Review of Ecosystem Research conducted as part of the studies to assess the impact of the eastern tropical Pacific yellowfin tuna purse seine fishery on dolphin stocks by scientists at the Southwest Fisheries Science Center, La Jolla California March 6-8, 2002

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Executive Summary

Nine papers presented by the SFSC were aimed at determining whether there was a large-scale ecosystem change in the ETP between the dolphin surveys in the MOPS years (1986-1990) and the STAR years (1998-2000). They examined physical oceanographic characteristics, primary production indices, fish larvae, prey species of dolphins, dolphins targeted by the tuna fishery as well as non-targeted dolphins and whales, and seabirds. Although, none of the papers dealt specifically with tuna, the time trends of the tuna were also provided (Reilly et al., 2002a).

While certain species or aspects of the ecosystem did support statistically significant trends in the data, these tended to be rare. Also, for certain of the species that did reveal a significant trend, it was unclear whether this was caused by changes in the ETP, as not all of their life history was confined within the ETP (e.g. Tahiti petrel). On the basis of these data there is little evidence of a significant change in the ecosystem in the ETP between the 1980s and 1990s.

However, the few years of data available during the MOPS and STAR surveys are generally not enough to establish statistically significant trends given the high and irregular variability at time scales of 2 to 7 years associated with ENSO events.

The cumulative analysis of Fiedler (2002) indicated that a regime shift began in the ETP around 1976-77 that lead to warmer sea temperatures and a deeper thermocline. No significant shifts have been detected since then.

This is consistent with recent findings by McPhaden and Zhang (2002) who suggested the warmer conditions and reduced upwelling were due to a reduction in the equatorward transport or cooler waters from both north and south of the equator. They also found that the trade winds relaxed over this time and that there were changes in the amplitude and frequency of ENSO events (fewer La Niñas and more and longer El Niños).

These changes imply reduced primary productivity, although this has not been confirmed. The responses to the physical oceanographic changes at higher levels of the food chain are also unclear and have not been established, in large part due to a lack of data sets that extend back to before the regime shift.

It is unclear whether the amplitude of the changes in the physical environment that occurred from the 1960s and 1970s to the present are large enough to produce a significant effect on the dolphin population, their prey and other components of the ecosystem.

Several suggestions were aimed at improving the quantitative assessment of changes in the ecosystem. Some of the more important recommendations are listed below.

- Use of non-parametric methods to quantify trends in the physical and biological datasets.
- A more complete comparison of the MOPS and STAR data with those collected by the SFSC during the late 1970s and late 1960s.
- Initiate data recovery project on the EASTROPAC surveys as soon as possible to prevent additional loss of any data.
- Perform stepwise elimination as part of the CCA in order to highlight those independent variables contributing most of the explained variance of the dependent variables.
- Include more independent variables in the CCA such as the SOI, an Equatorial Front index, nutrients, prey fishes and squids (in the case of dolphins) and dolphins (in the case of seabirds).
- Detailed examination of the relationship between the distribution of the prey, dolphins and seabirds to the Equatorial Front.
- Determine if there were any changes in the amplitude and frequency of the variability in the physical variables, not just their mean values.
- Complete processing the nutrient samples and the bongo tows.

1. Background and Terms of Reference

The Southwest Fisheries Science Center (SFSC) of the National Marine Fisheries Service have been conducting studies aimed at assessing the impact of the eastern tropical Pacific (ETP) yellowfin tuna purse seine fishery on dolphin stocks which associate with these tuna. Assessment of dolphin abundance have been made from surveys conducted in 1986-1990 and in 1998-2000 with the principal objective being to determine if the dolphin populations that had been historically reduced in size by tuna fishing are increasing over time. While no final decision has been made on the status of the dolphin populations, if they are not recovering it will be important to determine whether this could be the result of an ecosystem change.

The SFSC, as part of their research, undertook a suite of ecosystem measurements during the dolphin surveys. Primarily on the basis of these they prepared a series of nine papers covering various components of the ecosystem including physical and biological oceanography, larval fishes, prey fishes, seabirds and cetaceans. They attempted to determine if these showed any evidence of a shift or change in the ecosystem. The review panel was instructed to determine, on the basis of these papers and the associated presentations, if there had been a change in the ecosystem of the ETP.

2. Description of Review Activities and Summary of Findings

The 9 working papers and 6 background documents were provided on the web approximately a week prior to the meeting. In addition to an introductory paper, there were two working papers on the physical and biological oceanography, two on dolphins, one on prey fishes of dolphins, one on seabirds, one on ichthyoplankton, and one on ecosystem trends. These papers were based principally upon data derived from the dolphin surveys conducted in 1986-1990 (the Monitoring of Porpoise Stocks or MOPS program) and 1998-2000 (the *Stenella* Abundance Research or STAR project). The papers' objectives were to assess whether there had been a major change in their individual component of the ecosystem and for the dolphins, seabirds and prey fishes to determine how closely their distributions were associated with indices of the physical environment and primary production. Six additional papers were provided as background prior to the meeting. Several other background papers were provided at the meeting. The working papers were generally well prepared, given that most were completed just prior to being posted on the web for this review. The papers were at different stages, however, and some suffer from not having had enough time to complete processing of samples or to conduct a complete analysis. For example, no nutrient data were presented since the STAR samples have not yet been analyzed (Fiedler and Philbrick, 2002). Also, no species information from the oblique bongo tows taken as part of the ichthyoplankton program was available because identification of the material collected has not been completed (Mosher et al., 2002). The delay of the ichthyoplankton samples is not unexpected given the long time required to process the large number of samples, especially given the numerous species encountered. The presentations during the onsite review provided the essential results from the papers, and in some cases new and additional information and data. The authors of the review papers were extremely helpful in responding to questions by the review panel and providing additional information and papers on the various ecosystem components.

