovery of dolphin stocks from depleted levels?*** The specific focus of this report can be further broken down into two basic questions:

1. Has there been a change in the ETP ecosystem?
2. Are there temporal patterns in the ecosystem and how are they best described?

This report reviews a series of working papers that outline and interpret the ecosystem data collected in the ETP during 1986-2000.

Summary of Findings:

1. Has there been a change in the ETP ecosystem? Weighing all the evidence, the short answer to this question is "No". However, given the sparse time series (particularly, the eight year gap between the MOPS and STAR programs), a more accurate answer is ***"Given the limited temporal resolution of the available ecosystem data, it is not possible at this time to detect any recent change in the ETP ecosystem that might affect the recovery of depleted dolphin stocks."***

2. Are there temporal patterns in the ecosystem and, if so, how are they best described? The answer to this question is clearly "Yes", but only for some of the data series. The clearest signal occurs during the 1988-1990, when a variety of species tended to increase in abundance. Some of the species that increased (*i.e.* prey species) were short_lived, fast growing organisms that could easily have doubled their abundance within a year or two. However, the cetaceans are all long_lived species that are slow to reproduce and have low fecundity. Thus, the apparent increases in abundance observed in some depleted dolphin stocks during 1988-1990 cannot be attributed to population growth. A more likely explanation is that the apparent increases in cetacean abundance during 1988-1990 reflect changes in distribution.

Specific recommendations:

1. If any future sampling is to be carried out, more attention should be paid to the design of the sampling regimes for the oceanographic and plankton data.

2. Since they represent a key link to the higher trophic levels, the existing prey samples need to be analyzed in greater detail.

3. The only large pre-1977 data set available for comparison to the MOPS/STAR data would seem to be that from the EASTROPAC project. However, to date, these data have never been full analyzed or even converted into an electronic format. Resources should be made available to enable these data to be analyzed and electronically archived before they are completely lost.

4. The authors should explore whether the application of distribution-free statistical methods might offer a way to better deal with some of the admittedly sparse data series

5. The available data on the condition of the ETP dolphins seems woefully inadequate. Dolphin sampling from the fishery ended in about 1992. There should be a requirement stating that anyone who kills a dolphin in the fishery must provide the carcass for scientific analyses. Access to a steady supply of animals would enable researchers to better track changes in growth rates, reproductive status, or the effect of other physiological stressors.

Table of Contents

1. Introduction and Background: Purse-seining for tuna in the Eastern Tropical Pacific (ETP, hereafter) began in the later 1950's, after it was discovered that spotted dolphins (*Stenella attenuata*) and spinner dolphins (*Stenella longirostris*) formed dense, mixed aggregations with yellowfin tuna (*Thunnus albacares*). Since the dolphins spend much of their time at the surface, this made it easy for fishermen to spot and track the tuna schools, and encircle the mixed aggregations with large purse seines. In the early days of the fishery, little (if any) attempt was made to minimize dolphin mortality during seining operations. Some estimates put the number of dolphins killed annually by the purse-seine fishery to be as high as 200,000 - 800,000.

In 1972 the U.S. Congress passed the *Marine Mammal Protection Act* (MMPA), in part, as an attempt to reduce the impact of activities such as purse-seine fisheries on dolphin stocks. Among its numerous recommendations, the MMPA stated that "*measures should be taken immediately to replenish any species or population stock which has diminished below its optimum sustainable level.*" Furthermore, the MMPA also noted that "*there is inadequate knowledge of the ecology and population dynamics of such marine mammals and of the factors which bear upon their ability to reproduce themselves successfully.*"

Following passage of the MMPA, new techniques were introduced to reduce the direct mortality sustained by dolphins captured in purse seines. Of the 20 stocks of small cetaceans that had suffered direct fishing mortality in the ETP, two stocks were of primary concern: the eastern spinner dolphins and the northeastern offshore spotted dolphins. By the late 1980's, the abundance of these stocks had declined to about 44% and 28% of their pre-exploitation levels (respectively), and both were designated as depleted. By 1992, however, it was reported that fishery-related mortality of ETP dolphins had fallen to levels considered unlikely to impede the future recovery of these depleted stocks (*i.e.* direct fishing-related mortality is now believed to be 0% in about 90% of seine sets).

In1997 the International Dolphin Conservation Program (IDCPA) was established by an act of Congress. Its mandate was to determine whether purse-seining continues to have significant adverse impact on depleted ETP dolphin stocks. Data used in the IDCPA assessments came from two primary sources: the Monitoring of Porpoise Stocks (MOPS) project which ran from 1986-90, and the *Stenella* Abundance Research (STAR) project which ran from 1990-2000. Both projects involved massive field efforts, generally 4 months of marine mammal and ecosystem surveys per year, on each of two large oceanographic vessels, plus the collection of a wide variety of ancillary biological and oceanographic data.

A preliminary IDCPA report was submitted to Congress in 1999. At that time, no evidence of significant recovery of the depleted ETP dolphin stocks. Furthermore, there was no indication of any significant change in the ETP ecosystem that could explain the apparent lack of recovery. At that point, however, data was still being collected under the STAR program, which wasn't complete until 2000. Following on from that preliminary 1999 IDCPA submission, this review examines with the complete set of MOPS and STAR ecosystem studies. An international panel of five ocean scientists (none of whom had any formal ties to either the MOPS or STAR programs, nor to the NMFS) was formed to review the results of these ecosystem studies. The overall management question that was put to the review panel was as follows "*Has there been a change in the ETP ecosystem that might affect the recovery of dolphin stocks from depleted levels?*"

In March of 2002, NMFS scientists from the Southwest Fisheries Science Center (SWFSC) who had conducted the MOPS and STAR programs produced a series of working papers for the review panel. The review panel met with the scientists at the SWFSC from March 6-8, 2000 where the NMFS scientists presented their data and provided interpretations of their results. The meeting also afforded an opportunity for the review panel to raise further questions about the ecosystem studies and offer alternative interpretations of the results. The working papers presented to the review panel covered seven key areas:

- *Physical oceanography of the ETP*
- *Biological oceanography of the ETP*
- *Estimates of ETP cetacean abundance*
- *Descriptions of variability in ETP cetacean habitat associations*
- *Variability in ETP seabird abundance and habitat associations*
- *Variability in the abundance of prey fishes and squids in the ETP*
- *Variability in the abundance of ETP ichthyoplankton*

The review panel was instructed to consider the results from these working papers in light of two specific questions:

- *Has there been a change in the ETP ecosystem?*
- *Are there temporal patterns in the ecosystem and how are they best described?*

In the review that follows, I first present a brief summary of each working paper, and then provide my own interpretation of the findings, in light of these two questions. I conclude the review with some overall impressions of the ETP Ecosystem Research program, and by offering some specific recommendations regarding further analysis of the existing data, and considerations for any future data collection. A Bibliography of all the working papers and other background materials used by the review panel is also provided.

