

REVIEW OF EASTERN TROPICAL PACIFIC (ETP) OCEAN ECOSYSTEM STUDIES

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EXECUTIVE SUMMARY

A total of nine papers were made available for review prior to the March 6-8 CIE Ecosystem Review Meeting at the Southwest Fisheries Science Centre of the National Marine Fisheries Service in La Jolla, California. These Ecosystems Studies represent an impressive body of excellent research covering a huge geographical area (20 million km²). The volume of data collected and analysed during the NOAA dolphin abundance assessment cruises is unprecedented for the ETP, and has greatly contributed to the scientific knowledge of this vast and complex oceanic ecosystem.

The data have been carefully collected using standardised protocols over the different survey years, and the approach to answering the central question of whether or not there has been an ecosystem change has been thorough and in many cases innovative. The power of the studies to detect change has been greatly increased by examining a large number of environmental variables, taxa and trophic levels which include data on physical and biological oceanography; on seabird populations; on prey fishes and squids; on ichthyoplankton; and on other cetaceans collected concurrently during the NOAA survey cruises.

All of the data sets showed inter-annual variations, and strong ENSO signals. None showed any convincing signs of decadal changes that would indicate an environmental or regime shift in the ETP since the 1980s, except for the IATTC yellowfin and bigeye tuna data. However, these are likely to represent top-down fisheries effects rather than a bottom-up environmental effect.

The short (15 years) and disjointed time series for most of the data sets is a recognised constraint in determining decadal-scale changes. Furthermore, the lack of data prior to the 1960s prevents determination of whether the environment has changed between the period when dolphin stocks were presumed to be abundant and the period when dolphins had been severely depleted by the tuna purse-seine fisheries. This will constrain an attempt to attribute cause, if it is found that depleted dolphin stocks have not recovered.

In summary, all of the papers and the presentations given during the meeting are of high quality, the analyses are robust and the conclusions are sound.

INTRODUCTION

Background

The eastern tropical Pacific (ETP) supports a highly productive yellowfin tuna fishery, which owes much of its success to the high visibility of surface feeding schools of tuna when mixed with dolphins and marked by large flocks of seabirds (Au and Perryman 1985). Since the late 1950s, the tuna fishery has been setting purse seines on these mixed species schools resulting, at least in the early years of the fishery (1960s through the early 1970s), in very high mortality of the associated dolphins, particularly spotted and spinner dolphins (Perrin 1969, Gosliner 1999). The National Marine Fisheries Service (NMFS) has been monitoring these dolphin stocks since the 1970s and populations are believed to have been reduced by this incidental fishing mortality to about 20% of their pre-1959 abundances. Concern for the status of the mammals led to the development of improved seining techniques through the 1970s, which allowed the dolphins to be released from the net after pursing. By the mid to late 1970s the incidental kill of dolphins had been drastically reduced and by 1991 it was estimated to be below the replacement value for the depleted stocks (Gosliner 1999).

Extensive dolphin abundance surveys were conducted from 1986-1990 (Monitoring of Porpoise Stocks (MOPS) project). However, continued concern that the fishery may still be adversely affecting these depleted dolphin stocks lead to the Secretary of Commerce being directed to determine whether the chase and encirclement of dolphins by tuna purse seine operations is having an adverse effect on any depleted dolphin stock. As a result, in 1997, the NMFS was mandated by a Congressional Act (the International Dolphin Conservation Program Act (IDCPA)) to undertake this research over the next five years. Since 1997, scientists of the Protected Resources Division at the Southwest Fisheries Science Center (SWFSC), NMFS have been engaged in a suite of studies (*Stenella* Abundance Research (STAR) project) designed specifically to assess the impact of the eastern tropical Pacific yellowfin tuna purse seine fishery on dolphin stocks that associate with these tuna. An important component of these studies is an assessment of the population size of the potentially affected dolphin stocks. Should the assessments indicate no increase (lack of recovery), three broad categories of factors will be considered as possible causative agents: a) effects from the tuna fishery; b) effects from the ecosystem; and c) an interaction between the proceeding two factors.

This need to attribute causality for a potential lack of recovery serves as the primary justification for the suite of ecosystem studies, which are the subject of this review. By investigating the spatial and temporal variability of the physical and biological characteristics of the oceanic ecosystem of which the dolphin stocks are a part, it is hoped that trends in dolphin abundance will be better understood. 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. This latter issue is highly controversial in view of the substantial economic implications, and particularly relevant to persons involved with NMFS, the US and non-US tuna industry, and environmental groups. As such, the research findings are being carefully scrutinized and externally reviewed by a number of different review panels

commandeered by the Center for Independent Experts (CIE), before their release at the end of 2002.

This report represents one of the external reviews of the Ecosystem Studies component of the IDCPA project.

Topics for Review

The current CIE review includes a suite of studies subsumed under the general topic of *Ecosystem Research in the Eastern Tropical Pacific*. The basic approach of these studies has been to compare ecosystem parameters over time with a primary goal being to look for indications of a potential ecosystem shift that may have affected the recovery of depleted dolphin stocks.

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;
- **Flyingfishes:** distribution, relative abundance, and habitat relationships;
- **Seabirds:** distribution, absolute abundance, and habitat relationships;
- **Cetaceans:** distribution, absolute abundance, and habitat relationships.