I begin my review by making a number of general comments that apply to the entire suite of papers or at least to more than one of the papers. I then comment on each of the review papers individually. This will be followed by my opinion on whether there has been a significant change in the ecosystem. The last two subsections provide brief comments on possible research consideration in the advent of further field studies and then on what a lack of recovery of the dolphin populations may mean.

General Comments on the Ecosystem Study Papers

- Few if any of the review papers provided information on seasonal variability, although this was clearly available based upon discussions following the presentations and from some of the background papers (e.g., Au and Perryman, 1985; Reilly, 1990; Spear et al., 2001). Such information would have placed the results from the August to November surveys into better perspective. For example, what were the seasonal changes that one expects in the physical properties or chlorophyll-a concentrations? Are there seasonal shifts in the distribution of the fish, dolphin, or seabirds? What dolphins and seabirds are migrating into and out of the surveyed area? How might these affect the interpretation of the results from the ecosystem studies? Finally, why were the surveys conducted during the August to November period? The answer to this latter question was revealed during the discussions accompanying the presentations but should have been provided in at least one of the working papers.

- In terms of documenting possible ecosystem changes that could impact dolphin recovery, a longer-term perspective is required than between the 1980s (MOPS) and the 1990s (STAR). There are two main reasons for this. First, both surveys were conducted after the dolphin stocks had been drastically reduced through tuna fishing practices. Second, they were both in the period following the regime shift in 1976-77. While this shift was most clearly documented for the North Pacific, Fiedler (2002) provided evidence that this year also coincided with physical oceanographic changes within the ETP. He also concluded that there had been no other significant shifts since then. Thus a better comparison to help answer the question of possible impacts of the environment on dolphin abundance would be between the 1990s and the 1960s or early 1970s when the dolphin population was high. It is recognized that the data are not available for most ecosystem indicators, but there are some. Temperature is one example, and indeed Fiedler (2002) provides time series of the sea surface temperatures for the ETP region from observations back to the early 1900s as well as a reconstructed time series from corals and tree rings taken from Mann et al. (2000). These data suggest that the 1980s and 1990s experienced some of the warmest conditions in the 340-year time series and also some of the highest year-to-year variability. The possibility of developing a salinity time series from the NODC database should be examined. NCEP winds for the ETP are available from the 1950s and need to be explored to determine what, if any long-term changes occurred within the ETP. A time series of the upwelling index derived from the horizontal divergences in the winds should be developed. Long-term data are available on tuna, although these are highly influenced by the fishery.

- Still on the matter of longer-term comparisons, little reference was made of the results from the surveys conducted by the Southwest Fisheries Science Center from 1976-1980 as reported by Au and Perryman (1985) nor with the EASTROPAC surveys of 1967 and 1968. Although the major surveys during the late 1970s were conducted during the winter months (January to March), they still provide valuable information for comparison with the summer surveys of the 1980s and 1990s. The EASTROPAC cruises are particularly important for they offer the possibility of comparisons with a time of high dolphin abundance and prior to the regime shift. On the basis of discussions during the presentations, much of the EASTROPAC data is not in electronic form and some of it is in jeopardy of being lost, if not already lost. It is critical to the question of ecosystem change that a recovery program begins immediately to retrieve and archive these data. Their importance cannot be underestimated. Delay could result in the loss of valuable data capable of providing insight into the question of ecosystem change.

- Canonical Correspondence Analysis was the statistical method used to explore associations of the dolphins, seabirds and their prey with a number of physical and primary production indices. This is an appropriate technique. For conformity, the same variables should be used in each of the analysis, unless the authors can justify the reason for including a variable in one analysis and not in another. Also, in the some cases the form of the index is expressed differently. In one paper the log of the surface chlorophyll-a was used, in another the surface and euphotic zone chlorophyll-a values were used. Again for conformity, they should be standardized. More importantly, stepwise elimination of those variables accounting for the least amount of variance should be performed to determine the essential indices and possible redundant variables. In regards to the latter, I expect that temperature, salinity and sigma-t may be redundant. Temperature appears to be the most significant variable based on the correlations between the physical variables and the different axes. In the analysis performed for seabirds, the surface chlorophyll-a and the integrated chlorophyll-a through the euphotic zone were used as independent variables. I again expect that these may be redundant. Finally, once the analysis is completed the physical interpretation of each of the axis should be provided, if apparent. This should not be simply a reiteration of the most important variables but what those combined variables represent, e.g. does it represent ENSO conditions, similar physical conditions but in different geographical locations, dominated by primary production indices, etc.? Reilly and Fiedler (1994) and Fiedler and Reilly (1994) provided such physical interpretations of the dolphin habitat associations so the authors have thought about this.

- The studies on habitat association were largely exploratory, i.e. the statistical analyses were performed using a large number of independent variables and one sees what comes out of the analysis. Another approach would be to examine specific hypothesis, i.e. choose particular variables for the analysis based upon past studies or what the authors thought was important. The latter is an example of confirmatory statistics. For the purposes of the review, the exploratory statistical approach was not unreasonable; however, it should be acknowledged that they are exploratory. In any event, interpretation of the results should be discussed in light of specific hypotheses. Did the exploratory results fit prior understanding of how the ecosystem works? A number of hypotheses were advanced in several of the background documents provided both prior to and during the on site meeting, and discussed during the presentations. I suggest that such hypotheses should be clearly laid out in the papers.

- Fronts in the ocean tend to be areas of high productivity due to the associated circulation and mixing processes. In the ETP, the Equatorial Front is located just north of the equator separating the Equatorial Surface Waters from the Tropical Surface Waters. Previously published studies showed the importance of this front to dolphins (Au and Perryman, 1985) and to seabirds (Ballance et al., 1997; Spear et al., 2001). Indeed, in 1977 during targeted field studies, 23 out of 27 dolphin schools were located along the front (Au and Perryman, 1985). The sampling during the 1980s and 1990s were aggregated at larger spatial scales and so the front was not adequately resolved. However, the continuous sampling of temperature and salinity during the survey would allow determination of when the ships crossed the front. The position of the dolphin schools and seabird flocks relative to the front therefore should be easily determined. The relationship of the prey fishes and the ichthyoplankton, broken down by species, to the front would also be highly informative. The front is expected to be important for some species but not all. For the surveys conducted in 1998-2000, the SEAWIFFS imagery would allow resolution of the spatial structure of the front as well as its temporal variability. Resolution of these frontal structures may be most important and at least it should be examined to determine how important it is, especially for dolphins. Given the possible importance of the Equatorial Front, some index of its position and strength should be developed. These could then be incorporated into the CCA. An index based upon the NCEP SST data could allow development of a time series of the Front back to the 1950s and thus determination of whether there has been any long term trends in this feature.