2. Review of ETP Ecosystem Research Working Papers

2.1 ETP Environmental Change: A pair of papers were presented in which the available physical and biological oceanographic data were reviewed. This included a variety of data collected during both MOPS and STAR research cruises: CTD, XBT, SST, sea-surface chlorophyll, primary production, zooplankton biomass (during STAR only), as well as supplementary oceanographic data from a variety of other ocean climate data-sets (*e.g.* satellite data). Data were examined from two perspectives. The first explored patterns in the ETP environment attributable to ENSO and/or other decadal scale ocean climate phenomena. The second focused on shorter time-scales and examined interannual environmental variability between 1986_90 (MOPS years) and 1998_2000 (STAR years).

2.1.1 Summary of Results: In terms of SST and other physical factors, the first analysis showed that ETP environmental variability is strongly dominated by the ENSO signal (with a characteristic time-scale of 2-7 years). This variability is evident mainly in terms of the westward extent of an equatorial cold-tongue and the size of the Eastern Pacific warm pool. The cold-tongue is generally larger (smaller) and thermocline depth is depressed (shoals) during El Nino (La Nina) conditions. Analysis also showed evidence of an oceanic regime shift between 1976-1977. This agrees with studies from other ecosystems in the Pacific Ocean, and elsewhere on the planet, although the magnitude of the regime shift signature in the ETP was comparatively small (*i.e.* surface layer warming of only a few 10^{th}'s of a degree). Interestingly, there was no evidence for any subsequent significant regime-shifts in the ETP, the unlike the situation in the NE Pacific where another regime shift appears to have occurred in 1998. The author pointed out that, relative to other regions of the Pacific, the ETP appears particularly resistant to significant regime shifts in ocean climate. The second mode of environmental variability in the ETP occurs at seasonal time-scales (*i.e.* intra-annual variability), and is most significant in coastal environments such as the California Current and Humboldt Current ecosystems. Relative to ENSO and seasonal variability, however, the analysis found that decadal scale variability (10-30 yrs) in the ETP is comparatively weak. Similarly, the effect of long term environmental variability attributable to large scale climate change (>100yrs) in the ETP is largely unknown.

Biologically, the distribution of sea-surface chlorophyll (Chl) showed that phytoplankton standing stocks in the ETP were lowest (highest) during El Nino (La Nina) conditions. In any given year, Chl levels were usually highest along the equator and off the coast of Peru, with occasional secondary highs in the Costa Rica Dome and the California Current. Primary productivity data were quite sparse, making it all but impossible to detect interannual trends. In general, primary productivity, like Chl, was highest along the equator. Zooplankton biomass data were also quite sparse, being confined largely to the STAR years. As with the phytoplankton data, the general picture of zooplankton biomass was one of high concentrations banded along the equator.

2.1.2 Interpretation: Based on the data presented, there is little evidence for any sort of regime_shift in the ETP since 1977. Thus, it would appear that the MOPS and STAR data sets are both are from the same ocean climate regime. Despite this, there were still some differences between the two study periods (SST was about 0.23EC colder during STAR than during MOPS, and the thermocline shoaled by about 1m). However, although statistically significant, the biological importance of such minor physical changes is almost certainly negligible.

Taking a longer view, it is conceivable that environmental changes accompanying the 1977 shift may have made the ETP ecosystem less suitable for dolphin stocks. It can be argued, therefore, that the apparent failure of these stocks to recover may be tied to events that occurred more than 20 years ago. As there is virtually no pre-1977 data available against which to compare the MOPS and STAR data, however, this possibility cannot be easily tested. Nonetheless, there are still some tantalizing hints: it was reported to the panel that phytoplankton and zooplankton biomass during STAR seem to have been somewhat lower than during the EASTROPAC program (in the late 1960's). If this were the case, lower levels of phytoplankton and zooplankton production in recent years might be signalling a reduction in the amount of energy available to higher trophic level species such as dolphins. Unfortunately, the EASTROPAC data have never been adequately worked up and so, at present, it is impossible to test this hypothesis.

In hindsight, it is always easy to criticize the way in which data were collected. Nevertheless, it is still unfortunate that the biological oceanographic data were collected at such coarse resolution during MOPS and STAR. Part of this stems from the fact that the two programs were primarily meant as marine mammal surveys and, thus, comparatively little time was devoted to oceanographic measurements. However, it also seems that little consideration was given to how the oceanographic data might later be used in addressing the bigger question of linking environmental variability to higher trophic levels in the ETP.

For instance, neither the Chl nor primary productivity data were size-fractionated. This is a fairly routine step that most oceanographers employ when collecting phytoplankton data. The reason for doing this is quite simple: changes in phytoplankton community composition that may not show up in bulk estimates of either total Chl or total primary productivity can have significant effects on food-chain efficiency and/or food-chain length. For instance, a switch from large diatoms to picophytoplankton during an El Nino event could theoretically reduce the energy available to higher trophic levels in the ETP (by increasing the length of the food chain), even though no signal might be apparent from either satellite ocean colour data or ship-based measurements of total Chl or total primary production.

As a general observation, much of the data from MOPS and STAR seem to have been examined primarily in terms of looking for differences between *mean* states. This is understandable, particularly given the short times series and the eight year gap in the data during the 1990's. However, this focus on comparing mean states does have the potential to mask biological responses that might have more to do with changes in the *variance* of either environmental or biological factors. For instance, although the *mean* intensity of ENSO effects in the ETP may not have changed appreciably, is it possible that what the animals respond to has more to do with temporal trends in the *variance* in the ENSO signal? Put another way, although environmental conditions at two different times (e.g. MOPS vs. STAR periods) may appear the same to us (as estimated by the mean state of rather coarsely measured environmental indices), the organisms inhabiting the ecosystem may perceive the two periods as having different levels of environmental "graininess" depending on patterns of environmental variance.

2.2 Estimating the Abundance of Cetaceans in the ETP: This working paper was based on line-transect surveys for marine mammals during both MOPS and STAR research cruises (averaging 25,000-30,000 km per year), and includes abundance estimates for both target and non-target cetacean species. Target species included three stocks of spotted dolphins (*i.e.* northeastern, western/southern and coastal stocks) and a stock of eastern spinner dolphins. Non-target cetaceans included four stocks of common dolphins, plus pilot whales, sperm whales and Bryde's whales and striped dolphins. Data collection involved the use of high-power binoculars by two observers (one on each side of vessel). In addition to species identification, school size, and distance from ship, various oceanographic and weather-based covariates were recorded (*e.g.* sea-state, whether birds were present, sighting cue, etc.). The researchers also used helicopters to take aerial photos to help verify species identifications (and counts) and to permit the quantification of observer-specific counting bias. The ancillary data were used to help improve the abundance estimators, and to prorate the unidentified marine mammal sightings.

2.2.1 Summary: When annual estimates were examined using linear regression, only northern common dolphins and pilot whales appeared to increase significantly during the combined MOPS/STAR study period. Other stocks showed no statistically significant increases throughout the same period. A caveat to these results, however, is that the non-target cetaceans all range throughout the Pacific, and spend only part of their time within the ETP study area. In fact, the only stocks contained completely within the survey area were the central common and the eastern spinner dolphins. Thus, any short term changes observed in the abundance of such stocks probably reflect changes in geographic distribution rather than actual population growth.

