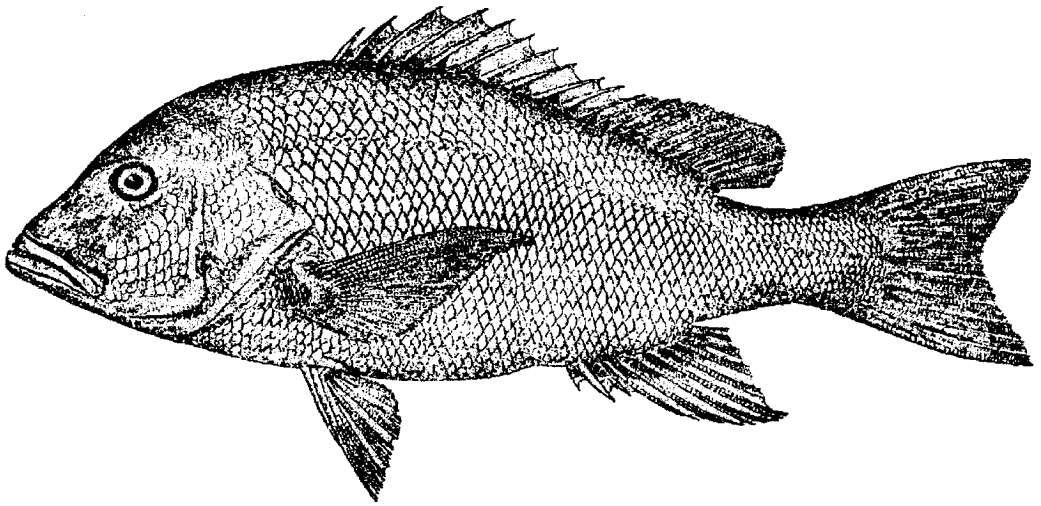
Consolidated Report on the Peer Review of Red Snapper (*Lutjanus campechanus*) Research and Management in the Gulf of Mexico



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for

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Executive Summary

Background

Gulf of Mexico red snapper provide an important fishery resource utilized by a wide variety of user-groups within the southeast United States. As such, the Gulf of Mexico Fishery Management Council (Council) has established a Fishery Management Plan (FMP) to enhance the red snapper resource and restore it to a more optimal potential. The Magnuson-Stevens Fishery Conservation and Management Act of 1996 (Act) requires the Secretary of Commerce to conduct a thorough and independent evaluation of the scientific and management basis for conserving and managing the red snapper fishery in the Gulf of Mexico.

Despite a substantial amount of scientific stock assessment work, a significant amount of controversy remains about the status of Gulf of Mexico red snapper and the appropriate management actions that might need to be taken to rebuild the red snapper stock in the Gulf of Mexico. Typically the controversy has centered around the following issues:

- the level of red snapper bycatch being taken and its estimation, particularly in recent years;
- whether the assessments are accurately characterizing improvements in the stock in recent years and whether regulations are, thus, too restrictive;
- the possibility that commercial statistics might be under reported in the commercial data series; and
- the accuracy and precision of recreational estimates, particularly in recent years, which affect both the determination of status of the stock and the allocation between recreational and commercial users.

These issues led to the Congressional mandate for an independent scientific assessment of the status of red snapper in the Gulf of Mexico and a peer review of the scientific information *in toto*, including the fisheries statistics, the assessments, and the appropriateness of the scientific advice used for management. An independent stock assessment was conducted under contract to National Marine Fisheries Service by a team of scientists headed by Dr. Brian Rothschild at the University of Massachusetts.

Three peer review meetings were conducted by three separate panels of independent experts, organized according to subject area:

- The Statistics Review Panel examined the accuracy, precision and adequacy of the commercial, recreational and charter boat red snapper catch and effort statistics.
- The Economics Review Panel reviewed the cost-benefit analyses conducted in preparation for Amendment 8 to the Reef Fish Fishery Management Plan, including a review of all reasonable alternatives to an individual fishing quota program for the red snapper fishery in the Gulf of Mexico.
- The Science and Management Review Panel reviewed the scientific and management basis for managing the red snapper stock in the Gulf of Mexico. In addition, the Science and Management Review Panel reviewed information *in toto* and included a review of the following information:

- reports from the statistics review[1],
- the results from the 1995 assessment;
- the independent assessment conducted at the University of Massachusetts;
- the appropriateness of the scientific methods, information, and models used to assess the status and trends of the red snapper stock; and
- the appropriateness and adequacy of the management measures in the fishery management plan for red snapper for conserving and managing the fishery.

The specific issues to be considered by each review were framed in a series of goals and specific questions to be addressed. Each panel member was required to produce an independent report of his or her conclusions from the review process, including responses to the questions.

The Consolidated Report

This report represents a consolidation of the thirteen independent reviewers reports resulting from the three review panel meetings. It was developed entirely from the written record and describes the findings and recommendations included in the individual reports. It is limited to the areas addressed in the reviewers' reports and care has been taken not to interject opinions not expressed in those reports. The individual who compiled this consolidated report did not attend the review meetings.