Review Procedure

A total of nine documents (including an introductory paper, four working papers, two draft reports and two papers under review in a primary refereed journal) were supplied to reviewers prior to the March 6-8, 2002 CIE Review Meeting at the SWFSC, NMFS, in La Jolla, California. These are listed in Appendix I. A large number of additional background documents comprising papers published, or under review, in primary refereed journals and a 1999 Report to Congress were also provided before and during the meeting (also see Appendix I).

At the meeting the review panel was apprised of the background and key objectives of the overall IDCPA project to assess the tuna-dolphin problem by the Project Director, Steve Reilly, and was given an overview of the ecosystem study components by the Ecosystems Section Head, Lisa Ballance. The panel was reminded of the focus question to be addressed in the current review, that is:

- *“Has there been a change in the ETP ecosystem?”*

and specifically asked to determine:

- *“Are there any temporal patterns in the ecosystem indicators, and if so, how are these best described?”*

The panel was duly reminded that the question of whether or not the dolphin stocks are showing signs of recovery, and if not, the attribution of this lack of recovery to the fishery and/or the environment is beyond the intended scope of the current review.

The panel was then given useful background information on the yellowfin tuna fishery in the ETP by Dave Bratten of the Inter-American Tropical Tuna Commission (IATTC). Following this, each review paper was presented by one or more of the authors and discussed in detail among the five members of the review panel, authors and other scientists of the Protected Resources Division of the SWFSC. Reviewers were also afforded the opportunity to speak one on one with project scientists and to critically examine and discuss the computerized databases for consideration of further analyses.

FINDINGS

This review represents an independent report of comments, concerns and recommendations arising from a thorough review of the Ecosystem Studies papers and data sets, and discussions held with project scientists at the SWFSC and other review panellists during the 3-day meeting. It should be noted that the comments in this review are focussed around (but not exclusive to) the general disciplines of fisheries, biological oceanography and pelagic (oceanic) ecology of fish, with special attention given to flyingfishes. Comments from other reviewers on the panel are expected to focus on other areas of specialisation, such that all aspects of the research should be thoroughly reviewed.

Provided here are specific comments and recommendations, where appropriate, on each of the nine papers reviewed. These are given, for each paper separately, in list form for ease in responding. This is followed by a summary of general comments and recommendations addressing the focus question of this Ecosystem Studies Review.

Specific Comments and Recommendations

1. Eastern tropical Pacific ecosystem studies: Introduction

This paper gives a very useful introduction to the dolphin-tuna problem in the ETP and to the relevant background papers providing more details. It also provides a useful overview of the oceanography of the ETP, the approach to data collection and the data sets available for addressing the central question of ecosystem change in the ETP.

Specific comments are listed below:

- Mention of the actual average annual yield (in mt) of the yellowfin tuna fisheries from the purse seine boats in the ETP would help to set the context for the socio-economic importance of the dolphin-tuna problem.
- I do not agree that the ecosystem studies will simply provide 'useful academic information' in the event that dolphin stocks are found to have recovered. It is important to emphasise that ecosystem monitoring is now recognised as being an integral and very necessary part of successful conservation and management of sustainable use of marine resources (Norse 1993, Sherman 1994). Environmental monitoring should not be marginalised, as has occurred in the history of

this project, which has resulted in incomplete and relatively short (15 yr) time-series for most of the environmental indicators.

2. Environmental change in the eastern tropical Pacific Ocean: I. Observations in 1986-1990 and 1998-2000

This paper provides a useful visual presentation in the form of contour maps, showing yearly (Aug-Nov) fields of environmental parameters (physical and chemical oceanographic data: sea surface temperature (SST), thermocline depth and surface chlorophyll concentration) collected during line-transect dolphin abundance survey cruises from August to November in each of the years 1986 - 1990 (MOPS surveys) and 1998 - 2000 (STAR surveys) in the ETP. It also summarizes and compares biological oceanographic data (primary productivity from August to November in a 1990 MOPS survey, and zooplankton abundance from August to November in a 1967 EASTROPAC survey) with comparable data collected from August to November in the 1998-2000 STAR surveys.

These data are also presented graphically (over a longer time-series (1980-2000) for SST and thermocline depth) as mean fall (Aug-Nov) anomalies to highlight inter-annual, ENSO and possibly inter-decadal (between MOPS and STAR sampling periods) variability in the entire survey area and in the core survey area separately.

The paper concludes that whilst there are clear spatial patterns as would be expected for the different water masses, and clear regional effects of ENSO variability, there are no significant differences for any of the variables between the 1986-1990 and the 1998-2001 time-periods, with the exception of SST which shows a statistically significant cooling of 0.27 °C. The authors further conclude that a temperature change of this magnitude is unlikely to be important in the ETP where SST varies by several degrees between seasons and years. They further note that some data sets (e.g. primary productivity and zooplankton volume) are inadequate to draw any conclusions about change.

Specific comments are listed below:

- The paper provides a very useful visual summary of the oceanographic environmental data collected during the two periods of dolphin abundance cruises (MOPS and STAR surveys), and illustrates well the spatial scales of variability (between and within water masses) as well as temporal (inter-annual) variation.
- The abstract is overly brief, mentions 'added sampling programs' without explanation and does not adequately explain the research findings in the context of the data constraints, particularly for the primary productivity and zooplankton volume data sets. In short the abstract undersells the contents of the paper.
- The introduction does not mention comparison of data with additional and historical data sets covering the years 1980-1985 and 1991-1997 for SST and thermocline depth, and 1967 for zooplankton volume.
- The methods are comprehensive and clear for the oceanographic sampling. In fact, methodological information is given for parameters (conductivity, salinity, nutrient concentrations, and indices of micronekton prey availability) which are not presented in this paper, and are therefore unnecessary. Furthermore, the detailed description of the problems with comparing EASTROPAC and STAR survey macrozooplankton tows would be more appropriate

in the discussion. The description of the statistical analyses is perhaps overly brief. For example, it is not clear what type of ANOVA is being performed to compare the two data sets.