- The Costa Rica Dome is another physical feature that appears to be very important for dolphins and seabirds. A short paragraph describing what makes the Dome unique would help the unfamiliar reader. Can an index be developed that captures some of the essential variability within this feature? This may be related to temperature, density, winds or chlorophyll-a within the Dome. Such an index or indices could be used in the CCA. As with the suggestion about fronts, this is attempting to get at the some of spatial structure within the ETP. As quoted by Fiedler (2002) from McGown et al. (1998) “the role of climatic variation in regulating marine populations and communities is not well understood...probably because of the mismatch between the scales of important atmospheric and oceanographic processes and the spatial and temporal dimensions of biological research programs.” To what degree does this apply in the case of the ETP ecosystem studies?

- In regards to habitat associations, the aim of this work is to understand what physical or primary production properties are important to the distribution of dolphins, seabirds and prey fishes. Insights into these associations have been gleamed from the CCA. However, further understanding could be obtained through stratifying the data differently. One way is to stratify by geography. Given that the 1990s surveys were largely confined to the core area, one could restrict the analysis to this region for the entire time series, as has been done for some variables. Another way is to stratify the data based on water masses. Although the physical environment was able to capture less than 20% of the variance based on the CCA analysis, perhaps stratifying by water masses and examining the variability within the water masses as opposed to the entire region may help to account for more of the variance. I also found it confusing and troubling that several of the papers used different geographic stratification when analyzing or presenting the data. Some used the entire survey area, others focused on the core area while the ichthyoplankton was presented within

11 separate regions 15º latitude by 15º longitude. For comparative purposes, the analyses should use the same geographic stratification unless if can be justified why not.

- Most of the analyses were performed on mean abundances. Of equal importance, or perhaps even more importantly, is the variability. The biology has evolved or adapted to account for this variability, but if the amplitude or frequency of variability is changing significantly then one might expect a different biological response. It is important, therefore, to examine changes in variability. Has the variability changed? McPhaden and Zhang (2002) have reported that there have been fewer La Niñas and more and longer El Niños in recent years. What affect does this have on the ecosystem in the ETP? Are these changes reflected in the variability of the physical characteristics of the regions such as sea surface temperature, thermocline depth, etc.?

- For the biological data, the focus of the papers was addressing possible changes in abundance. However, changes in growth, size-frequency, species composition (where appropriate) and recruitment are all as important at abundance. These should be explored where the data allow.

- Generalized additive models were used to improve the estimates of seabird abundance. These appeared to increase the precision and accuracy over previously used methods. Since they worked for seabirds, why not use them for prey fish and squids as well as dolphins and whales?

Specific Comments on the Ecosystem Study Papers

<u>Review Paper #1</u>
<u>Eastern Tropical Pacific Ecosystem Studies: Introduction (Balance et al.)</u>

This paper provided a very brief but good introduction including the purpose of the studies, the tuna-dolphin associations, the field surveys and some of the physical oceanographic background. I have no major concerns with this paper but do have a couple of comments.

The statement "If dolphin populations have recovered, ecosystem studies provide useful, but mainly <u>academic</u> information about dolphins and their environment". A somewhat similar statement appears in Review Paper #9. I disagree. I do not think that the ecosystem studies are simply academic exercises, even if the dolphin populations are recovering. Until we gain better knowledge of the ecosystem and its variability, we will not be able to adequately understand and predict the variability of its components, including dolphins. Indeed, the push towards ecosystem management worldwide acknowledges this fact. Another reason for understanding the environment is that any recovery of the dolphins likely requires the necessary environmental conditions. Such statements as these can be used by some managers or bureaucrats to justify not funding ecosystem studies if they feel that they are simply "academic exercises". I would delete this statement from the paper.

"A lack of recovery for these dolphins that is not congruent with some other change in the ecosystem would provide support for the hypothesis of fishery effects as the most likely cause." While this statement is true, it must be remembered that one cannot prove that there was not an environmental change, for the appropriate environmental variable may not have been examined. The analysis can only prove if there was a significant change.

Review Paper #2
Environmental Change in the Eastern Tropical Pacific Ocean: I. Observations in 1986-1990 and 1998-2000 (Fiedler and Philbrick)

This paper presents yearly fields of the physical and biological oceanographic data collected during the dolphin surveys and augments these with longer-term information from NCEP data and measurements of zooplankton collected during EASTROPAC. It concludes that the effects of El Niño and La Niña are evident in the data and that there is no significant difference between the data collected during MOPS and STAR years. No nutrient data are provided because of a delay in processing the samples.

I would suggest that this paper be combined with Review Paper #3 (see below) into a better and more comprehensive paper. It should present longer data sets, where available, to determine the long-term trends. Datasets should include a minimum of sea temperature (and perhaps salinity data), as well as thermocline depth, thermocline strength, and winds. This information would allow the MOPS and STAR years to be put into a longer-term perspective and bears significantly upon the question of whether there has been an environmental change in the ETP.

The Introduction should be lengthened to inform the reader what earlier studies had concluded about the physical and biological variability of this ocean region.

In the Methods Section on page 4, the statement is made that "phytoplankton pigment concentration is an adequate index of primary productivity". This needs to be justified (reference?) as certainly it is not the case in temperate waters. Zooplankton can crop down the phytoplankton biomass to low levels although the primary production can remain high. Also this statement does not appear to be justified based on Figure 6. Please spell out what the acronym EASTROPAC stands for.