2.2.2 Interpretation: In addition to the fact that distributional shifts can confound estimates of population growth in the ETP, it is not clear whether movement of a given stock into (or out of) the ETP in any given year occurs because conditions in the ETP are getting better, or because conditions outside the study area have gotten comparatively worse. One possible way to address this might be to re-examine the data to look for coherent temporal shifts in the abundance of species with similar feeding habits.

On a technical note, it seems odd that although there are no data from 1990-1998, the results are still presented as continuous time-series covering the period from 1985-2000. Connecting the 1990 data points to the 1998 data points creates the visual impression that many of the stocks are increasing through time, even though the statistics tell us this is not the case. In addition, the variance in the annual estimates is clearly different within the two data-sets (higher interannual variance in abundance estimates during MOPS years). Perhaps a better strategy might be to use either an ANOVA-type approach (or, alternatively, an analogous distribution-free technique) to test the hypothesis that annual population estimates from the two data-sets are not significantly different. Boot-strapped confidence intervals would also help the interpretation of the cetacean data.

Another point to keep in mind is that several of the stocks in question were actively hunted in the past (*e.g.* pilot and sperm whales), but it is not known at what point in their post-whaling history these species are currently operating. This complicates the process of using these stocks as environmental indicators. Are such stocks increasing in the ETP because the environment is particularly suitable, or because they are still undergoing a post-whaling rebound? In other words, combining stocks that were heavily affected by whaling and fishing with stocks that may not have experienced a similar mortality history complicates the question of whether any of these stocks are currently operating at or near their carrying capacity.

The most important point in this analysis is that population estimates for the most depleted stocks (*i.e.* the northern-offshore spotted and eastern spinner dolphins) show no sign of recovery, despite significant reductions in fishing-related mortality. If anything, it appears that some of the stocks might still be declining. At best, the depleted stocks are still only at about 30% of pre-fishery abundances. Three of the four depleted stocks (*i.e.* the northeastern spotted, the western/southern spotted, and the eastern spinner stocks) appear to have increased in 1988-89 but declined again in 1990. However, given the very slow rate of growth in dolphin populations (about 4% a year), it is unlikely that these short-lived increase in 1988-89 can be accounted for by population growth.

This last point raises the question of what rate of recovery should be expected in these depleted dolphin populations once fishing mortalities were reduced? Certainly, recent

research suggests (in particular, see papers by Jeff Hutchings 2000, 2001) that the recovery times of severely depleted commercially fish stocks generally takes much longer than initially predicted. Hutchings found that most overexploited fish populations in which abundance had declined by more than 60% exhibited little or no recovery even 15 years after collapse, and even under significant reductions in fishing related mortality. This implies that factors other than fishing may be important in stock recovery.
One likely possibility is that in severely depleting a given stock, we decrease it's natural buffering capacity, such that otherwise minor events (*e.g.* small changes in the environment or changes in biotic factors) can take on disproportionate importance. Thus, if there has been no significant change in the ETP environment that can explain the lack of dolphin recovery, perhaps the researchers should look more closely at some of the biological characteristics of the depleted dolphin stocks (*e.g.* calving rates, growth rates, juvenile survival, increased susceptibility to disease, etc.).

2.3 <u>Interannual Variability in ETP Dolphin Habitat</u>: This working paper considered the question "*Given that there have now been about 10 years of essentially zero fishing-mortality on ETP dolphins, and yet no significant recovery, has there been a change in either dolphin habitat availability or habitat use?*" The analysis involved the use of Canonical Correspondence Analysis (CCA) to combine both biological and oceanographic data. The sampling unit for the CCA was the survey day. In other words, the CCA compared daily encounter rates with various types of dolphin schools against daily means of variables such as SST, salinity, Chl, thermocline depth and strength. Latitude and longitude were included to see if they added any geographic explanatory power. Data collected during poor sighting conditions (*e.g.* conditions worse than Beaufort 4) were excluded. The analysis first considered data from the two study periods (MOPS and STAR) separately, before combining the two data sets to look for decadal scale effects.

2.3.1 Summary of Results: For the MOPS period, the total variability in species data explained by the first two canonical axes was only 10-15%. In terms of the different cetacean stocks, the STAR analysis explains about 45% of common dolphin distributions, but did poorly for the others (generally less than 10%). CCA bi-plots for the MOPS and STAR periods show good characterization of common dolphin habitat, but poor separation of the habitat for other stocks. When the MOPS and STAR data were combined, "year" and "decade" were added into the analysis as a categorical variables. Looking at years showed a statistically significant effect, but explained only an additional 1.8% of the variance. Likewise, including decade as a categorical variable (*i.e.* MOPS vs STAR) explained a statistically significant (but biologically trivial) 0.8% of the variance.

2.3.2 Interpretation: In short, it appears that environmental factors (or at least the ones used in this analysis), are not good predictors of the distribution of ETP cetacean stocks.

However there are at least two other points that must also be considered. First, it may be that the particular suite of oceanographic variables used in the analysis (e.g. SST, salinity, Chl, thermocline depth) may not be particularly relevant to long-lived, highly social, highly mobile, *k*-selected species such as dolphins. Second, it must be kept in mind that, relative to other oceanic environments, the ETP is comparatively homogeneous. Thus, most of environmental gradients are generally quite weak (except near the edges of water masses), and may therefore not be perceived strongly by dolphins.

To summarize, it would appear that the overall lack of explanatory power of the environmental variables in describing dolphin habitat is either telling us (i) that ETP environmental variability is generally very low, (ii) that the CCA analysis focused on the wrong estimators of environmental variability, or (iii) that ETP dolphins are well enough buffered against environmental change that they do not perceive the environmental variability measured by the CCA. One way to deal with this last possibility (and perhaps extend the explanatory power of this analysis) would have been to include data on the presence of tuna or flying fish. These are species that often co-occur with ETP dolphins but which may be more sensitive to environmental variability.

2.4 Ichthyoplankton Abundance During MOPS and STAR: This working paper catalogued the larval fish data collected during MOPS and STAR, and provides a preliminary attempt to characterize patterns in larval fish abundances during the two periods. Ichthyoplankton samples were collected at night using a Manta net, which only samples the upper 15cm of the water column. About1450 Manta tows were conducted during the two programs. Unlike the other biological data sets that the panel examined, the ichthyoplankton data also included samples from in 1992. The STAR data set also includes a complementary series of samples collected from oblique bongo-net tows.

2.4.1 Summary of Results: Ichthyoplankton collections were dominated by three or four species, the most abundant of which was *Vinciguerria lucetia*. Recurrent group analysis was used to identify significant interspecific associations. Two main species groups were identified: the first consisted of 6 onshore species (denoted the *Polydactylus* group), while the second (the *Oxyporhamphus* group) included a group of 4 offshore fish species.