- Table 1 is a little unclear. *, ***, and NS should be defined in the legend. It should be made clear that the ANOVA results are given as p values and the '(no effect)' should be removed.
- The Figures are clear and provide a very useful visual display of the temporal and spatial variability in the environmental variables.
- Why is the 1967 EASTROPAC zooplankton volume data set being compared with a 3-year (1998-2000) pooled data set, when all other comparisons showed each year independently?
- It is not clear why analysis of the SST and thermocline depth data were restricted to a 1980-2000 time series, when these data are presumably available for a longer period?
- Conclusions are rather minimal. More effort could have been put into discussing the problems with comparing the data sets from the different surveys, and the fact that the time series are short and incomplete for some of the parameters, which makes detection of change over this time frame very difficult, especially given the frequency and varied strength of ENSO events. Furthermore, the conclusions do not revisit the stated purposes of data collection as given in the introduction (i.e. to help interpret changes in dolphin stock abundance; to advance knowledge of dolphin stock distribution and ecology; to monitor inter-annual change in the study area; and to contribute to ongoing programs investigating oceanography and ocean-atmosphere interactions in the ETP).
- Oceanographic environmental time-series data are difficult to analyse especially over such a vast geographic area because of the strong spatial as well and different scales of temporal variability. The authors have done a good job of teasing these patterns apart both visually (through maps and graphs) and statistically in order to make sense of the patterns and allow longer-term temporal change (if any) to be detected.

Broad spatial patterns are marked and basically similar among years in describing the four different surface water masses and smaller scale predictable oceanographic features of the ETP. Furthermore, the spatial patterns are essentially consistent (at least for SST and thermocline depth) over the survey years, although inter-annual and ENSO events are obvious.

I agree with the authors that there is no sign from this relatively short time series of environmental indicators of any long-term ecosystem shift in the ETP survey area or the core area (which represents the more crucial habitat for the depleted dolphin stocks).

3. Environmental change in the eastern tropical Pacific Ocean: II. Review of ENSO and decadal variability

This second paper in the two part series on environmental change in the ETP, provides a very useful assimilation and review of published, longer time series of physical environmental data (SST, thermocline depth, and other related oscillation indices) from a number of different sources and over a number of different time scales in the ETP, eastern equatorial Pacific and the NE Pacific. It also provides an excellent review of documented biological effects of ENSO and decadal scale variability (or 'regime shifts') in the physical environment, on marine populations (in particular marine mammals) and ecosystems of the ETP and other areas of the Pacific Ocean.

The author concludes that there has been no real change in ENSO periodicity over the long term (for at least the last 5000 years). He also concludes that longer scale decadal variability (manifested as oscillations in periods of SST warming and cooling) is apparent in both the NE and tropical Pacific, but is much more marked in the former, and that the variability in the two areas appears to be antagonistic, such that there may be forcing from either side. He concludes that there is no evidence of environmental change (in terms of a climate or regime shift) in the ETP since 1977, and questions whether the slight increase in SST (by + 0.1°C) and a shoaling of the thermocline by 6 meters apparent since 1980 is of any significance given the much greater magnitude of seasonal and ENSO variability in SST and thermocline depth in the ETP region.

The author points out that biological effects of ENSO variability have been reported for fish, birds, pinnepeds and cetaceans, and usually involve changes in distribution, as the distribution of preferred water masses and prey change. He also points out that the most dramatic population effects (mass mortalities and breeding failures) have been reported in coastal or island populations with localised breeding or feeding grounds. However, in virtually all cases, recovery has been rapid after an El Niño event is over. In particular, he states that k-selected species (e.g. marine mammals) tend to be resilient to ENSO variability as a result of low turnover rates (high longevity, delayed maturity, low reproductive rates) and a generalised diet that includes mesopelagic species (less affected by ENSO variability). He reports that ENSO effects have been noted for ETP dolphins (northeastern offshore spotted and eastern spinner dolphins), which have extended their range slightly in El Niño years, but that no population effects have been detected, nor have they moved out of the area.

Specific comments follow:

- The abstract does a reasonable job of summarising the intent and findings of the paper except for the effects of environmental changes on dolphins which are simply stated as ‘being discussed’
- The time scales over which the physical oceanographic environmental parameters are examined in this paper are much more appropriate than those presented in Part 1 for detecting decadal or longer scale changes or even climate change in the ETP, which may in turn be affecting the ability of depressed dolphin stocks to recover. However, I would like to see greater emphasis on comparison of conditions prior to the depletion of dolphin stocks (i.e. prior to the 1959 start of the tuna seine fishery) with those in the post-mortality era (i.e. after the mid 1980s) when dolphin stocks were expected to recover. The current emphasis is on examining the trends over the last 20 years (1980 - 2000) which only represents the era of depressed dolphin stocks.
- In the review of ENSO variability, 1986-1987 is listed as a La Niña event, presumably in error (pg. 4, para. 3).
- Acronyms are not adequately translated (e.g. NINO3, COADS and EASTROPAC).
- It is not clear from the beginning whether or not Eastern Equatorial Pacific, Eastern Pacific and Eastern Tropical Pacific are being used interchangeably or refer to different areas of the ocean, although introduction to Figure 1 later on suggests that they are in fact different areas.
- One of the examples in the ETP of biological changes in response to ENSO variability that stands out, is that of the Galapagos penguins which have apparently not recovered from a 77% mortality which occurred in the 1982-83 El Niño. It is interesting that the ETP dolphins were believed to have been depressed to similarly low levels at around this time by the fishery, and it appears that

they too have not recovered. If an explanation has been offered for this lack of recovery in penguins (maybe an island breeding habitat disturbance?) then it should be given here to defray a possible link with the dolphin situation.