Under the Results Section, the thermocline depth fields are introduced without stating how they were defined. This, I take from reading some of the other review papers and background papers, is the depth of the 20ºC isotherm. No mention is made of remote sensing in the paper, however, there are satellites for which temperature and chlorophyll-a biomass estimates are available. This is discussed further below under Review Paper #3. Why include the plots of primary production between EASTOPAC and STAR if the conclusion is that observed differences are likely an artifact? This could be discussed without the plot. While there are observable differences between ENSO years as pointed out by the authors, a clearer picture should emerge from paper of what the overall oceanic response in the ETP during El Niño and La Niña years is.

Several other questions need to be addressed. How does yearly averaging affect the results? What is the spatial structure of the changes? What is the correlation between sea surface temperature and the thermocline depth? Are the increased chlorophyll-a levels just north of the equator related to the Equatorial Front?

The paper is largely qualitative. More quantitative analyses should be carried out including correlation analysis. Further suggestions are provided below in the discussion under Review Paper #3.

Review Paper #3

Environmental Change in the Eastern Tropical Pacific Ocean: II. Review of ENSO and Decadal Variability (Fiedler)

This paper carries on the discussion of the physical oceanography and primary production as well as providing a review of biological responses to ocean changes for higher levels of the food chain. It examines the relative importance of ENSO events and decadal variability on the observed changes in the physical oceanography and the biology of the ETP. The majority of the paper is a review of previously published works. It concludes that the ENSO scale events with a period of 2-7 years are the dominant mode of variability with much less variability at decadal time scales (10-30 years). Evidence of regime shifts in the ETP was also explored. A shift in the ETP sea surface temperatures from predominantly below normal temperatures to above normal temperatures occurred around 1976-77 as revealed by a cumulative sum analysis. This corresponds to the time of a major regime shift in the North Pacific (Hare and Mantua, 2000). No other regime shifts were detected after 1977 in the ETP, including between the MOPS and STAR years. An important observation for the purpose of this review is that the variability and trends in temperature and thermocline depth vary spatially within the ETP, e.g. between the Core Area or Warm Pool and the NINO3 region.

In the Introduction, the statement is made that the interannual variability in the eastern equatorial Pacific is greater than in any other region of the world's ocean. What is the amplitude of this variability? What is the reference? Is it Delcroix (1993)? I thought that the ETP was an area of low variability. If so, then how can this be reconciled with the large interannual variability or are my impressions incorrect? Perhaps it depends spatially where within the ETP one is talking about? What does the acronym NINO3 stand for? At the bottom of page 2, the statement is made that "Changes that have occurred over the last few decades are generally similar to changes that have occurred for centuries." In the abstract, however, it states that "an unusually persistent warming prevailed in the early 1990's..". Are these statements consistent?

Within the section on ENSO variability, 1986-87 is listed as a year in which there were both an El Niño and a La Niña.

SEAWIFS has been collecting chlorophyll-a data since 1998 and could be used to examine its spatial variability. The authors were aware of the satellite data and presented some of them during the on-site talk, based I believe upon Greg et al. (2002). A discussion of the satellite data should be incorporated into the paper. (I believe that the author was planning on doing this but he obtained the Greg et al. reference too late to do so for the review paper). The question of how the measured chlorophyll-a values from the dolphin surveys compare to the satellite observations should be addressed.

Under the section entitled ETP Decadal Variability and Trends, on page 16 when describing the monthly mean fields derived from models delete the words "Short but accurate". Although Figure 5 clearly shows the annual cycle in temperature and thermocline depth, presentation of the statistical analysis of the seasonal cycle would provide a quantitative estimate of the mean amplitude and phase. Since anomalies of both temperature and thermocline depth are provided in Figs. 6 and 7, the seasonal cycle has already been calculated although the method used was not described. It may simply have been the average of the monthly means over all available years although another more elegant method is to perform harmonic analysis (see Smith, 1983). The variances for the seasonal cycle and the low-frequency time series with this cycle removed can then be compared. A trend analysis was performed for the surface temperature and the thermocline depth using the observed data including the seasonal cycle (see Fig. 5). The trend analysis should be performed on the anomaly time series to prevent any possible influence from the seasonal cycle, although, I do not expect any significantly different result. The gridded temperature and thermocline depth offer the opportunity to determine the spatial differences in the relative importance of seasonal, ENSO and longer-term changes in accounting for their observed variability.

Figures 2 and 7 indicate that the 1990s relative to the rest of the 1900s were warm. So were the 1980s, although there was colder-than-normal conditions for short periods in both the mid-and late years of this decade. This needs to be discussed more. Is it part of a broad-scale change in the Pacific or is it limited to the ETP? Discussion in relation to the findings of McPhaden and Zhang (2002) is needed.

As mentioned above, Review Papers #2 and #3 should be combined. I recommend that this combined paper should (1) review what is known about the physical and biological oceanographic variability in the ETP area, including both temporally (i.e. ENSO and decadal scale events) and spatially. In regards the latter, during the presentation of this paper, results of an EOF analysis were presented from the published literature. These results or those from a more up-to-date EOF analysis should be discussed. (2) The time series of temperature, thermocline depth and winds should be broken into its seasonal, ENSO and longer-term variability components.

The amount of variance (both absolute and in percent of the total) should then be determined. I have already discussed methods for estimating the seasonal variability above under Review Paper #2. The ENSO-induced variability should be determined through correlation or regression analysis of the physical and productivity indices with SOI or other appropriate index. This would allow determination of ENSO-induced time series. A less desirable method to separate out the ENSO variability would be to band-pass filter the seasonally detrended data, using periods of 2-7 years. This is less desirable because it would capture some non-ENSO related variability in this frequency band. Once the ENSO related time series was determined, it should be subtracted from the seasonally detrended data to obtain the low-frequency or "decadal" time series. Time series of the important EOF modes should also be presented and discussed. (3) This would be followed by a discussion of the data collected during MOPS and STAR. The results on the longer term (ENSO and decadal) variability would indicate how the MOPS and STAR years fit into the overall patterns.