In responding to the task set for them, the panel members each produced a separate report presenting their independent, professional review of the specific components of the assessment and management of red snapper on which they were required to comment. None of the reviewers had access to any of the other independent reports. The thirteen panel members each used a different report structure to present their findings. Whilst each of the reports provide comments on the major issues, the depth of coverage of each issue varies between reports, depending on what the individual reviewers chose to focus on. In cases where a reviewer did not respond on a particular point or question, this was not construed as tacit agreement or disagreement with the findings of the other panel members; rather it was simply assumed that on these particular issues, the panelist in question made no comment.

In the main body of the consolidated report, for the avoidance of doubt, the comments made and conclusions drawn in the panelists reports are attributed directly to the authors. In this summary an attempt has been made to provide a synthesis of the general results of the review process. As such, no specific references are made to the panelists reports, and some of the conclusions presented here may not be fully represented in all of the reports from a particular panel meeting. Therefore, it should not be assumed that all of the panelists agreed completely with these general conclusions. The reader is referred to the main body of the report for a detailed presentation of all the comments and recommendations made in the panel members individual reports.

Although the Science and Management Review was chronologically the last of the three meetings to be held, because it represents the culmination of the review process, it is presented first in this report. It is also considered in more detail than the other reviews for the purposes of this executive summary.

[1]The reports from the economics review were not available at the time of the meeting of the Science and Management Review Panel.

The Science and Management Review

Question 1. *Is the available scientific evidence consistent with the conclusion that the red snapper stock in the Gulf of Mexico is biologically overfished as defined in the fishery management plan?*

The finding shared independently by all the panel members is that all scientifically credible assessments of red snapper in the Gulf of Mexico, including additional assessments run at the panel meeting, very strongly support the conclusion that the stock is severely overfished. The overfishing definition is 20% transitional spawning potential ratio (SPR). All assessments which take account of all sources of catch, regardless of the assumed bycatch estimate or juvenile and adult natural mortality rates, indicate that transitional SPR is in the region of 1%. The most optimistic assessments indicate an overall SPR level in the region of 10%.

Question 2. *If so, and the management objective is to prevent further overfishing and to promote rebuilding of depleted stocks, are the management measures in Reef Fish Fishery Management Plan appropriate to achieve the objective, or are they too severe or not severe enough?*

The management objective is to reach a target level of 20%SPR by the year 2019. In answering this question, the panel members provide two levels of response. There are general summary responses, in which they all independently express their concern that to a greater or lesser extent, the management measures on the reef fish FMP are not appropriate to achieve the objective. In all cases the concern is that the measures are not severe enough, and principally that they are not robust to uncertainty. In addition there are more specific responses relating to the management of the directed fishery for red snapper and the control of bycatch in the shrimp fishery, including suggestions for alternative approaches and recommendations for future action.

Question 3. *Are the estimates of the biological parameters, model assumptions, and model specifications appropriate for the available data and the actual fishery?*

Several of the panel members provide detailed comments and information in direct or indirect response to this question. In addition to biological parameters, model assumptions, and model specifications, comments are also provided on related topics of data and information, including landings data, surveys, observer programs and shrimp effort data. The general conclusion is that there are a number of weaknesses that can and should be attended to, particularly the wider incorporation of uncertainty into the assessment, but in the mean time these aspects of the assessment constitute a sufficient basis for sound management decisions to be made.

Question 4. *Are the model results and conclusions from the assessments the most scientifically sound interpretation of all available information?*

All the panel members independently note that the uncertainties associated with fisheries science can only be reduced by substantial research and monitoring, and that consequently it is always possible to produce new models and new interpretations. They generally conclude that the models used by

NMFS for the red snapper assessment are sufficient to provide advice that is robust to the uncertainties and which can hence lead to management decisions which are similarly robust.

Several panel members focus on a projection in which the current policy (50% reduction in bycatch mortality by 1997, Goodyear's (1995) estimates of discard mortality) was evaluated, with the rates of juvenile mortality set to 1.5 and 0.75 for ages 0 and 1 respectively, and using the LGL values for bycatch. Under these circumstances the current TAC level would not permit stock recovery by 2019. Only when the TAC was lowered from 9 million to 6 million pounds did %SPR exceed 20%SPR by 2019. Several panel members independently conclude that if uncertainty is to be accounted for, the TAC must be reduced to 6 million pounds or less if the rebuilding target is to be reached in the desired time.