- The organisation of the paper is a little confusing, with the ‘biological effects’ sections being placed in the middle of the ‘oceanographic variability’ sections. I would prefer to see the ‘oceanographic variability’ sections grouped together up front.
- The conclusion provides a nice summary of the findings of the review of biological effects of ENSO variability in the Pacific, but does not mention the findings of the review on biological effects of decadal change.
- I fully support the conclusions of the author regarding a general lack of any obvious long-term shifts in the physical environment of the ETP since 1977, when there appears to have been an oscillation from a very minor cooling of surface waters, to a minor warming. I would also emphasise the fact that this mild oscillation has hardly been detectable in the ETP warm pool (which is the key habitat of the depressed dolphin stocks) since at least the mid 1920s.

4. Estimates of abundance of striped and common dolphins, and pilot, sperm and Bryde's whales in the eastern tropical Pacific Ocean

This paper examines abundance trends in cetaceans not targeted by the tuna-seine fishery, to look for any changes that may signal environmental changes that could be affecting the target cetacean species (northeastern offshore spotted and eastern spinner dolphins) in the ETP. Line transect surveys were carried out from August - November each year from 1986-1990 (MOPS surveys) and from 1998-2000 (STAR surveys). Of particular note is the fact that these abundance estimates have benefited from recent advances in conventional line-transect methods involving multivariate modelling and correcting for the probability of detecting cetaceans under a variety of different conditions. Furthermore, estimates of group size have been corrected for bias, based on aerial photographs of a sub-sample of schools. As such, they represent estimates with a high level of confidence in their accuracy, for which the authors should be congratulated.

Specific comments follow:

- In the abstract it would be more useful to summarise the patterns or trend in the abundance for each species, rather than simply listing the high and low abundance estimates. The abstract as it stands does not do justice to the findings or conclusions of the paper.
- It is a great shame that earlier surveys in the 1970s and 1980s did not routinely collect data on the non-target cetacean species and therefore these earlier data cannot be used to extend the time series presented here back into the period when target dolphins were more abundant.
- Whilst it is appreciated that effort was stratified slightly differently in the MOPS and STAR years, and thus data analysis was also stratified differently to obtain the best estimates of abundance, it would be interesting to post-stratify the MOPS data into core and outer areas (as done in the STAR surveys), and focus comparisons between the MOPS and STAR years using only the core area which represents the key habitat of the target (depleted) dolphin stocks. In this way, it may be easier to detect change in the key habitat of the northeastern offshore spotted and eastern spinner dolphins (target species). This post-stratification should not cause a problem in the abundance estimates for the core area, since effort in the core area was similarly high in all years. I would also suggest that a finer level of post-stratification be attempted using the ranges of the different target species (as shown in Figure 1) and look for any signals in the habitat of the target species separately.

- The $f(0)$ value is not adequately explained, particularly in the Table legends.
- The statement that striped dolphins were consistently the most abundant species (pg. 7, para. 4) does not appear to be accurate, since estimates for southern common dolphin exceeded those of striped dolphins in five of the eight years (see Table 5).
- Figure 3 is visually misleading since there are no data for 7 years (1991-1997) and yet there is a line joining the 1990 and 1998 data points. I would suggest that the two data sets are not joined and would perhaps be better represented as a bar chart. On this issue, I also have concern with the use of a linear regression to assess abundance trends, since there is such a large gap in the middle of the series. An ANOVA approach to comparing the two data sets may be more appropriate to determine if stock abundances have changed over time.
- More attention should be given to explaining the high inter-annual variability in the abundance estimates, which suggests that populations of several of the species (e.g. central common dolphins, southern common dolphins and Bryde's whales) have more than doubled from one year to the next. This is clearly not possible given the k-selected life histories of these animals, and would suggest that there is movement in and out of the sampling area, or that extreme patchiness or some other factor is causing significant bias in the estimates. Perhaps a more in-depth look at the populations most endemic to the ETP (central common dolphins) should be undertaken.
- I agree with the authors that no clear trends in either direction are evident in the current data set for any of the cetacean species presented, although I would like to see an alternative analysis as stated above to better test for abundance changes between the two sampling periods.

5. Eastern tropical Pacific dolphin habitats - Inter-annual variability 1986 - 2000

This paper is particularly clearly written and examines preferred habitat characteristics and the geographical distribution of these habitat types for seven types of cetacean single and mixed species schools (most frequently set upon by the purse seine fishery) using data from the 1998-2000 STAR surveys, and compares them with those observed a decade earlier during the 1986-1990 MOPS surveys.