Review Paper #4
Estimates of Abundance of Striped and Common Dolphins, and Pilot, Sperm and Bryde's Whales in the Eastern Tropical Pacific Ocean (Gerrodette and Forcada)

This paper presents the methodology and the abundance estimates for several species of dolphins and whales from line transect data collected in the ETP. The methodology developed to estimate abundance from the line transect data is impressive and state-of-the-art. Data were collected during 1986-90 and 1998-2000. As the authors acknowledge, no substantial analysis of the trends in the abundance estimates from 1986 to 2000 is provided. However, simply linear analysis suggest that the northern common dolphins and the pilot whales had higher abundances during the later period while all other species and stocks show no significant trend.

Under the Results section, the percentage of the area sampled should be indicated. I estimate approximately 2%. Is this correct? Discussion on the effects on the estimates of using different strata during the 1980s and 1990s surveys is needed. Estimated uncertainties, even if somewhat subjective, need to be included in any plots and tables. The basis of such estimates needs to be detailed. Most of the species for which abundance estimates were made spend part of their time outside of the surveyed area. This means that any changes in abundance could be interpreted in several ways. They may be due to physical or biological oceanographic effects within the sampled area that result in the animals not moving into the area or they may be due to effects outside the region which lead to more or less animals moving into the sampled region. There is also the possibility that the number of animals moving into the region are approximately equal each year but show interannual differences in surveyed abundance simply due to the changes in the timing of migration with respect to the time of the surveys. Problems of interpretation arise wherever and whenever the abundances are high along the boundaries of the surveyed area. These need to be discussed and incorporated into the uncertain values of the abundance estimates.

While at first glance, it would appear that more reliance on areal reconnaissance might help improve dolphin abundance estimates in particular, the panel was informed that the distances to be covered are too large and there are difficulties with coastal airports. This makes it too dangerous for sampling using aircraft.

Review Paper #5
Eastern Tropical Pacific Dolphin Habitats – Interannual Variability 1986-2000 (Reilly et al.)

Using CCA analysis, this paper examines the relationship between annual values of several oceanographic indices and dolphin abundances during the periods 1986-1990 and 1998-2000. The paper shows similar distribution of dolphins in the two periods. Oceanographic habitats were also generally similar during the two periods, as well as in the 1970s as described by Au and Perryman (1985). There was an indication, however, that during the 1990s the dolphins were in slightly cooler, more productive waters. It is not clear whether this was due to differences in ENSO variability between the two periods or differences in sampling.

The following three comments were discussed under general comments but bare repeating here. First, presentation of hypotheses before the results would have been helpful. The present draft simply indicates who examined habitat associations previously and states that they developed hypotheses. The introduction should present the actual findings of these earlier studies and state what the hypotheses were. Second, determination of which oceanographic variables were most important and which might be redundant should be carried out through stepwise elimination in the CCA. Since annual values are being used, include the SOI as a seventh index. Third, physical interpretation of what each of the axes represent needs to be emphasized more. Figures 5 and 6 help in this regard.

The use of annual values when the sampling within the surveys was different, is a concern in interpreting the results, a fact acknowledged by the authors. As they suggest, this should be examined further.

Several of the references referred to in the text were not included in the reference list (e.g. Gauch, 1982; Whittaker et al., 1973; Ter Braak, 1988; etc.) and some were incorrect (e.g. Au and Perryman, 1984, on p.12). On page 8 under Results, the first sentence, the “Beaufort 4 or better”; the “better” should be changed to “lower”.

Review Paper #6
Investigations into Temporal Patterns in Distribution, Abundance and Habitat Relationships within Seabird Communities of the Eastern Tropical Pacific (Ballance et al.)

Using data from line transects obtained during the dolphin surveys, information on seabirds are presented. Although there were over 200 species of birds identified, the analysis concentrates upon the 9 indicator species or taxa, of which 4 are associated with tuna, labeled tuna-dependent in the working paper. Their distribution, abundance and habitat associations are explored. General additive models (GAMs) were used to improve the abundance estimates. There were no significant linear or quadratic trends for any of the tuna-dependent species and only the Tahiti petrel of the non-tuna dependent species showed a trend, that of a linear decrease. The paper concludes on the basis of the lack of trends in the other species that this decline was mostly likely due to other factors, such as a decline in the breeding colonies.

Under Abundance, one of the four variables in the GAMs analysis was ocean depth. It was unclear why this was included. This needs to be explained. The use of GAMs was shown to be an improvement in producing distribution plots. This begs the question, why not use GAMs for all of the seabird distribution plots? The comparison between the yearly average of the at sea estimates of sea-bird abundance with the on land breeding estimates, for the single species where both were available (Juan Fernandez petrel), was impressive. This gives rise to the question of how uncertain are the individual year estimates? Are they as good as the comparison of the average over all years to the on-land estimates? If so, there is very large year-to-year variability in the seabird population of several species. Are the abundance estimates therefore real or are they biased by the temporal and/or spatial sampling? How does the timing of the surveys vary between years and how does this match with migration patterns?

As part of the Habitat Associations Section, a description of what each axis physically represents is needed. For the CCA, why not include dolphin and prey abundances as independent variables? This would provide a quantitative estimate of how important they are relative to physical and biological oceanographic indices.

Review Paper #7
Temporal Patterns in Distribution and Habitat Associations of Prey Fishes and Squids (Pitman et al.)

This paper presents information on flying fish, laternfish and squid, some of the major prey items of dolphins and seabirds. Data were collected during the dolphin surveys using dip nets during 1986-1990 and 1998-2000. The most interesting result was the general increase in abundance levels in most species from 1986 to 1990 and then beginning at low levels again in 1998 and increasing up to 2000. No significant differences between the early and later periods were detected, however. Habitat associations of the prey fish and squid were explored using the CCA.