Question 5. *Are uncertainties in the assessments and their management implication adequately expressed to allow informed management decisions?*

The treatment of uncertainty in the various assessments presented to the panel is discussed throughout all the panelists' reports and indeed forms a central theme in the evaluation of management strategies aimed at achieving the stock rebuilding target. They independently note that uncertainties in the assessments are addressed in a simple manner through sensitivity analyses and stochastic forecasting. All the panel members express in various ways the opinion that as a basis for management advice, insufficient account has been taken of the large amount of uncertainty in the assessments and input assumptions. In particular, several panelists specifically suggest that more account needs to be taken of uncertainty in bycatch estimates and juvenile natural mortality. Uncertainty is a major factor in what decisions will need to be taken with respect to the management of red snapper and interacting fisheries. The panel members independently conclude that, given the large amount of uncertainty in assumptions and data that flow to the assessments from a variety of sources, it is likely that only scenarios with much more stringent TAC reductions and/or bycatch reductions could possibly lead to recovery to 20%SPR within the desired time frame.

Question 6. *Is the current management of red snapper in the Gulf of Mexico and the scientific advice consistent with a precautionary approach to fisheries as expressed in the United Nations Food and Agriculture Organization Code of Conduct for Responsible Fisheries?*

The FAO Code of Conduct sets out principles and international standards of behavior for responsible practices with a view to ensuring the effective conservation, management and development of aquatic living resources, with due respect for the ecosystem and biodiversity. In responding to this question, the panelists chose to focus on particular aspects of the FAO Code, which they saw as the most applicable in this case. The issue that most of the panelists focus on is the application of the Precautionary Approach to Fisheries (Section 7.5 of the FAO Code). In particular; *The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures* (paragraph 7.5.1). While there remains considerable uncertainty about the current status of the resource and the expected outcomes of reducing the juvenile by-catch and adult fishing mortality, the review panel believes that it is clear that the stock is seriously overfished, and that the existence of these uncertainties should not be used as a reason for inaction.

In addition to answering the specific questions set for them, the Science and Management Panel comments extensively on the issue of bycatch of red snapper in the shrimp fishery and its importance for the assessment. Particular problems associated with the estimation of bycatch are raised, mainly confirming the detailed conclusions of the Statistics Panel. The use of an at-sea observer program for monitoring bycatch is recommended by both the Statistics and the Science and Management Panels. There is also discussion of the means of reducing the bycatch and possible alternatives to the use of Bycatch Reduction Devices (BRDs), for example through reduction of effort either *in toto* or using spatial and/or temporal closures. The possible imposition of a bycatch quota is also considered.

At the end of the section presenting the results of the Science and Management Review, there are two sections summarizing recommendations made by the panel members in relation to the assessment and management of the red snapper resource. The general conclusion, reached independently by all the panel members, is that if red snapper is to be recovered to above the overfishing definition of 20%SPR, the fishing mortality rate on both juveniles (bycatch) and adults (directed fishery) needs to be reduced. Precise levels of reduction will depend on the degree of certainty required for recovery by the specified date of 2019. The values most commonly referred to in the text of the panelists reports are that if total bycatch can be effectively reduced by 50%, the commercial TAC could be set as high as, but no higher than, 6 million pounds. This level would reduce further in the event that:

- effective bycatch reduction decreases, and
- if full and proper account is taken of estimation errors and uncertainties in critical forecast inputs.

It is also pointed out, however, that it is not feasible under the current management regime to keep catches constant (as assumed in the management projections) as the stock recovers and catch per unit effort increases.

Statistics Review

The reports of the Statistics Review focus primarily on the answering of the five questions put before the panel, as they relate to the five main categories of data collection programs. The categories are summarised below. The first four each comprise a number of on-going programs of differing scope and design. The fifth is a collection of special studies, rather than a single program.

1. Commercial Red Snapper Fisheries Data Collection Programs

    - Total landings census
    - Logbook program for catch and effort data
    - Trip interview program (TIP)
    - Brief commercial observer program in 1995 to study mortality or discarded fish

2 Recreational Red Snapper Fisheries Data Collection Programs

    - Marine Recreational Fishery Statistics Survey (MRFSS)
    - Texas Marine Sport Harvest Monitoring Program
    - NMFS Charter boat survey
    - NMFS Headboat survey

3. Fishery Independent Data Collection Programs

   - Summer South East Area Monitoring Assessment (SEAMAP)
   - NMFS Fall groundfish survey.

4 Commercial Shrimp Fisheries Data Collection Programs

   - General canvas landings program
   - Trip Interview Program (TIP)
   - Voluntary at-sea observer programs

5. Biological characteristics, morphometrics, fecundity and post release morality

   - Morphometric study from Louisiana (Wilson, Render and Neiland 1994)
   - Age-Length Study by Panama City, FL Lab (Allyn Johnson, 1996)
   - Release Mortality (Cage Studies)
   - Release Mortality (Headboat Studies)
   - Release Mortality (Commercial hook-and-line Studies of discard fish)

For each of these components of the data collection process, the panel considered the following issues:

1. *Are the designs of the data collection programs appropriate?*
2. *Does the estimation protocol for each program take into account the design aspects of the data collection programs?*
3. *Is sampling level and coverage sufficient to adequately describe the target population?*
4. *Are there identifiable biases in the results of the surveys?*
5. *Is the precision of the estimates appropriately expressed?*