An elegant multivariate canonical correspondence analysis (CCA) was used to integrate all measured variables simultaneously to give a more accurate quantitative picture of the preferred habitat characteristics (including indices of thermocline depth (20°C isotherm), thermocline strength (15°C isotherm), primary productivity (chlorophyll concentration), and SST, surface salinity and density). The model was further improved by the addition of a further variable (geographical position) and year (as a covariate). The key objective was to examine for any change in the preferred habitat characteristics of the cetaceans, or any substantial changes in the geographical distribution of those habitats, that might indicate an ecosystem shift between the two decades.

The paper concludes that there are insignificant differences between the models (preferred habitats) of the dolphin schools between the two decades, and that the distribution of preferred habitat types is essentially the same, although ENSO effects can be detected. As such there is no evidence of an ecosystem shift between these two periods.

Specific comments follow:

- The abstract is clear and concise

- The complex analysis has been very clearly explained and the visual presentation is very useful.
- The maps showing the geographical distribution of habitats as described by the model axes are particularly helpful in assessing possible change in the preferred environment of the different dolphin schools.
- The authors note that in general the models explained a relatively low proportion of the variance in dolphin school abundance (7 - 21 %), with the exception of common dolphins (48 - 50 %). As such they suggest that other factors such as prey availability, and possibly interactions with other cetacean species are likely to be more important in directly influencing the distribution of the various dolphin schools. This being the case, I would encourage the authors to incorporate some index of prey abundance (e.g. myctophidae, hemiramphidae and exocoetidae) for which good data exist (see Pitman *et al.* 2000, working paper 7) into the CCA models.
- I would also encourage the authors to follow up on their suggestion of distinguishing between the common dolphin stocks, particularly as the models appear to be particularly strong for this species.
- I entirely agree with the authors' conclusions that there is no signal of an ecosystem shift in the ETP since the mid 1980s in this data set.

6. Investigations into temporal patterns in distribution, abundance and habitat relationships within seabird communities of the eastern tropical Pacific

This paper examines temporal patterns in the distribution and abundance of nine species/taxa of seabirds (with a broad range of life history characteristics and foraging strategies) in the ETP, by comparing line transect visual survey data sets from three MOPS (1988-1990) and STAR (1998-2000) surveys. Patterns in preferred habitats are also investigated. The key objective is to use seabirds as indicators of marine ecosystem shifts, and determine if there have been any changes between the two sampling periods.

Visual count data were corrected for transect width that could be effectively sampled for small species under different visibility conditions. Data were also corrected for flying speed and direction in relation to ship speed and direction, to avoid bias. Oceanographic data were collected simultaneously with visual bird count data and a comprehensive CCA was used to investigate the relationship between seabird density and oceanic habitat over each of the survey years and over all years combined with year and decade added to the model as covariates.

Distributions were distinctly different among different species/taxa and different foraging strategists. Furthermore, there was notable inter-annual variation in distribution patterns within species but broad similarity over the decade. Abundance of each species varied among years, however, there were no significant trends in abundance over the study period for the four tuna-dependent species (i.e. those species dependent on tuna for aggregating prey and bringing it close enough to the surface to be caught by the birds) nor for four of the five tuna-independent species. The Tahiti petrel on the other hand has shown a significant decline in abundance between the late 1980s and the late 1990s, which the authors attribute to probable breeding colony perturbation.

The amount of variance in combined seabird distribution explained by the oceanic variables is relatively high (27-39 %), especially given that many of the birds counted were likely to be commuting and not actually using the habitat. The model is particularly strong for some species/taxa (e.g. phalaropes, wedge-rumped storm petrels and Juan

Fernandez petrels) where 55-80 % of the variance is explained. Species showed specific habitat associations with some inter-annual variability, but they basically remained consistent over time. The overall conclusions of the paper are that whilst inter-annual and ENSO variability is evident in the environmental indicators, there is no evidence of any longer-term (decadal scale) shift.

Specific comments follow:

- The comparisons of estimates based on at-sea counts with those based on breeding colony counts indicates an impressive level of accuracy for the corrected at-sea data base.
- The GAM plots of geographical distribution by abundance are extremely useful for comparing broad scale differences in distribution patterns
- The CCA analyses are not clearly interpreted and would benefit from a geographical plot of the distribution of habitat types represented by the main axes (as presented in Reilly *et al.* 2002, Working Paper 5). Furthermore, they could be somewhat simplified by removing variable parameters that are essentially the same (e.g. surface Chl and euphotic chlorophyll; thermocline depth and thermocline strength; salinity and sigma-t).
- Again I cannot fault the overall conclusions of the authors that no ecosystem shift is apparent in this time series.

7. Temporal patterns in distribution and habitat associations of prey fishes and squids

This paper attempts to forge a link between physical oceanographic parameters and dolphin stock and seabird abundance in the ETP by examining patterns in abundance and distribution of prey species (fishes and squids). Habitat associations of these prey species are also considered on a spatial and temporal scale, across the ETP and over MOPS (1986-1990) and STAR (1998-2000) survey years.

Prey species were sampled at nighttime dipnet stations. Oceanographic data (SST, salinity, surface and euphotic zone chlorophyll concentration, sigma-t, thermocline depth and strength) were collected simultaneously at these stations. By far the most abundant families in the dipnet samples were flyingfishes (Exocoetidae: which were further classified into short-winged, two-winged species group and four-winged species group), lanternfish (Myctophids) and squid (Ommastrephidae: which were classified into large, medium and small), all of which are important components of the diet of the target dolphin species as well as for many seabird species. The analyses were therefore restricted to these groups.