In the Methods section, it was mentioned that lamps were used during the night sampling and that this would possibly attract organisms. I also believe that during the presentation it was mentioned that lamps were not used on all samples. Some discussion is needed of the effects of using lamps and on comparing stations where lamps were used with those where they were not, if this was indeed the case. It was also stated that sighting information was used to determine estimates of some species but I was unclear where these data were used.

In the Habitat Association section, axis one in Fig. 11 defines a habitat with cool, high saline waters with a deep, weak thermocline and lower chlorophyll-a levels. A physical explanation of what this combination of variables represents is needed. It does not fit with either the “cool upwelling” or “coastal tropical” habitats, i.e. the major patterns identified by Reilly and Fiedler (1994) identified for dolphins.

The panel was informed during the presentations that the size information of the prey fishes is available. It is therefore recommended that the trends by size be examined to determine if all size categories show an increase through the 1980s and again in the 1990s, or whether they are driven by one or two particular size groups. This could have important implications as to whether such observed trends may or may not be important to dolphins and seabirds.

The CCA was performed on abundance estimates of the prey. Equally important, especially for the prey is its patchiness. Are they spread more or less uniformly or are they patchy? Are there more patches in one year than another? Do the size of the patches show interannual variability? I believe that the data that were collected will allow examination of these questions.

Review Paper #8
Preliminary Report on Ichthyoplankton Collected in Manta (Surface) Net Tows on Marine Mammal Surveys in the Eastern Tropical Pacific: 1987-2000 (Moser et al.)

This report presents preliminary results of net tows for ichthyoplankton carried out in conjunction with the dolphin surveys. The number of occurrences and raw counts were pooled for 1987-1992 and 1998-2000. Average concentrations of the 10 highest-ranking larval fish taxa over these years are also provided within 11 separate areas (15º of latitude by 15º of longitude) covering the ETP. Although bongo tows were taken during the surveys, these samples have not been processed. A recurrent group analysis revealed two main groups. The first was principally associated with coastal communities whereas the second was made up of offshore or oceanic taxa. Initial results revealed no obvious differences in community composition and distribution between the earlier and later periods. While the abundance of coastal taxa was higher in the later period, this is believed to be due to the fact that there was greater effort in the nearshore coastal regions during those surveys as compared to the earlier ones.

The Manta net samples approximately the top 15 cm. In the absence of information on the vertical distribution of larvae, caution must be exercised in interpreting the net data as regards to year-to-year variability in abundance. That is, differences in surface abundances between years may not reflect real changes in numbers or concentrations but simply be due to differences in the vertical distribution of the larvae from year-to-year. The changes in vertical distribution may be caused by year-to-year changes in the strength of the vertical mixing.

At the end of the subsection on Occurrences and Abundances in the Results section, the statement was made that "The average volume of water filtered on each survey cruise may be a factor affecting egg and larval abundance, since average volumes of water filtered by Manta net tows were higher during 1992-2000 compared to earlier surveys". This needs to be explained, as the reason is not obvious.

The analyses of these data are in a very preliminary stage.

<u>Review Paper #9</u>
<u>Information to Evaluate Regime Shifts in the Eastern Tropical Pacific Ocean (Reilly et al.)</u>

This paper presents the time series of the physical and biological oceanographic indices along with the abundance estimates of dolphins, tuna, prey fish and squid, fish larvae and seabirds. They conclude that there were no shifts or trends in the oceanographic indices over the time scale of the surveys but the tuna did show a shift and low-frequency trends.

Non-parametric statistics, such as rank correlations, should be used to examine the possibility of trends. This would include the statistical probability of obtaining the observed number showing a positive (or negative or lack of a) trend out of the total number of indices available.

Has there been evidence of an Ecosystem Change?

The important management question, as presented to our review panel at the beginning of the on site presentations was "Has there been a change in the ecosystem (physical and/or biological) that might affect the recovery of dolphin populations from depleted levels." They noted, however, that our review panel had a narrower focus. It was to address the question "Has there been a change in the ecosystem?" Another panel will answer the management question. We are to consider temporal patterns (are there trends and how are they described) from data presented on seven ecosystem components, i.e. physical and biological oceanography, cetacean abundance of non-target species, cetacean habitat associations of the target species, seabirds, prey fishes and squids, and ichthyoplankton.

The time scale over which the change is determined is most critical. The review papers covering the different ecosystem components varied depending upon the available data, but were primarily between the 1980s and 1990s, the MOPS years versus the STAR years. This was in large part in response to the questions being asked of them and clearly laid out in the Report to Congress (SFSC, 1999). They took the form of four questions. These were:

Question 4a: "Is the present magnitude or extent of preferred dolphin habitat, in the area of the affected stocks, within the range of variation observed during 1986-1990?"

Question 4b: "Are the present indices of ecosystem productivity, in the area of the affected stocks, within the range of variation observed during 1986-1990?"

Question 4c: "Do the time series of annual indices of El Niño/La Niña conditions and abundance of preferred habitat in the ETP for the period since 1970 indicate a regime shift in the ETP during that period?"

Question 4d: "Do the analyses of abundance of sea birds, dolphin prey, and dolphin competitors in the ETP indicate a reduced availability of prey for dolphins in the period since 1991?"

I will first provide my assessment of these questions and then address the broader scale question of the appropriateness of the time scale of the comparisons.

Fiedler (2002) and Fiedler and Philbeck (2002) addressed the first two questions and the answers were yes to both, conclusions for which I concur. The range of variability was, in general, similar during the MOPS and STAR years. This was true for the dolphin habitat (temperatures, salinities, density, thermocline depth or thermocline strength) and the productivity indices (chlorophyll-a concentrations and primary production). Again most of these showed discernible trend in the data but in terms of the productivity indices the data time series are too short with the year-to-year variability observed to determine with any statistical reliability whether there was or was not a trend. Using data from 1980 to 2000, Fiedler (2002) did document a statistically significant deepening of the thermocline in the Warm Pool of the ETP of just over a quarter of a meter per year for a total increase of almost 6 m over the years examined. However, if one restricts the analysis to just the MOPS and STAR years, there is no indication of a statistically significant deepening (this is based on a non significant ($p>0.1$) rank correlation (0.37) between years and thermocline depth using the years 1986-1990 and 1998-2000). This points out the difficulty of establishing significant trends when restricted to so few years of data.