The panelists' reports contain a substantial amount of detailed consideration of the statistical issues associated with the assessment of red snapper, and it would be inappropriate to attempt to summarize this here. Several comments are made, however, which relate generally to a number of the statistical programs being reviewed. For example, there is general concern regarding the lack of presentation of measures of precision of quantities estimated through data analysis and that the low level of scrutiny of the statistical framework within which to consider the quantities being observed. The view is expressed that the current data collection programs attempt to mitigate questions of uncertainty through the use of overwhelming sample sizes. It is suggested that properly expressed measures of uncertainty could lead to greater efficiency in data collection and estimation procedures. There is also concern expressed over the opportunistic nature (e.g., the Trip Interview Program) and/or incomplete coverage of some data collection programs and the bias in catch and effort estimates which can result. Voluntary programs are also criticized in this respect.

All the Statistics Panel members individually conclude that no other single subject under the statistics review has generated as much controversy or as much outside review activity as the estimation of bycatch of red snapper in the commercial shrimp fishery. A separate section is therefore devoted to a consolidation of the panel members' comments and recommendations on this topic. The panel members all independently express the opinion that proper estimation of bycatch is important for providing a scientific basis for management decisions about red snapper in the Gulf of Mexico. In essence, the panel members all individually consider that the poor quality of the dataset undermines the results of the indirect approaches to estimating shrimp bycatch presented at the panel meeting by both NMFS and LGL. They consider the present GLM-based methodology of estimating the red

snapper bycatch from the shrimp fishery to be inappropriate. In various ways, the reports all indicate that provision of measures of uncertainty for bycatch estimates is vastly complicated by the use of methods which multiply estimates of bycatch per unit effort (BPUE) and estimates of total shrimp effort. Each panel member makes recommendations for alternative approaches, which strongly favor the testing and possible use of a variety of more direct methods of estimating or predicting the bycatch, without relying on this composition of estimates. The recommendations range from alternative estimation procedures using existing data, incorporating explicit measures of uncertainty, to suggestions for future data collection through the further development of the at-sea observer program. The use of at-sea observers is also recommended on vessels targeting red snapper for collecting information on discards.

The Economics Review

The Economics Panel was also presented with a series of questions for its consideration, but in order to incorporate the wide range of comments made in the individual reports, the consolidated report of the economics review is presented in three main sections; the commercial red snapper fishery, the recreational red snapper fishery and an economic analysis of the reduction of bycatch in the commercial shrimp fishery. Once again the reader is referred to the main body of the report for a detailed presentation of the panel members reports, due to the difficulties in summarizing the substantial amount of information they contain.

According to the economics review, the management of the red snapper fishery is an integrated management problem, having at least three well-identified groups who are major stakeholders: the commercial red snapper fishermen, the recreational sector (headboats/charter boats and private fishermen), and the commercial shrimp fishery. The reports of the panel members are generally complimentary of the attempts made by NMFS to resolve the complex issues which arise from this situation. The panel generally expresses satisfaction with the description of the economic effects of an ITQ system for the Gulf of Mexico red snapper and the set of alternative policies considered for the commercial fishery. The principal limitation to the analyses was considered to be the incomplete integration of the three sectors: commercial, recreational, and the bycatch of red snapper by the shrimp fleet.

Information on the commercial red snapper fishery is presented in subsections focusing on the various alternative management strategies which have been under consideration for the commercial sector at one stage or another, and are discussed in the panel members' reports. These are open access with and overall quota, limited entry, season closures, effort control, 2-tier license, trip limits, split season, first 15 days each month and, Individual Transferable Quotas (ITQs). The reports indicate strong support from the panel, for a variety of economic reasons, for the introduction of ITQs in the red snapper fishery as soon as possible. The main caveat associated with this recommendation is that the implementation cost of an ITQ system is 20 to 25 percent higher than either the *status quo* or the license limitation system, and the annual running costs, assuming a high enforcement scenario, may be nearly three times as expensive.

Several panel members express concern about the poor data and lack of economic analysis of the recreational sector. The efforts made by NMFS to correct some significant data deficiencies are noted, and more research in this area is recommended in the panel members' reports. It is suggested that the economic value of the recreational fishery needs to be assessed to determine the appropriate allocation between recreational and commercial fisheries. All the panel members express concern in various ways at the quota overages by the recreational sector. Several suggestions are made in the reports regarding the approach to regulation of the recreational fishery.

With respect to the economic analysis of bycatch reduction, all the panel members note that the analysis of impacts on the shrimp fishery is more thoroughly developed than the effects on the red snapper fishery and suggest that this deficiency should be corrected. The main criticism leveled by several of the panel members, however, is that alternatives to the use of BRDs were not fully explored.