Broad distribution patterns for each of the taxa groups are clearly presented for each year as density contour maps, and annual means of relative abundance are shown graphically. Taxa show clear affinities for different water masses, but there is much inter-annual variation in the general distribution patterns and in the areas of high abundance. The trends in mean abundance over the years are surprisingly similar among taxa groups (with the exception of small squid). The data sets show a general increase from a relatively low value in 1986 to higher values (on average 4 fold larger) through the MOPS years. This is then followed by low abundance again in 1998 and a gradual increase through 2000. The authors suggest that this pattern is showing the affects of ENSO variation, with El Niño events occurring in 1986-87 and again in 1997-98.

CCA analyses were used to investigate the interaction of relative abundance of prey species with the multiple habitat variables and geographic position variables (latitude and longitude). The CCA models explained high levels of variance in the abundance of some taxa (i.e. myctophids: ~ 50-75 %; short-wing flyingfish and large squids: > 25 %). Interpretation is therefore restricted to these groups. Models show inter-annual variation but are essentially similar over the long term within taxa groups indicating that ENSO variability is the dominant environmental feature, rather than any longer (decadal scale) shift.

Specific comments are listed below:

- This paper represents a huge and impressive data set of abundance and distribution of prey species which are difficult to sample, over a vast geographic area of ocean. The approach of using these data to look for environmental signals, through examination of yearly distribution patterns, abundance indices and habitat associations is excellent.
- Description of data collection methods and which data sets were used in the current analysis could be improved. For example, it does not explicitly state that data were collected on each of the MOPS (1986-1990) and STAR (1998-2000) surveys from August to November. In fact the implication is that sampling begins in 1986 and continues every year afterwards (pg. 1, para. 3). The sampling years (but not months) are however clearly shown in Table 1.
- Furthermore, the fact that either one or two attracting lamps and either one or two persons were used at the dipnet stations to count and catch observed organisms suggests that effort was highly variable over the surveys and that bias in the estimates of abundance is therefore very likely. This point was clarified by the author in discussion, who confirmed that the data presented here represent a large sub-sample of the dipnet stations in which he was present and conditions were kept standard. This needs to be made clear.
- Other details need to be made a little clearer also; for example, were samples collected and counted only in the illuminated zone, and if so how large was this? It is not explicitly stated why samples were collected. In this paper, only the counts were analysed. Were all samples attracted to the area caught (removed)? If not, how were newly entering individuals distinguished from those already present by the observers estimating numbers? The author again clarified some of these points in discussion, by reporting that organisms did not remain in the illuminated zone but were continuously drifting through it. As such there was not a problem of 'accumulation' in the illuminated zone. He also stated that virtually all specimens were collected. Again these points need to be stated in the description of the sampling technique, since they have important implications for the accuracy and usefulness of the estimates.
- Although data on moon phase and cloud cover were collected, there has been no attempt to see whether these parameters affect the availability of prey species to the sampling gear. I would recommend that this be done.
- The coverage of the ETP by all dipnet samples over all years, as illustrated in Figure 1, is indeed impressive.
- It would be nice to see a Table documenting the actual total number of each species and taxa group that were counted and collected. This would show the sample sizes and give a better idea of the percent species composition.
- The apparent high inter-annual variability within taxa of their overall distribution and location of centres of abundance is likely to be compounded by the fact that sampling was relatively coarse (at

most a single sample per 100 nmi of transect) given the inherent patchiness of oceanic fish (e.g. for flyingfish: Oxenford et al. 1995). Furthermore, the method of kriging observed values to produce the contour plots has likely resulted in a visual misrepresentation of abundance where samples are sparse (e.g. for myctophids, the large patches of orange in the southwest and southeast corners of the sampled area in 1986; and the large patch of orange around the Galapagos islands in 2000, are likely to be artifacts produced by low density sampling in these areas).

- The ordination biplot from the CCA analysis is unnecessarily complex. Variables that essentially indicate the same thing should be removed.
- I am again in agreement with the general conclusions of this paper with regards to the absence of any evidence of a decadal scale shift in the ocean environment between the mid to late 1980s and the late 1990s, and the fact that inter-annual and ENSO scale variations are the dominant feature.

8. Preliminary report on ichthyoplankton collected in manta (surface) net tows on marine mammal surveys in the eastern tropical Pacific: 1987–2000

This paper represents an extensive collation and preliminary analysis of a vast data set of ichthyoplankton collected by manta net (neuston net) tows during the yearly August–November MOPS (1987–1990 and 1992) and STAR (1998–2000) survey cruises. The data are presented as densities on distribution contour maps for 17 species/taxa groups, and by 10 species/taxa groups categorized into two groups of co-occurring species/taxa (an oceanic assemblage - *Oxyporhamphus* group; and a neritic assemblage - *Polydactylus* group) for examination of annual variation in distribution and abundance. These groups were generated by a recurrent group analysis to determine appropriate indicator taxa for identifying environmental shifts.

Overall larval abundance was greater in the latter (STAR survey) years than the MOPS survey years. The authors note that the very high value in 1992 is an artifact (at least for the neritic group) caused by sampling since the survey was restricted to the core area in that year. The authors also note that high volumes of water filtered in the latter years may have somehow biased the results, although not necessarily resulted in high larval densities.

The paper concludes that there were no consistent inter-annual trends in spatial distributions of larval concentrations in any of the 10 key indicator species/taxa groups (as identified by the recurrent groups analysis). Nor were there any indications of shifts in species composition. They note that for the neritic (*Polydactylus*) group, larval abundance appears to have increased over the two sampling periods (MOPS and STAR surveys), but that no such dichotomy is apparent for the oceanic (*Oxyporhamphus*) group.