In answer to question 4c, Fielder (2002) documented a regime shift around 1976-77. I also agree with his conclusion, which was based upon cumulative analysis of the sea surface temperatures for both the Warm Pool and in the NINO3 region. They showed a change in the trend of the cumulated sum of the indices in 1976-77. The trend change also was evident in the cumulative sums of the Southern Oscillation Index (SOI) and the Trans-Niño Index (TNI). Although not as large a shift as in the North Pacific, never the less the shift was evident in the thermal indices within the ETP. This conclusion is different than that reached in the Report to Congress (SFSC, 1999), but the cumulative analysis had not been carried out at that time. The biological data do not show any discernible shifts but observations prior to the mid-1970s are sparse and the data series, in general, are too short to substantiate a regime shift or not. The only biological time series that is long enough to cover the longer period of time is for tuna and although they show distinct trends, their variability is complicated by the effects of fishing. Yellowfin tuna show both the total and spawning biomass to have changed in the mid-1980s from a period of low biomass (1975-1984) to one of high biomass (1985-2000) with the 2000 estimates the highest or second highest on record. In contrast, bigeye tuna biomass was principally above average from 1975 to 1990, afterwhich it plunged and remained low until the late 1990s. In 2000, it appears as if it has recovered and is now at levels above the long-term mean.

To answer question 4d, I performed rank correlation analysis using the physical oceanographic data, the prey fishes and squids, the seabirds and the non-targeted dolphins. Ranks from 1 to 8 for years and for each of the indices were determined using the plots from Reilly et al. (2002a). Each time series was ranked in order from the highest value (rank of 1) to its lowest or largest negative value (rank of 8). Correlations between the rankings for each time series with the year time series were then determined. In terms of the prey fishes, there was no apparent reduction as none of the species presented showed a significant trend in the data. The dominant pattern as pointed out by Pitman et al. (2002) is one of generally increasing prey from the mid-1980s to 1990, a decline by 1998 when the STAR surveys began and an increase in prey during the time of these latter surveys. As for seabirds, only one of the nine species of birds showed a statistical trend. That was the Tahiti petrel whose abundance index showed a significant decline, as was pointed out by Balance et al. (2002). Since this bird breeds in Tahiti it is not clear whether its decline is due to events in the ETP or elsewhere. For the non-targeted mammals, the 3 stocks of common dolphins, as well as the Bryde’s and pilot whales all showed a tendency to increase from the 1980s to the 1990s. However, the trends were significant at the $p \leq 0.05$ level only for the northern common dolphins and the pilot whales. The striped dolphin and the sperm whales showed a decline in abundance indices, although only the latter was statistically significant. On the basis of these results and the evidence presented in the working papers on prey species (Pitman et al., 2002), seabirds (Ballance et al., 2002) and non-targeted mammals (Gerrodette and Forcada, 2002), there is no indication that there was a reduced availability of prey for dolphins in the period after 1991.

However, having stated that there appears to be little evidence for a major change in the ecosystem of the ETP between the 1980s and 1990s, based primarily upon the years of the MOPS and STAR surveys, it is not clear that this provides the comparison needed. There are several reasons for this. First, there is no supporting evidence to suggest that the 1980s were years of good environmental conditions for dolphin survival, growth or reproduction. Indeed this is a period of low dolphin numbers, albeit reduced to these low levels by fishing-related mortality. A better comparison with conditions in the 1990s would be when the dolphin populations were high, i.e. in the early to mid-1970s and preferably in the 1960s. Second, a change from cold to warm conditions in the ETP occurred around 1976-1977 (Fiedler, 2002). This also suggests that comparisons of the 1990s should be made with pre-1976 conditions, again the 1960s or the first half of the 1970s, to determine if changes to other physical or biological oceanographic indices, prey fishes, other mammals or seabirds occurred. Third, the few years used for comparison are very short to establish a trend with any statistical reliability. Indeed, restricting the analysis to the MOPS and STAR years there was no indication of a trend in thermocline depth, however, using the longer time series revealed a gradual deepening over the 1980s and 1990s. Although no trend was detected in sea surface temperatures for the ETP over the same time period, the longer time series of sea surface temperatures presented by Fiedler (2002) does suggest a rise in temperature during the 1980s and 1990s relative to the 1960s and 1970s. Warming in the ETP and a deepening of the thermocline is consistent with recent findings by McPhaden and Zhang (2002). Such long-term trends should lead to a decrease in primary production and subsequent phytoplankton biomass (chlorophyll-a levels). The warmer temperatures and deeper thermocline also suggest possible poorer habitat for common dolphins based on the results of Reilly and Fiedler (1994) and Reilly et al. (2002). McPhaden and Zhang attributed the warming temperatures and increasing depth of the thermocline depth to a slowing down of the equatorward meridional transport. They also noted two other important changes. The first was a broad-scale weakening of the trade winds from the 1970s to the 1990s. The second was fewer La Niña events and more frequent, stronger and longer-lasting El Niño events.

Possible Future Field Studies

While the conducted studies have provided insights and understanding of the dolphin-tuna-seabird interactions, and some hints into possible ecosystem changes, the large uncertainties in the results and the short time series available suggest that this problem will continue for some time. Thus, it would be highly advantageous to conduct further field studies, directed towards surveying dolphin abundance and ecosystem variability. If such studies do materialize, I suggest the following for consideration.