1. Background, goals and scope of the reviews

1.1 Introduction

Gulf of Mexico red snapper provide an important fishery resource utilized by a wide variety of user-groups within the southeast United States. As such, the Gulf of Mexico Fishery Management Council (Council) has established a Fishery Management Plan (FMP) to enhance the red snapper resource and restore it to a more optimal potential. The Magnuson-Stevens Fishery Conservation and Management Act of 1996 (Act) requires the Secretary of Commerce to conduct a thorough and independent evaluation of the scientific and management basis for conserving and managing the red snapper fishery in the Gulf of Mexico. Specifically Section 407(a) of the Act required the Secretary to "initiate an independent peer review to evaluate:

> (A) the accuracy and adequacy of fishery statistics used by the Secretary for the red snapper fishery in the Gulf of Mexico to account for all commercial, recreational, and charter fishing harvests and fishing effort on the stock;
>
> (B) the appropriateness of the scientific methods, information, and models used by the Secretary to assess the status and trends of the Gulf of Mexico red snapper stock and as the basis for the fishery management plan for the Gulf of Mexico red snapper fishery;
>
> (C) the appropriateness and adequacy of the management measures in the fishery management plan for red snapper in the Gulf of Mexico for conserving and managing the red snapper fishery under this Act; and
>
> (D) the costs and benefits of all reasonable alternatives to an individual fishing quota program for the red snapper fishery in the Gulf of Mexico."

The Act further required that during the review process that, "commercial, recreational, and charter fishermen in the red snapper fishery in the Gulf of Mexico are provided an opportunity to -- (A) participate in the peer review under this subsection; and (B) provide information to the Secretary concerning the review of fishery statistics under this subsection without being subject to penalty under this Act or other applicable law for any past violation of a requirement to report such information to the Secretary." The Secretary is required to "submit a detailed written report on the findings of the peer review conducted under this subsection to the Gulf Council no later than one year after the date of enactment of the Sustainable Fisheries Act." The Secretary's report to the Gulf Council was due on October 11, 1997.

1.2 A brief history of the fishery and its management

Red snapper have been exploited in the Gulf of Mexico for many decades using a variety of gears. In addition to the commercial fisheries, in the last 20-30 years recreational fishing for red snapper has also developed. Also, trawling by shrimp vessels over the last two or three decades has resulted in a bycatch of red snapper which were discarded dead and which contributed to the overall fishing mortality of red snapper. Landings of red snapper by commercial fishing vessels from 1964 through 1994, estimated recreational harvest from 1979 through 1994, and estimated discards of red snapper by the shrimp trawl fishery in the Gulf of Mexico are illustrated in Figures 1, 2 and 3 respectively.

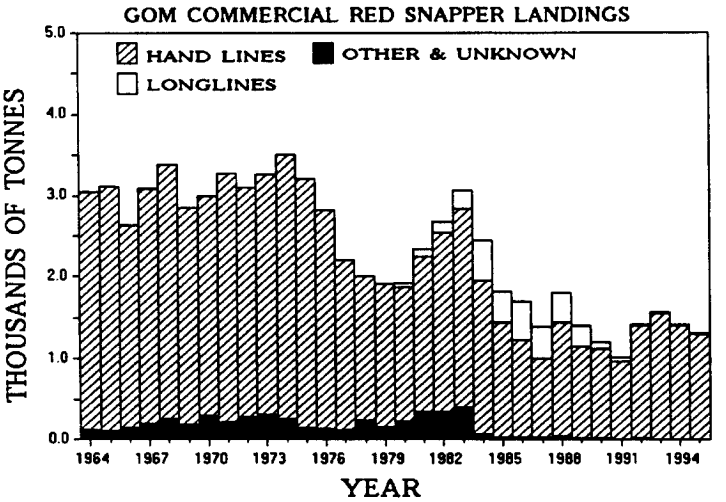

Figure 1. Commercial landings of red snapper from U.S. waters of the Gulf of Mexico (figure 44 from Goodyear 1995).

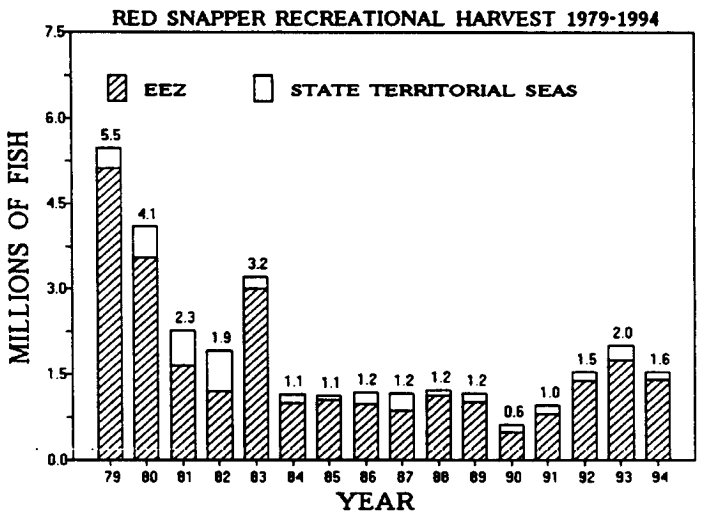

Figure 2. Estimated numbers of red snapper harvested by recreational fishermen, 1979 to 1994 (figure 57 from Goodyear 1995).