Specific comments follow:

- The data presented here represent a vast sampling effort for ichthyoplankton over the entire ETP region. The samples have been carefully analysed and the data are clearly presented.
- The text (pg. 3, para 1) and the legends for Figures 5–7 are slightly ambiguous. It is not clear whether “no. of members in the group” refers to the average number of members (i.e. species) attributed to the group or found in the designated group, or to the actual density (number of individual fish per 100 m³) of group members? Also does ‘sample’ refer to the raw data or to value corrected to 100 m³.
- Whilst acknowledging that this paper represents only a preliminary analysis of the vast data set, it would be nice to see a simple ANOVA conducted on the annual mean larval density values (per

species/taxa group) to determine whether there are statistically significant differences between the two decades (MOPS and STAR surveys). At present they are presented only as histograms with no error bars.

- It would also be interesting to see the data post-stratified into core and outer areas, as for many of the other studies to see if any trends can be picked up, particularly for the core area. This may also resolve the problem of the 1992 data set, which represents only core area samples, being compared with the other years that have data from both areas.
- Again the authors cannot be faulted in their conclusions that there is no evidence of any environmental shift in the ETP over the period examined (1986-2000).

9. Information to evaluate regime shifts in the eastern tropical Pacific Ocean

This paper is extremely useful in bringing together the key data sets of all of the studies being used here to assess changes in environmental conditions in the ETP, as well as an additional data set on the estimated abundances of two species of tuna from IATTC. The nine data sets (physical oceanographic parameters, biological oceanographic parameters, larval fish abundance, prey species abundance, seabird abundance, targeted dolphin abundance, non-targeted cetacean abundance, yellowfin tuna biomass and bigeye tuna biomass) have been standardised and presented as anomalies from their long term means, to allow simultaneous comparisons among data sets for evidence of synchronised temporal changes.

It is noted however that only the tuna and the physical oceanographic data (salinity, thermocline depth, SST and wind stress) had sufficiently long time series to allow a fair appraisal of decadal scale patterns, and no shifts or trends are apparent in the oceanographic series. Interestingly, both tuna time series do appear to show shifts or rather 'oscillations' (upwards in 1985 for yellowfin tuna, and downwards in 1992 for bigeye tuna). However, the authors suggest that these can perhaps be attributed to a top-down effect from the fishery, since there is no evidence of corresponding shifts in environmental variables.

Specific comments follow:

- It should be noted that inter-annual variation in the larval fish data set is compounded by differences among year in sampling effort over the whole survey area, such that 1992 which shows up as a high abundance year in most of the 17 species/taxa groups was likely to be a result of the sampling being restricted to the more productive core area in that year.
- Likewise, the very low primary productivity levels recorded for 1990 are believed to be an artifact of the value estimation process.
- I agree with the authors that the outstanding constraint with these data sets is their limited length and interrupted nature such that decadal scale shifts would be hard to detect. It is also apparent for the complete series, that there has been no regime shift in the environment since 1980. It should be noted of course that this does not include the era when dolphin stocks were substantially larger, before massive incidental killings by the tuna-seine fishery.

General Comments and Recommendations

Overview

The Ecosystems Studies presented to the Panel during this CIE Review represent an impressive body of excellent research covering a huge geographical area (20 million km²). The volume of data collected and analysed during the MOPS (1986-1990) and STAR (1998-2000) survey years is unprecedented for the ETP, and has greatly contributed to the scientific knowledge of this vast and complex oceanic ecosystem.

It should also be noted that interpretation of the environmental indicators in the ETP is extremely complex and is exacerbated by the fact that the area is so huge; that it encompasses four distinct surface water masses and a number of strong oceanic features (eg. the Costa Rica Dome, Equatorial Front); and that it has higher inter-annual variation of physical and biological oceanographic parameters than in any other of the world's oceans, because of the natural cycle of the ocean-atmosphere system known as ENSO.

The data have been carefully collected using standardised protocols over the different survey years. The approach to answering the central question, "Has there been a change in the ETP ecosystem?", has been thorough and in many cases innovative. It has been well recognised that the power of these ecosystem studies to detect change, will increase with the number of environmental variables, taxa and trophic levels included, and with the time period spanned. Consequently, the overall project (which had a key thrust to monitor targeted dolphin stocks by line-transect based surveys) analysed substantial additional data on the physical and biological oceanography; on seabird populations; on prey fishes and squids; on ichthyoplankton; and on other cetaceans, which were collected concurrently during the NOAA vessels survey cruises.

Most of the data sets have been extensively analysed and appropriately treated to tease out temporal variation on inter-annual, ENSO and decadal scales. The papers have been well written and were clearly presented, and I am in complete agreement with the overall conclusions of each one (as indicated in the specific comments above). All of the data sets showed inter-annual variations, and strong ENSO signals. None showed any convincing signs of decadal changes that would indicate an environmental or regime shift in the ETP since the 1980s except for the IATTC yellowfin and bigeye tuna data. However, since the two species appear to have undergone 'shifts' in population biomass at different times, and no other data sets corroborate with either of these, it is far more likely that they represent a top-down fisheries effect.