The general trend among the onshore species of the *Polydactylus* group was for comparatively low abundance during MOPS, followed by high abundance in 1992, and a general trend for increasing abundance through the STAR years (1998-2000). It is noted, however, that due to higher nearshore sampling effort during STAR years, the latter trend may be partly an artefact. In contrast, members of the offshore *Oxyporhamphus* group showed no clear increase in abundance from MOPS to STAR years, remaining more or less steady throughout the time period.

2.4.2 Interpretation: Beyond these preliminary findings, there is not much that can be concluded yet. Apart from inventorying the ichthyoplankton samples, the analysis of the data set has only just begun. However, a more basic consideration is that, given that larval fish abundance data are notoriously noisy (since ichthyoplankton are incredibly patchy in space and time), it is not clear how to tie any observed changes in ichthyoplankton abundance with the environmental data. Moreover, since relationships between larval abundance and subsequent recruitment are usually insignificant for all but a very few marine fish species, it is by no means clear that the any observed increases in larval abundance translate into increased population growth of these species.

A couple of options should be considered. For instance, the ichthyoplankton from the STAR bongo net surveys have yet to be identified or enumerated. This may prove to be an important comparison, as the Manta net is really only effective in sampling obligate neustonic species (*e.g.* flying fishes, dolphin-fishes). Do larvae that are distributed deeper in the water column (*e.g.* larval myctophids) show the same basic trends in abundance as the neustonic species? Likewise, it might also prove instructive to compare the MOPS and STAR ichthyoplankton with samples collected during the EASTROPAC expedition. The EASTROPAC data were collected from vertical net tows (as opposed to neuston tows), and are therefore be better compared to the (as yet unanalyzed) STAR bongo samples. However, a comparison with the historical data may still prove problematic, since most of the EASTROPAC data were apparently never converted into any sort of electronic format.

The most effective way to link changes in the larval fish community to environmental conditions would be to use otolith microstructure to examine interannual variability in larval growth rates between study periods. This approach might offer a means for detecting (and help quantify) any putative bottom-up effect on ETP ecosystem productivity. However, the MOPS/STAR ichthyoplankton samples were preserved in formalin (as opposed to ethanol) and so this option is not feasible. Likewise, the analysis of larval gut contents has been used elsewhere to determine whether significant changes in zooplankton community composition might affect larval feeding and (perhaps) growth and survival. Although larval gut contents could still be examined from this data set, the fact that the accompanying zooplankton samples (*i.e.* the prey available to the larvae) were collected with 505 and 333 Fm mesh nets will complicate the interpretation of any observed changes in larval diets (since the prey consumed by larvae are often much smaller than this).

2.5 <u>Seabird Abundance and Habitat Use in the ETP</u>: This paper analyzed ETP seabird abundances and habitat using the same CCA analysis that was employed to examine dolphin habitat (section 2.3). Nine seabird species were chosen as “indicator species" to represent the range of habitat diversity and foraging guilds of about 100 species of seabirds that in occur in the ETP. The indicators generally included those species that are most abundant in the ETP, and can be divided into "tuna-dependent" and "tuna-independent" species. In terms of feeding behaviours, the list includes zooplankton feeders, micronekton feeders, zooplankton/micronekton feeders and nekton feeders. Only two indicator species were entirely restricted to the ETP. Thus, at any point in time the other seabird species may have been immigrating/emigrating or simply transiting through the ETP. This will have implications for the CCA's ability to accurately quantify patterns of habitat association. Like the marine mammals, the ETP seabirds are essentially all *k*-selected species species.

Survey data were collected along 300m wide strip-transects. This method assumes that all birds within the 300m wide strip are detected. During bad weather conditions the strip width was shrunk to 200m. MOPS seabird data were collected during 1988-1990 and STAR data from 1998-2000. Total counts for each of the 9 indicator species ranged from about 1000-16,000. As with the CCA analysis of dolphin habitat, the sampling unit was 1 survey day (which usually represented about 185km of track-line).

2.5.1 Summary of Results: Interannual, intra-decadal and possibly interdecadal trends were evident in seabird abundance and habitat associations. As with the analysis of dolphin habitat, intra-decadal variability was greater than interdecadal variability. In terms of abundance, only Tahiti petrels showed a significant trend across the entire time period (a decline). However, it was also reported that this decline apparently had more to do with conditions in the breeding colony than with conditions in the ETP. No differences were detected between patterns in "tuna-dependent" and "tuna-independent" indicator species.

Seabird abundance data were also analyzed using General Additive Models (GAM), a technique particularly well-suited to non-random surveys, and for modelling complex non-linear trends. The variables used in the GAM included: latitude, longitude, ocean depth, and distance to the nearest land. Population estimate from the GAM are believed to be accurate to within about 10%. As in the previous analysis population estimates from the GAM showed no significant trends in abundance across the MOPS and STAR periods (with the aforementioned exception of Tahiti petrels).

In terms of distributions, species-specific patterns remained consistent at large spatial scales (*e.g.* between water masses) and through time. Not surprisingly, the degree of spatiotemporal patchiness varied between the nine species. When individual survey years were analyzed separately, about 25-40% of the variability in abundance was explained. When broken out by both species and by year, the ordination explained >25% of the variance for only six of the nine indicator species. When all the years were lumped together the oceanographic variables (SST, salinity, Chl, thermocline depth and strength) only explained about 20% of the total variance. When "year" or "decade" were included, each explained only a further 1% of the variance.

2.5.2 Interpretation: The question is to what extent observed differences in abundance and/or distribution have anything to do with conditions in the ETP *per se*. Given that seven of the nine indicator species range outside the ETP, overall abundance and distribution patterns will be strongly influenced by interannual variability in the immigration/emigration of these species into and out of the ETP. Being *k*-selected species, it also seems probable that the response of such long-lived, highly mobile species to any decline in ETP habitat conditions would be to leave, rather than to show *in situ* declines in abundance. Thus, it is not surprising that a CCA based strictly on environmental conditions in the ETP did not explain a large proportion of the variation in the distribution and abundance of these birds.

2.6 <u>Temporal Patterns in Habitat & Abundance of Dolphin Prey</u>: This working paper reported results from surface surveys of dolphin prey species conducted during MOPS and STAR. Data were collected by dipnet for 1h after sunset on each survey day. The dipnet samples were usually collected at the same time as evening CTD casts. A total of 2041 such samples were collected (average about 225-300 samples per year).

2.6.1 Summary: The dipnet data were lumped into 5 main prey categories: myctophids, *Oxyporhamphus micropterus*, *Exocoetus* spp, 4-wing flying fish and squids (small, medium and large). These groups represent the most abundant near-surface prey species throughout the ETP. In terms of behaviour, most of the lanternfish and squids undergo some degree of diel vertical migrations, while the flying fish species generally stay near the surface. In contrast to the *k*-selected dolphin and seabirds, these prey species all tend to be *r*-selected (*i.e.* short-lived, fast growing species), with the potential for rapid population growth under favourable conditions.