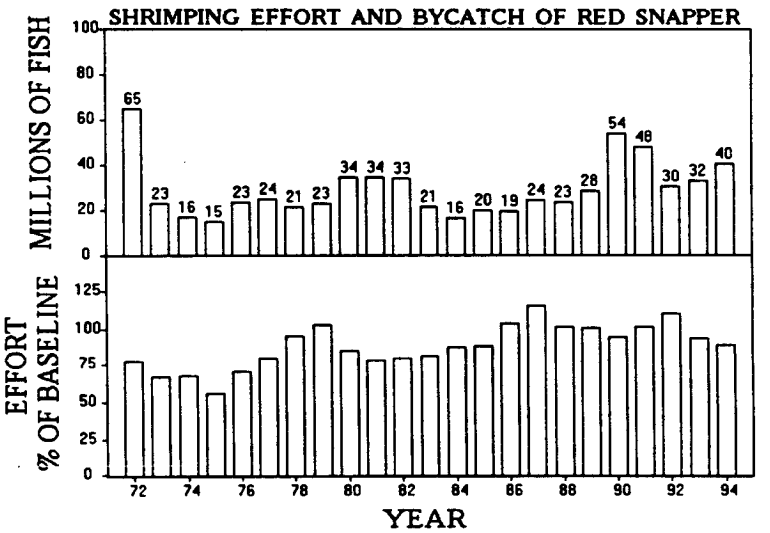

Figure 3. Estimates of the annual total numbers of red snapper discarded as shrimp bycatch and weighted shrimping effort by year (figure 68 from Goodyear 1995)

U.S. Gulf of Mexico red snapper are presently managed under the 1984 Gulf of Mexico Fishery Management Council's Reef Fish Fishery Management Plan (FMP) and subsequent amendments which were designed to provide for further protection for the stock. The Gulf red snapper stock is currently considered to be overfished. This has been attributed to a combination of overexploitation by directed fisheries (commercial and recreational), high bycatch mortality of juvenile fish in the shrimp fishery, and biological characteristics of red snapper, which make it vulnerable to overfishing. A major fisheries management goal of the Council and NMFS is to restore the stock to a non-overfished status. The maximum duration of the recovery period is set by regulation to no more than 1.5 times the unfished generation time, which is itself the consequence of the interactions of growth, mortality and fecundity. To achieve these goals, the Council has implemented a suite of regulations including recreational bag limits, minimum sizes, commercial quotas, commercial trip limits within the open season, special management zones where bag limits and minimum size regulations are more restrictive and permitting systems to restrict new entries into the commercial fishery. While recent studies have indicated that progress has been made in rebuilding the red snapper stock, it is felt that a major impediment to the recovery progress is the impact of shrimp bycatch.

Stock assessment analyses on Gulf of Mexico red snapper have been prepared by NMFS in 1986, 1988, 1990, 1991, 1992, 1993 and 1995. These analyses were reviewed by the Council's Reef Fish Stock Assessment Panel. The Stock Assessment Panel consists of scientists from State agencies, academia and NMFS. Subsequent to the review, the Stock Assessment Panel made recommendations for allowable biological catch (ABC) based upon those analyses, additional analyses conducted at their meetings and the stated goals of the FMP. In turn the analyses and ABC recommendations were reviewed by the Socio-Economic Panel and Scientific and Statistics Committee of the Council were then used as the basis for making total allowable catch (TAC) decisions and to develop a long term management strategy and the regulatory tactics to achieve the management goals.

Additionally, there have been several special scientific review panels which dealt with scientific issues that affect red snapper assessment and management including: bycatch estimation; estimation of shrimping effort used in bycatch estimations; development of observer programs to monitor bycatch; determination of appropriate thresholds defining overfishing; and evaluation of recreational catch estimates.

Nevertheless, a significant amount of controversy remains about the status of Gulf of Mexico red snapper and the appropriate management actions that might need to be taken to rebuild the red snapper stock in the Gulf of Mexico. Typically the controversy has centered around the level of red snapper bycatch being taken and its estimation, particularly in recent years; whether the assessments are accurately characterizing improvements in the stock in recent years and whether regulations are, thus, too restrictive; the possibility that commercial statistics might be under reported in the commercial data series; and the accuracy and precision of recreational estimates, particularly in recent years, which affect both the determination of status of the stock and the allocation between recreational and commercial users.

These issues have led to the Congressional mandate for an independent scientific assessment of the status of red snapper in the Gulf of Mexico and a peer review of the scientific information *in toto*, including the fisheries statistics, the assessments, and the appropriateness of the scientific advice used for management. An independent stock assessment was conducted under contract to National Marine Fisheries Service by a team of scientists headed by Dr. Brian Rothschild at the University of Massachusetts.