In summary however it must be noted that the major constraint in answering one of the key concerns of the IDCPA (i.e. If the depleted dolphin stocks have not recovered, can this be attributed to an ecosystem effect?) is that the majority of the data sets only cover the period after the dolphin stocks were severely depleted and expected to be recovering (i.e. from the mid 1980s to 2000). As such, there is no information for the period when dolphin stocks were presumably abundant (i.e. prior to the late 1950s when huge incidental kills by the tuna purse-seine fishery began). This is a particularly serious problem (and one which is acknowledged by the project scientists) since the present environment in which the dolphin are expected to be recovering, cannot be compared with that when dolphin stocks were healthy (abundant). A further constraint is that many of the data sets only span 15 years, and are also discontinuous over this span. Determining decadal scale change over such short time series is extremely difficult.

In light of the above comments, a few recommendations are made here which are separate and distinct from the specific recommendations made for each paper.

Recommendations

Given the potentially substantial implications to the tuna purse-seine fishery if a non-recovery of dolphin stocks cannot be attributed to a change in the ecosystem of the ETP, I would recommend that additional effort is invested into building a more robust case for the apparent lack of change in the environment. As such, I would suggest that additional data are sought to lengthen the current time series, and that the current data set is fully utilised to address the central question of whether or not there has been some shift in the environment that may be effecting the recovery of the depleted dolphin stocks in the ETP. Specific suggestions are listed below:

- It is imperative to explore all earlier (pre 1970s) data sources and data bases available for the ETP, to see what comparable data can be extracted and used to examine differences or similarities with the data sets so far analysed here. Of particular interest are: (i) The ichthyoplankton data from the EASTROPAC cruises of the 1960s which are believed to still be available in raw data form and could therefore be digitised for addition to the current data sets, (ii) any other fisheries related data sets which may be available for this area, such as sharks; (iii) the archived dolphin teeth samples which may have important environmental marks; and (iv) seabird flock data which are believed to go back to 1978.
- It is important to continue this environmental monitoring into the future, as the dolphin-tuna problem is unlikely to be resolved or even understood in the short term.
- It would be interesting to further the analyses of the prey species data set (see Pitman *et al.* 2002, Working Paper 6) by also considering growth rates (certainly of juveniles) in the more abundant species (e.g. *Oxyporhamphus* sp.) as an additional indicator of possible changes in environmental conditions. Metabolic rates (and thus growth rates during the early life history) of tropical oceanic species are typically high (Lipskaya 1974, Oxenford and Hunte 1983), and therefore relatively easy to measure with length-based methods. Furthermore, larval and juvenile fish growth rates are known to be strongly affected by environmental conditions (eg. in flyingfish: Oxenford *et al.* 1994).

Whilst it is appreciated that otoliths are not available (since specimens have been stored in formalin), a large subsample has been measured for length. As such, the computerised database of species-specific length frequencies could be used to examine the modal progression of length frequencies by cohorts over the 4-month survey period each year to obtain a mean annual growth rate. These could be compared among years to examine for any changes that might signal a change in the environment.

- I would like to see post-stratification of the data in all of the studies into core and outer areas, and further emphasis on looking for signals in the core area since this represents the key habitat of the target dolphin species.
- Further research into the nature of the tuna-dolphin association would probably be of great benefit in focussing the environmental monitoring onto factors that are likely to directly effect the dolphin populations.

- It may be informative to add prey species abundance and bird associations as variables in the canonical correspondence analysis of the targeted dolphin habitat analysis (see Reilly *et al.* 2002, Working Paper 5).

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APPENDIX I - BIBLIOGRAPHY OF ALL MATERIALS PROVIDED

Papers Provided for Review

1. 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.
2. 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.
3. 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.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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.
9. 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 Papers Provided Prior to and During the Meeting

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

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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* (in review).

Forcada, J. (undated). Multivariate methods for size_dependent detection in conventional line transect sampling. SWFSC, NMFS, La Jolla, California, 23pp.

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

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Smith, R.C., D. Ainley, K. Baker, E. Domack, S. Emslie, B. Fraser, J. Kennett, A. Leventer, E. Mosley-Thompson, S. Stammerjohn and M. Vernet (1999). Marine ecosystem sensitivity to climate change: Historical observations and paleoecological records reveal ecological transitions in the Antarctic Peninsula region. Bioscience 49(5): 393-404.

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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.

APPENDIX II - LIST OF ACRONYMS

ANOVA -	Analysis of variance
CIE -	Center for Independent Experts
EASTROPAC -	Eastern Tropical Pacific research cruises
ENSO -	El Niño / Southern Oscillation
ETP -	Eastern Tropical Pacific ocean
IATTC -	Inter-American Tropical Tuna Commission
IDCPA-	International Dolphin Conservation Program Act (1997)
MOPS -	Monitoring of Porpoise Stocks project (1986-1990)
NMFS -	National Marine Fisheries Service
NOAA -	National Oceanographic and Atmospheric Administration
SST -	Sea surface temperature
STAR -	<i>Stenalla</i> Abundance Research project (1998-2000)
SWFSC -	Southwest Fisheries Science Centre

APPENDIX III - STATEMENT OF WORK

Consulting Agreement Between The University of Miami and Dr. Hazel Oxenford

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 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 proceeding 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 late 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;

Flyingfishes: distribution, relative abundance, and habitat relationships;

Seabirds: distribution, absolute abundance, and habitat relationships;

Cetaceans: distribution, absolute abundance, and habitat relationships.

Potential 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 report should be addressed to the AUM Independent System for Peer Reviews, A and sent to David Die, UM/RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149 (or via email to ddie@rsmas.miami.edu).

Signed _____

Date _____