Multi-year increases in abundance were observed for several prey taxa within each study period (*i.e.* within MOPS and within STAR) but not between decades. In general, many of the prey species started at low numbers and then increased during each series (*e.g.* low in 1986 and increasing toward 1990, then low again in1998 and increasing toward 2000). In almost every case, species-specific abundances (as well as the variance in abundance) were higher during MOPS. A CCA analysis was also applied, following the same procedure as for seabirds and dolphins. The overall conclusion was basically the same as for the seabirds: there is species-specific variability in both abundance and habitat association, but the variability seems to be greatest within as opposed to between decades. The explanatory power of the CCA was somewhat higher for the prey species than for seabirds and dolphins (explaining up to 50% of the variability in myctophid abundance). This is probably because the higher growth rates and shorter lifespans of the prey species make them more responsive to environmental variation.

2.6.2 Interpretation: The tendency for prey species to increase between 1986_1989 mirrors the pattern of increased abundance seen in some of the ETP dolphin stocks (section 2.2). However, whereas the dolphins (being *k*-selected) would seem incapable of having increased their numbers over such short time-scales (which is why changes in dolphin abundance were interpreted as changes in immigration/emigration), these various *r*-selected prey species are certainly capable of doubling their numbers in 3-4 years. In contrast to the MOPS years, however, there was no apparent increase in dolphins during STAR, whereas the prey species seem to have experienced a second period of increasing abundance. Moreover, the abundance trends observed in the prey species are consistent across both species and water masses.

Given that both MOPS and STAR began shortly after strong ENSO events (in 1983 and 1997, respectively) it is tempting to suggest that the observed increases in prey abundance mark the recovery of these stocks after ENSO-related declines. Also of note is that the ichthyoplankton abundances show very different trends during these same periods (section 2.4): although the offshore *Polydactylus* group seemed to increase in abundance toward the STAR years (after peak abundances occurred in 1992), the abundance of this group was generally low throughout MOPS. The second group (the offshore *Oxyporhamphus* group) showed no evidence of increase during either period. Then again, the typical correlation one finds between larval and adult abundances in marine fish species (even in short-lived fish like these) is usually very low. It would have been particularly interesting to see how the abundance of these two groups (*i.e.* prey species and larval fish) responded after the 1993-94 ENSO. However, no comparable data exist from that period.

My one comment on the methods used in this study is that each hour of dipnetting was taken as representative of prey availability for an *entire day* (*i.e.* about 185 km of transect). Given the highly patchy distribution of flying fish and squids (not to mention dolphins), this seems a rather simplistic way of describing the dolphin prey field. As was the case for the MOPS/STAR larval fish and zooplankton/phytoplankton data, I can't help but think that there wasn't too much consideration given to how the prey data that were being collected might ultimately figure into the ETP ecosystem analysis. Examining trends in the abundance of these prey species is certainly one way of estimating the food available to higher trophic levels. However, some of these data could (and should) be analyzed further.
For instance, the authors told the panel that ETP flying fish grow so fast that the increase in size is detectable by eye over the four months of a survey year. Given that these species feed near the lower levels of the food web, it might be instructive to examine interannual variability in their growth rates, perhaps as a function of either temperature or prey (*i.e.* zooplankton) availability. This might provide one more way to explore links between (potential) bottom-up changes in ETP ecosystem productivity and production at higher trophic levels. Unfortunately, as was the case with the larval fish samples, none of the samples were set aside for otolith analyses. However, the formalin-preserved fish can (indeed should) still be used to reconstruct length-based growth trajectories for each year. Given that many of the myctophids are also fast growers, the same analysis should be extended to this group, too.

2.7 Information for Evaluating Regime Shifts in the ETP: This paper integrated the results from all the other working papers. The goal was to look for coherent patterns among physical and biological time-series as evidence for regime shifts in the ETP. The exercise was motivated by Hare and Mantua's (2000) application of this same technique to detect regime shifts in the NE Pacific: examining over 100 time series from the NE Pacific, Hare and Mantua found evidence for several regime shifts. Of particular interest was that at least one such shift in the NE Pacific (in 1998) showed up primarily in the biological (as opposed to physical) time series. In the current exercise, the authors normalized all of their data series and then re-plotted them as time-series of annual anomalies. Freely admitting that their data were quite thin, the authors did not perform any additional statistical analyses. What we are left with, then, is primarily an exercise in visual inspection of time series.

2.7.1 Interpretation: The most striking thing is the overall sparsity of data. With the exception of the physical oceanographic data and the tuna biomass time series, the remaining series each consist of 5-8 observations over a 16 year time period. Although this point has been mentioned previously, it is only when the data are examined together that the challenge of detecting recent changes in the ETP ecosystem becomes apparent.

Examining the various physical times series, there is no clear evidence for any change in ocean climate over the past 20 years. In general, the physical anomalies tend to change sign almost annually, with only occasional runs of two or three years with the same sign. The only visible pattern seems to be a tendency for anomalies in the core area to be in opposite phase to those from the overall survey area. This can be seen in three of the four series (salinity, thermocline depth and wind stress data). The wind anomalies seem to vary over somewhat longer periods (*i.e.* 2-3 year runs of consecutive positive or negative anomalies) than the other physical variables.

The sea-surface chlorophyll and primary productivity data are simply too few to allow any interpretation whatsoever. In any case, as neither the Chl nor the primary productivity data were size-fractionated, they are only of limited utility in detecting anything other than major shifts in total production. Unfortunately, the period from 1990 (when MOPS ended) until 1998 (when STAR began) corresponds closely with the time between the demise of CSCZ and the launch of SEAWifs, and so it is unlikely there are any ocean colour remote sensing data available to supplement the MOPS and STAR observations.

The larval fish data are slightly more coherent, the dominant trend being for species to generally show successive negative anomalies during MOPS, and tend toward positive (in many cases more variable) anomalies during STAR. Prey species display almost the opposite trend, generally switching from negative to positive anomalies during MOPS, and showing consistently negative anomalies during STAR. As discussed in Section

2.6, there is an overall tendency for the prey species to increase during each sampling period (but to decline between the two periods). This is perhaps one of the more robust patterns among the MOPS/STAR biological data.

The two tuna time series (annual biomass anomalies) represent the longest, and by far most complete, biological time series. Interestingly, both yellowfin and big-eye tuna show evidence for significant shifts in abundance in the late 1980's. However, the two species are apparently out of phase: whereas yellowfin anomalies switch from negative to positive (i.e. an increase in abundance) in 1985, big-eye abundance anomalies switch from positive to negative (i.e. decreased abundance), but not until about 1989. One possibility is that these changes are associated with changes in fishing pressure. Certainly, there is no clear signal of a bottom-up effect in the MOPS/STAR environmental data that could drive these changes, particularly given that the two species are responding in opposite directions.