Quotas set for the 1993, 1994 and 1995 commercial fishing seasons were filled in 95, 77 and 50 days, respectively. This trend of decreasing fishing seasons emphasizes the need for effort capacity

controls for the commercial fishery. Amendment 8 to the Reef Fish Fishery Management Plan sought to establish a individual transferable quota (ITQ) system for the fishery, however, Congressional constrains have prevented its implementation. Currently fishing effort is limited by requirements for red snapper vessel permit endorsements for fishing vessels participating in the fishery and trip limit system. In addition, NMFS has instituted a moratorium on the issuance of new reef fish commercial vessel permits (except for certain new permits issued through transfers of existing permits) through December 31, 2000.

1.3 The peer reviews

The peer review was divided into three separate reviews according to subject area, each conducted by panels of independent experts. The Statistics Review Panel examined the accuracy, precision and adequacy of the commercial, recreational and charter boat red snapper catch and effort statistics. The Economics Review Panel reviewed the cost-benefit analyses conducted in preparation for Amendment 8 to the Reef Fish Fishery Management Plan, including a review of all reasonable alternatives to an individual fishing quota program for the red snapper fishery in the Gulf of Mexico. The Science and Management Review Panel reviewed the scientific and management basis for managing the red snapper stock in the Gulf of Mexico. In addition, the Science and Management Review Panel reviewed information *in toto* and included a review of the following information:

- reports from the statistics and economic reviews,
- the results from the 1995 assessment;
- the independent assessment conducted at the University of Massachusetts;
- the appropriateness of the scientific methods, information, and models used to assess the status and trends of the red snapper stock; and
- the appropriateness and adequacy of the management measures in the fishery management plan for red snapper for conserving and managing the fishery.

Each review panel met once. The panel meetings were for the presentation of information to the reviewers by scientists, fishery managers, and fishing industry representatives. Reviewers reports were based on their own conclusions and viewpoints. Each reviewer submitted a report independently to the Director of the Office of Science and Technology, National Marine Fisheries Service. A more detailed review of the issues addressed by each of the three reviews is provided in Section 3.

The original plan required each panel to meet for 4 to 5 days. The first half of each meeting consisted of presentations by scientists from NMFS, fishery management agencies, academia, and the fishing industry who had been involved in research or management of red snapper in the Gulf of Mexico or as part of the fishing industry. Industry representatives were also given the opportunity to present material to the reviewers during this time. Individuals who wished to "provide information, ..., concerning the review of fishery statistics,..." as provided for in the Sustainable Fisheries Act were allowed to do so during the Statistics Review. The second half of each meeting was reserved for panel deliberations and preliminary report writing. Following the panel meeting, the panel worked by correspondence. A final report was prepared by each of the reviewers and submitted to the Director of the Office of Science and Technology between 2 and 4 weeks after the conclusion of the review meetings.

An independent contractor was selected to prepare this final consolidated report which incorporates the findings, recommendations and discussions of the reviewers' reports. The reviewers' reports are included in this report in their entirety in Annex I.

The initial outline schedule for the reviews was as follows:

Day 1	-	Presentations of research, sampling methodologies, statistics, cost/benefit analyses, fishing industry perspectives, etc.
Day 2	-	completion of presentations
Day 3 (am)	-	comments by observers
Day 3 (pm)	-	Reviewers discussion of issues raised during presentations
Day 4	-	Reviewers deliberations and formulation of report. Writing begins.
Day 5	-	Discussion, writing and additional analyses.
Week 2-4	-	Reports are compiled and edited and final reports submitted

There were no verbal reports on the last day in order to preserve the independence of the individuals reviewers' written reports. The Economics Review lasted 4 days (see Annex IV for Agenda).

Detailed timetables for each of the reviews are presented in Annex IV.

1.4 The consolidated report

This report represents a consolidation of the thirteen separate independent reviewers' reports from the three panel meetings into a single report to the Director of the Office of Science and Technology, National Marine Fisheries Service. This report describes the findings and recommendations included in the individual reports. It is limited to the areas addressed in the reviewers' reports and care has been taken not to interject opinions not expressed in those reports. Where individual reviewer's reports disagree, or offer conflicting views, this report includes all the dissenting views. There are some points raised in individual reports on which not all the reviewers comment. In cases where a reviewer has not responded on a particular point or question, this should not be construed as tacit agreement or disagreement with the findings of the other panel members, rather it is simply that on these particular issues, the panelist made no comment.

The Statement of Work for undertaking the consolidated report is provided in Annex VIII.

1. Background, goals and scope of the reviews

2. Panel membership and nomination process

Each review was conducted by independent experts drawn from the appropriate disciplines. Nominations for each review panel were solicited through *Federal Register* notices (Annex VII) and through direct contact with the Gulf of Mexico Fishery Management Council, state fishery management agencies, fishing industry organizations, academic institutions throughout the U.S., Canada and the rest of the world, governmental organizations outside the US, and non-government organizations. Nominees for the each review required outstanding scientific or fisheries management credentials relevant to the subject area to which he/she is being nominated. Nominations were accepted from international as well as national scientific bodies, fishery management organizations or the fishing industry.