First, the previous ecosystem studies have piggybacked upon the dolphin abundance surveys. While this is understandable from a logistic point of view, it means that the sampling was not optimal for ecosystem studies. Carefully consideration should be given to the required sampling for each ecosystem component. Also, the spatial scale of the sampling may be too course to resolve the important features such as fronts and small scale eddies. Detailed sampling at the Equatorial Front and the Costa Rica dome need to be carried out. More complete information on the preferred prey of dolphins and the depths that they feed at are required. This would provide clues on the sampling required to determine possible future changes in prey species abundance or availability.

Dolphin Recovery

The focus of our review has been on the ecosystem and whether there has been a significant change that could possibly affect dolphin stock recovery. We have not been asked to assess whether there has been a recovery of the dolphin populations. If there has not been a recovery, it has been suggested in the papers and the presentations, this provides supportive evidence that the fishery is still impacting on the dolphins. Direct mortality from present fishing practices is suggested as low but still estimated in thousands of dolphins per year (Ballance et al., 2002a). In addition, we were informed that on average each dolphin is capture in the purse seine several times per year. While they are now released, this may represent a trauma that could affect their reproduction. Having said this, it must also be remembered that the recovery of populations from low abundance levels, at least of fishes, usually requires a lot longer time than expected, after the removal of direct fishing. This has certainly been the case for Atlantic cod off eastern Canada. The Canadian government imposed a moratorium on directed fishing for northern cod off Newfoundland and Labrador in 1992. Initial estimates for recovery by scientists were 5-6 years (based on the age of maturity) or perhaps by 2000 in order to allow the first generation in the post recovery age to spawn. However, by 2002 there is still no sign of recovery, in spite of the environmental conditions being favourable for cod during the past several years. The cod are not alone. Hutchings (2000) examined numerous fish stocks around the world and all, or almost all, took much longer to recover than was expected. Cause of these long recovery times is uncertain. They do suggest, however, that a lack of recovery by the dolphin stocks, if that is what is found, may not be due to either an ecosystem change or continued impact of fishing. It may be a natural response by a decimated population. However, having said that, the precautionary approach to fisheries in practice in most nations today would require that if there is evidence of a lack of recovery of dolphin populations, then fishing must be considered as a strong candidate until proven otherwise.

3. Conclusions/Recommendations

The papers presented by the SFSC focused upon whether there was a large-scale ecosystem change in the ETP between the MOPS years (1986-1990) and the STAR years (1998-2000). They examined physical oceanographic characteristics, primary production indices, fish larvae, prey species of dolphins, dolphins targeted by the tuna fishery as well as non-targeted dolphins and whales, and seabirds. Although, none of the papers dealt specifically with tuna, the time trends of the tuna were also provided

(Reilly et al., 2002b). While certain species or aspects of the ecosystem did support statistically significant trends in the data, these tended to be rare. Also for certain of the species that did reveal a significant trend, it was unclear whether this was caused by changes in the ETP, as not all of their life history was confined within the ETP (e.g. Tahiti petrel). On the basis of these data there is little evidence of a significant change in the ecosystem in the ETP between the 1980s and 1990s. However, there are important qualifiers. First is that the few years of data during the MOPS and STAR surveys are not enough to establish statistically significant trends given the high and irregular variability at time scales of 2 to 7 years from ENSO events. Second, the cumulative analysis of Fiedler (2002) indicated that the regime that began around 1976-77 in the North Pacific was also evident in sea surface temperatures and thermocline depths in the ETP. No significant shifts have been detected in the ETP since then. This implies a change between the 1970s and the 1980s-1990s. This is also consistent with recent findings by McPhaden and Zhang (2002) of a warming and deepening of the thermocline in the ETP between the 1970s and the 1990s in response to a reduction in the equatorward transport, both north and south of the equator. They also found that the trade winds relaxed over this time and that there were changes in the amplitude and frequency of ENSO events (fewer La Niñas and more and longer El Niños). These longer-term time series indicate significant changes in the physical environment. Longer-term series are required for dolphin comparisons. There is nothing to support the 1980s being particularly good, bad or indifferent for dolphins. Their numbers were low then, albeit due to fishing mortality. A better comparison is between the 1990s and a time when the dolphin abundances were high and their growth and recruitment were strong. This would imply comparisons between the 1960s and 1970s. Returning to the apparent warming in the ETP and the deepening of the thermocline, these imply reduced primary productivity, although this has not been confirmed. The high level biological response to such a long-term changes is unclear and has not been established. Unfortunately, it appears (to my knowledge at least) that the long time series needed to establish changes over the time scale of the 1960s and early 1970s to present are in most cases not available. It is also unclear whether the amplitude of the changes that have occurred from the 1960s and 1970s to the present are large enough to produce a significant effect on the dolphin population, their prey and other components of the ecosystem.

Several suggestions were provided for additional analyses or considerations aimed at improving the quantitative assessment of changes in the ecosystem. Some of the more important recommendations are reiterated below.

- Use non-parametric methods such as rank correlations to obtain a quantitative measure of the trends in the available data sets.
- Perform trend analyses on time series extending back to the 1960s and early 1970s for temperature, thermocline depth, winds and any other available variable.
- Compare the MOPS and STAR data with those collected during the late 1970s (Au and Perryman, 1985) and late 1960s (EASTROPAC data).
- Initiate data recovery project on the EASTROPAC surveys as soon as possible to prevent additional loss of any of these invaluable data.

- Perform stepwise elimination as part of the CCA in order to highlight those variables contributing most of the explained variance of the dependent variable.
- Include the SOI as part of the independent variables in the CCA and use prey in the analysis of dolphins and dolphins in the analysis of seabirds.
- Develop indices of the variability in the Equatorial Front.
- Examine the relationship between the distribution of the prey, dolphins and seabirds to the Equatorial Front.
- Examine changes in the amplitude and frequency of the variability, not just mean values.
- Proceed quickly with the processing of the nutrient samples and the bongo tows for ichthyoplankton.

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Appendix II: Statement of Work

Consulting agreement Between the University of Miami and Dr. Ken Drinkwater

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)