As with most of the other biological time series, anomalies from the seabird data are simply too sparse to make any conclusive statements. The only visible pattern is that seven of the nine indicator species switched from negative to strong positive anomalies in 1988-1989. However, as discussed in Section 2.5, the slow rate of population increase for these *k*-selected species, coupled with the fact that none of the species ranges are contained entirely within the ETP suggests this trend is due to a coherent shift in seabird distributions (*e.g.* enhanced emigration to the ETP from neighbouring regions). There is, however, no simple way to determine whether such a movement occurred in response to improved conditions in the ETP or poorer conditions elsewhere in the range of these species. It is interesting to note, however, that since many prey species were also increasing during the late 1980's (Section 2.6), feeding conditions for seabirds in the ETP may have been quite favourable during this period.

Among the cetaceans, the most complete time series were those for two of the target stocks: Northeastern Spotted and Eastern Spinner dolphins (for which data existed for 12 years between 1980-2000). These two, plus the anomaly series for Western/Southern Spotted dolphins (another target stock) all show a coherent pattern of strong positive anomalies in 1988-1989. However, as pointed put in Section 2.2 (and as was the case with the seabird anomaly series) the slow growth rates of these species makes it highly unlikely that this trend can be attributed to actual increases in ETP stock sizes. Interestingly, this same group of three target stocks also share a coherent pattern weak negative anomalies in 1998-2000. The remaining cetacean series (for both target and non-target cetacean stocks) generally consisted of eight observations between 1985-2000. Although no overall trend is evident, visual inspection hints that at least two stocks (Northern common dolphins and Pilot whales) may have experienced an increase between 1985-2000.

One further possibility for exploring these data might be to use some sort of distribution-free (*i.e.* randomization) tests to establish the statistical likelihood of the observed arrangements of anomalies. For instance, the anomaly time series for northern common dolphins shows an apparent trend towards increased abundance (4 consecutive negative anomalies followed by 3 consecutive positive anomalies). Perhaps by randomizing the sequence of the anomalies for this (and the other) series, the authors could get some idea of how many of the time series show "statistically extreme" patterns. In other words, such an approach might help to quantify whether some the interesting patterns evident from visual inspection are "statistically interesting" as well.

3. Overall Impressions of the ETP Ecosystem Research

The SWFSC scientists are to be commended for their efforts in collecting such an impressive array of data from such an enormous tract of the ocean, and for making as much headway with their analyses in the short time since data collection ended. To have compiled and analyzed this data set in just one year is a remarkable feat. This is clearly a talented group of scientists and, on the whole, I find their analyses, their interpretations, and their conclusions to be both scientifically rigorous and sound.

The specific question this review panel was asked to address was whether there has been a change in the ETP ecosystem that might be preventing the recovery of depleted dolphin stocks. Weighing all the evidence, the short answer to this question is "No". However, given the sparse time series (particularly, the eight year gap between the MOPS and STAR programs), a more accurate answer is ***"Given the limited temporal resolution of the available ecosystem data, it is not possible at this time to detect any recent change in the ETP ecosystem that might affect the recovery of depleted dolphin stocks."***

As to the question of whether there are temporal trends in the data set, the answer is "Yes" for some of the data series. The clearest signal occurs during the MOPS years, when a wide variety of species seemed to increase in abundance between 1988-1990. What is particularly interesting is that the apparent increases were detectable in both prey species (*e.g.* myctophids and flying fish) as well some of the dolphin and other non-target cetacean stocks. Given the differences in population growth rates of these different types of species, however, the underlying cause for these increases likely differ among the groups.

For instance, the various prey (myctophids, squids, and flying fish) are all ***r***-selected species (*i.e.* short-lived, fast growing) that can easily double their abundances within a year or two. In contrast, the cetaceans are all ***k***-selected species (long-lived, slow to reproduce, low fecundity). Thus, the apparent increases observed in some cetacean stocks during the MOPS years cannot be attributed to population growth *per se*. A more likely explanation (particularly in light of the fact that only one cetacean stock was entirely restricted to the study area) is that increases in cetacean abundance during MOPS reflect changes in cetacean distribution. Of course, it is impossible to tell whether these apparent increases occurred because cetacean habitat conditions in the ETP improved during this period, or because habitat quality outside the ETP declined over the same period. A similar situation exists for the seabirds, most of which also ranged outside the ETP study area. It must be kept in mind that, as large as it is, the ETP is not completely isolated, and many of the animals using the ETP also move regularly the between ETP and adjacent environments.

Some of the trends in abundance (particularly those in the prey species, as well as some of the larval fish) seem to be strongly influenced to ENSO activity. This finding fits well with one of the general conclusions drawn from these data: ENSO variability represents the dominant physical forcing in the ETP ecosystem. The 1990's were a decade of increased ENSO activity in the Pacific Ocean. It is interesting to speculate whether this change in the frequency of ENSO forcing might be playing a role in the lack of recovery of depleted dolphin stocks. As large, long-lived animals, dolphins have no doubt evolved a considerable buffering capacity against the normal range of environmental variability encountered in the ETP. Perhaps, however, as ENSO events (particularly strong ones) become more frequent, their ability to buffer against the increased environmental variability has been eroded. In other words, although the *mean* state of the ecosystem may not have changed appreciably in recent year, changes in the environmental *variance* might be occurring. Unfortunately, detecting subtle changes in the environmental variance within an ecosystem will require even higher resolution data than those needed to detect changes in the mean state of an ecosystem.

This may be due to strictly intraspecific factors (*e.g.* density dependent effects on age-of-maturity, fecundity, or failure to meet some threshold school size) or, alternatively, to interspecific interactions within the food-web. The assumption here seems to be that, since fishing was directly responsible for the initial depression of ETP dolphin stocks, then the relaxation of fishing mortality should *necessarily* result in a rebounding of the depleted stocks. This seems to be a rather big assumption.

A final observation: as pointed out in Section 2.2.2, one lesson learned from other species that have been over-fished (or have otherwise collapsed) is that recovery times are often *much* longer than predicted. One possibility that doesn't seem to have been considered in the ETP ecosystem research is that the lack of recovery of dolphin stocks may have little to do with changes in the ecosystem, and a lot to do with how drastically the stocks were depleted by the fishery in the first place. In other words, once a stock is severely depleted, it should necessarily be expected to recover at the same rate that might have occurred when the population was healthy. The problem, of course, is that under such a scenario it follows that, unless the overall productivity of the ETP has recently declined in some sort of bottom-up fashion (a possibility for which we see no evidence), then the energy that formerly went into dolphin production must now be going elsewhere. However, no other group of animals in the ETP seems to have recently experienced a sufficiently large increase in abundance to be argued to be the group that is getting all the "surplus energy" that might have formerly have gone into dolphin production. In many ways, it seems that the quote from the MMPA used in the Introduction still holds true: "*there is inadequate knowledge of the ecology and population dynamics of such marine mammals and of the factors which bear upon their ability to reproduce themselves successfully.*"

4. Additional recommendations:

1. If any future sampling is to be carried out, more attention should be paid to the design of the sampling regimes for the oceanographic and plankton data.

> 1a. Phytoplankton measurements (both Chl and primary production) should be size fractionated to permit detection of shifts in phytoplankton community composition that might have significant effects of food chain length, but which many not affect the total primary production.
>
> 1b. Larval fish samples should be split such that a portion are put aside for otolith analysis. Zooplankton should be collected with a finer mesh net to facilitate comparisons with gut contents of the larval fish

2. Since they represent a key link to the higher trophic levels, the existing prey samples need to be analyzed in greater detail.

> 2a. The existing flying fish data (and possibly the myctophid data) should be used to construct length-based growth trajectories. Comparing patterns in the annual growth rates of these fast-growing species, might shed more light on whether things have changed near the bottom of the ETP food web.
>
> 2b. These growth data should be compared to the zooplankton biomass samples to see whether interannual changes in zooplankton biomass are transmitted up the food web in the form of variability in the growth rates of key dolphin prey species.

3. The only large pre-1977 data set available for comparison to the MOPS/STAR data would seem to be that from the EASTROPAC project. However, to date, these data have never been full analyzed or even converted into an electronic format. Resources

should be made available to enable these data to be analyzed and electronically archived before they are completely lost.

4. The authors should explore whether the application of distribution-free statistical methods might offer a way to better deal with some of the admittedly sparse data series

5. The available data on the condition of the ETP dolphins seems woefully inadequate. Dolphin sampling from the fishery ended in about 1992. There should be a requirement stating that anyone who kills a dolphin in the fishery must provide the carcass for scientific analyses. Access to a steady supply of animals would enable researchers to better track changes in growth rates, reproductive status, or the effect of other physiological stressors.

Bibliography: Background Documents for the Center for Independent Experts Review of Eastern Tropical Pacific Ecosystem Studies, Southwest Fisheries Science Center, NMFS, NOAA, 6_8 March 2002.

*Archer, F., T. Gerrodette, A. Dizon, K. Abella, and A. Southern. 2001. Unobserved kill of nursing dolphin calves in a tuna purse_seine fishery. Marine Mammal Science 17(3):540_554.

Au, D.W.K. and W.L. Perryman. 1985. Dolphin habitats in the eastern tropical Pacific. Fishery Bulletin 83(4):623_643.

Au, D.W.K. and R.L. Pitman. 1986. Seabird interactions with tuna and dolphins in the eastern tropical Pacific. Condor 88:304_317.

*Ballance, L.T., R.L. Pitman and S.B. Reilly. 1997. Seabird community structure along a productivity gradient: importance of competition and energetic constraint. Ecology 78:1502_1518.

Clarke, E.D., L.B. Spear, M.L. McCracken, F.F.C. Marques, D.L. Borchers, S.T. Buckland, and D.G. Ainley. In Review. Application of generalized additive models to estimate size of seabird populations and temporal trend from survey data collected at sea. Journal of Applied Ecology.

Forcada, J. Multivariate methods for size_dependent detection in conventional line_transect sampling. Working paper for the Center for Independent Experts Review of eastern tropical Pacific dolphin abundance, Southwest Fisheries Science Center, NMFS, NOAA, 15_17 October 2001.

Hare, S.R. and N.J. Mantua (2000). Empirical evidence for North Pacific regime shifts in 1977 and 1989. Prog. Oceanogr. 47: 103_145.

Hutchings, J.A. (2000) Collapse and recovery of marine fishes. Nature 406: 882_885.

Hutchings, J.A. (2001) Influence of population decline, fishing, and spawner variability on the recovery of marine fishes. J. Fish Biol. 59 (Suppl. A): 306_322.

McPhadden, M.J., and D. Zhang. 2002. Slowdown of the meridional overturning circulation in the upper Pacific Ocean. Nature 415:603_608.

Perrin, W.F. 1969. Using porpoise to catch tuna. World Fishing 18(6):42_45.

*Perrin, W.R., R.R. Warner, C.H. Fiscus, and D.B. Holts. 1973. Stomach contents of porpoise, Stenella spp., and yellowfin tuna, Thunnus albacares, in mixed_species aggregations. Fishery Bulletin 71:1077_1092.

*Reilly, S.B. 1990. Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. Marine Ecology Progress Series 66:1_11.

Reilly, S.B. and P.C. Fiedler. 1994. Interannual variability of dolphin habitats in the eastern tropical Pacific. I: Research vessel surveys, 1986_1990. Fishery Bulletin 92:434_450.

*Robertson, K.M. and S.J. Chivers. 1997. Prey occurrence in pantropical spotted dolphins, Stenella attenuata, from the eastern tropical Pacific. Fishery Bulletin 95:334_348.

*Spear, L.B., L.T. Ballance, and D.G. Ainley. 2001. Response of seabirds to thermal boundaries in the tropical Pacific: the thermocline versus the Equatorial Front. Marine Ecology Progress Series 219:275_289.

*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. Prepared by Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U. S. Department of Commerce. 25 March 1999.

* Document requested by reviewers.

APPENDIX I - BIBLIOGRAPHY OF BACKGROUND DOCUMENTS

REVIEW DOCUMENTS

Ballance, L.T., P.C. Fiedler, T.Gerrodette, R.L. Pitman and S.B. Reilly (2002). Eastern tropical Pacific ecosystem studies: Introduction. Working paper for CIE Review of ETP Ecosystem Studies, March 6-8, SWFSC, NMFS, La Jolla, California, 7pp.

Fiedler, P.C., and V. Philbrick (in review). Environmental change in the eastern tropical Pacific Ocean: I. Observations in 1986_1990 and 1998_2000. Marine Ecology Progress Series (in review), 16pp.

Fiedler, P.C. (in review). Environmental change in the eastern tropical Pacific Ocean: II. Review of ENSO and decadal variability. Marine Ecology Progress Series (in review), 36pp.

Gerrodette, T., and J. Forcada (2002). Estimates of abundance of striped and common dolphins, and pilot, sperm and Bryde's whales in the eastern tropical Pacific Ocean. SWFSC Administrative Report LJ-02, 20pp.

Reilly, S.B., P.C. Fiedler, T. Gerrodette, J.M. Borberg and R.C. Holland (2002). Eastern tropical Pacific dolphin habitats _ Interannual variability 1986_2000. Draft Report, SWFSC, NMFS, La Jolla, California, 34pp.

Ballance, L.T., R.L. Pitman, L.B. Spear and P.C. Fiedler (2002). Investigations into temporal patterns in distribution, abundance and habitat relationships within seabird communities of the eastern tropical Pacific. A working paper for the CIE Review of ETP Ecosystem Studies, March 6-8, SWFSC, NMFS, La Jolla, California, 74pp.

Pitman, R.L. L.T. Ballance and P.C. Fiedler (2002). Temporal patterns in distribution and habitat associations of prey fishes and squids. Working paper for CIE review of ETP Ecosystem Studies, March 6-8, SWFSC, NMFS, La Jolla, California, 41pp.

Moser, H.G., P. E. Smith, R. L. Charter, D. A. Ambrose, W. Watson, S. R. Charter and E. M. Sandknop (2002). Preliminary report on ichthyoplankton collected in manta (surface) net tows on marine mammal surveys in the eastern tropical Pacific: 1987–2000. Working paper for CIE review of ETP Ecosystem Studies, March 6-8, SWFSC, NMFS, La Jolla, California, 67pp.

Reilly, S.B., L.T. Ballance, P.C. Fiedler, T. Gerrodette, R.L. Pitman, H.G. Moser and J.M. Borberg (2002). Information to evaluate regime shifts in the eastern tropical Pacific Ocean. Working paper for CIE review of ETP Ecosystem Studies, March 6-8, SWFSC, NMFS, La Jolla, California, 15pp.

Background Documents for the Center for Independent Experts Review of Eastern Tropical Pacific Ecosystem Studies, Southwest Fisheries Science Center, NMFS, NOAA, 6-8 March 2002.

*Archer, F., T. Gerrodette, A. Dizon, K. Abella, and A. Southern. 2001. Unobserved kill of nursing dolphin calves in a tuna purse_seine fishery. Marine Mammal Science 17(3):540-554.

Au, D.W.K. and W.L. Perryman. 1985. Dolphin habitats in the eastern tropical Pacific. Fishery Bulletin 83(4):623-643.

Au, D.W.K. and R.L. Pitman. 1986. Seabird interactions with tuna and dolphins in the eastern tropical Pacific. Condor 88:304_317.

*Ballance, L.T., R.L. Pitman and S.B. Reilly. 1997. Seabird community structure along a productivity gradient: importance of competition and energetic constraint. Ecology 78:1502-1518.

Clarke, E.D., L.B. Spear, M.L. McCracken, F.F.C. Marques, D.L. Borchers, S.T. Buckland, and D.G. Ainley. In Review. Application of generalized additive models to estimate size of seabird populations and temporal trend from survey data collected at sea. Journal of Applied Ecology.

Forcada, J. Multivariate methods for size-dependent detection in conventional line-transect sampling. Working paper for the Center for Independent Experts Review of eastern tropical Pacific dolphin abundance, Southwest Fisheries Science Center, NMFS, NOAA, 15-17 October 2001.

McPhadden, M.J., and D. Zhang. 2002. Slowdown of the meridional overturning circulation in the upper Pacific Ocean. Nature 415:603-608.

Perrin, W.F. 1969. Using porpoise to catch tuna. World Fishing 18(6):42-45.

*Perrin, W.R., R.R. Warner, C.H. Fiscus, and D.B. Holts. 1973. Stomach contents of porpoise, *Stenella* spp., and yellowfin tuna, *Thunnus albacares*, in mixed-species aggregations. Fishery Bulletin 71:1077-1092.

*Reilly, S.B. 1990. Seasonal changes in distribution and habitat differences among dolphins in the eastern tropical Pacific. Marine Ecology Progress Series 66:1-11.

Reilly, S.B. and P.C. Fiedler. 1994. Interannual variability of dolphin habitats in the eastern tropical Pacific. I: Research vessel surveys, 1986-1990. Fishery Bulletin 92:434-450.

*Robertson, K.M. and S.J. Chivers. 1997. Prey occurrence in pantropical spotted dolphins, *Stenella attenuata*, from the eastern tropical Pacific. Fishery Bulletin 95:334-348.

*Spear, L.B., L.T. Ballance, and D.G. Ainley. 2001. Response of seabirds to thermal boundaries in the tropical Pacific: the thermocline versus the Equatorial Front. Marine Ecology Progress Series 219:275_289.

*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. Prepared by Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U. S. Department of Commerce. 25 March 1999.

* Document requested by reviewers.

APPENDIX 2: STATEMENT OF WORK

Consulting agreement Between the University of Miami and Dr. John Dower

Background

Scientists of the Protected Resources Division at the Southwest Fisheries Science Center, National Marine Fisheries Service (NMFS, NOAA) are currently engaged in a suite of studies designed to assess the impact of the eastern tropical Pacific yellowfin tuna purse seine fishery on dolphin stocks which associate with these tuna. One component of these studies is an assessment of the population size of the potentially affected dolphin stocks. Population assessments have been made for the following years: 1986, 1987, 1988, 1989, 1990, 1998, 1999 and 2000 with a primary goal being to determine if the populations that were historically reduced in size are increasing over time. Should the assessments indicate no increase (lack of recovery), three broad categories of factors could be the cause: a) effects from the fishery; b) effects from the ecosystem; c) an interaction between the two factors.

This need to attribute causality for a potential lack of recovery serves as the primary justification for ecosystem studies. By investigating the physical and biological variability of the ecosystem of which the dolphin stocks are a part, we establish a context that can be used to better interpret trends in dolphin abundance. A lack of recovery that is not mirrored by some other change in the ecosystem would largely eliminate an ecosystem hypothesis, leaving fishery effects as the most likely cause.

It should be noted that this issue is controversial and particularly relevant to persons involved with NMFS, the US and non-US tuna industry, and environmental groups.

General Topics for Review

This review includes a suite of studies subsumed under the general topic of "Ecosystem Research in the Eastern Tropical Pacific." Our basic approach will be to compare ecosystem parameters over time with a primary goal being to look for indications of a potential ecosystem shift. The power of these ecosystem studies will increase with the number of environmental variables, taxa, and trophic levels included, and with the time period spanned (although most ecosystem data available for these investigations were collected concurrently with dolphin assessment data aboard NOAA research vessels and are restricted to the late 1980s and 1990s).

The general components included are as follows:

Physical and Biological Oceanography: sea surface temperature, thermocline characteristics, phytoplankton and zooplankton distribution and relative abundance;

Larval Fishes: distribution and relative abundance;

Flying fishes: distribution, relative abundance, and habitat relationships.
Seabirds: distribution, absolute abundance, and habitat relationships.

Cetaceans: distribution, absolute abundance, and habitat relationships.

Reviewers should be familiar with one or more of the following general disciplines; physical oceanography, biological oceanography, pelagic (oceanic) ecology of plankton, fish, birds, and cetaceans. Analysis methods will include use of certain multivariate techniques such as Canonical Correspondence Analysis and Generalized Additive Models. Familiarity with one or more of the taxa listed above will be helpful. Due to the broad scope of components included within this investigation, no single reviewer will be expected to have expertise in all relevant areas.

Documents supplied to reviewers will include draft manuscripts on topics listed above. A number of background papers (relevant publications and reports) will also be supplied.

Specific Reviewer Responsibilities

The reviewer's duties shall not exceed a maximum total of two weeks: several days to read all relevant documents, three days to attend a meeting with scientists at the NMFS La Jolla Laboratory, in San Diego, California, and several days to produce a written report of the reviewer's comments and recommendations. It is expected that this report shall reflect the reviewer's area of expertise; therefore, no consensus opinion (or report) will be required. Specific tasks and timings are itemized below:

1. Read and become familiar with the relevant documents provided in advance;

2. Discuss relevant documents with scientists at the NMFS La Jolla Laboratory, in San Diego, CA, for 3 days, from March 6-8, 2002;

3. No later than March 22, 2002, submit a written report of findings, analysis, and conclusions. The reports should be addressed to the "UM Independent System for Peer Reviews," and send to David Die, UM/RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149 (or via email to ddie@rsmas.miami.edu)