Any person or organization was allowed to submit nominations for any of the reviews. Nominations had to include a detailed listing of each nominee's background and experience pertinent to the review area for which he/she was being nominated. Panel members were paid a fixed, predetermined amount at a level comparable to that paid to Council members and commensurate with the amount of time required to participate in the review. It was anticipated that the Statistics and Economic Reviews would require 80 hours and the Science and Management Review would require 100 hours of each panel members' time (exclusive of travel time). In addition, all travel expenses for review panel members to attend panel meetings were paid by the government at the prevailing government rates.

The undertaking of the review was advertised via a series of notices to the *Federal Register*, press releases and mailshots. Copies of all *Federal Register* notices pertaining to the reviews, announcements and requests for nominations for review panels are provided in Annex VII. Copies of the mailing lists requesting nominations for review panels, announcing meeting dates and locations are provided in Annex VI.

Copies of the notice were mailed directly to 308 individuals or organizations who were listed in the NMFS Southeast Regional database with a known interest in the red snapper fishery. In addition, background information and requests for nominations were sent to 256 university departments in the U.S. and Canada with graduate programs in economics, fisheries and wildlife science, and statistics, 60 individuals worldwide with known expertise in the subject area and all university Sea Grant directors. Insufficient nominations were received as a result of the first *Federal Register* notice to form the three review panels, hence the second notice and the expanded mailing lists.

Panel members were selected by three senior NMFS scientists based on information contained in the nomination package. Some individuals who were nominated were disqualified because of apparent or potential conflicts of interest. The conflict of interest criteria applied were that nominees who had been directly involved in the collection, evaluation and interpretation of information used in the management of the red snapper or shrimp fishery in the Gulf of Mexico during the preceding four years, who may have gained financially from the outcome of the review, or whose immediate family, organization or company, as defined in the Magnuson-Stevens Fishery Conservation and Management Act, may have gained financially from the outcome of the review were not accepted.

The credentials of the selected panel members are provided in Annex II

2. Panel membership and nomination process

3. The issues for each review

3.1 The Statistics Review

The Statistics Review Panel was required to consider the accuracy and adequacy of fishery statistics for the red snapper fishery in the Gulf of Mexico which aim to account for all commercial, recreational, and charter fishing harvests and fishing effort on the stock. In addition, the Statistics Review was required to consider the collection of information on bycatch in the shrimp trawl fishery in the Gulf of Mexico and the estimation of total bycatch for the shrimp fishery. Reviewers were asked to consider the current data collection programs conducted by the National Marine Fisheries Service and states which are used in the assessment process, including the cooperative commercial fisheries statistics program, the Marine Recreational Fishery Statistics Survey, the headboat sampling program, the observer program which collects bycatch information for the shrimp fishery, fishery independent surveys and appropriate state sampling programs such as those conducted by Texas Parks and Wildlife.

3.1.1 Goals of the Review

The goal of the Statistics Review was to examine the fishery information collection programs in the Gulf of Mexico which provide the scientific data for managing the fishery, setting regulations, determining allocations and conducting stock assessments. Given the management objectives of the fishery management plan, the specific goals of this review were:

1. to determine whether the statistical designs of the data collection programs are appropriate for those fishery management plan objectives and the level of complexity encountered in the red snapper fishery in the Gulf of Mexico;

2. to determine whether the designs are properly addressed in the estimation protocols for total catch, bycatch and effort relative to the fishery management plan objectives;

3. to determine whether there are any significant biases in the data collection programs relative to the fishery management plan objectives; and

4. to determine whether uncertainties associated with the estimation of catch and effort are properly accounted for relative to fishery management plan objectives.

3.1.2 Questions Addressed

The following specific questions were addressed by the statistics review panel:

1. Are the designs of the data collection programs appropriate?

2. Does the estimation protocol for each program take into account the design aspects of the data collection programs?

3. Is sampling level and coverage sufficient to adequately describe the target population?

4. Are there identifiable biases in the results of the surveys?

5. Is the precision of the estimates appropriately expressed?

3.2 The Economics Review

The Economics Review was required to consider the data which are available to conduct economic inquiries and review and evaluate the economic analyses which are currently available and which contribute to the understanding of the economic ramifications of alternative management strategies for red snapper.

3.2.1 Goals of the Review

The goal of this review was to examine the analyses conducted in support of establishing an individual transferable quota system for the red snapper fishery and determine whether the analyses were sufficient and whether additional analyses of other alternatives are called for.

Specific objectives of this review were:

1. to assess the analyses which were conducted to describe the economic effects of an individual transferable quota system for red snapper and the alternatives to the individual transferable quota system that were considered under Amendment 8 to the Reef Fish Fishery Management Plan;

2. to review the alternatives to an individual transferable quota program as described in Draft Amendment 15 to the Reef Fish Fishery Management Plan;

3. to assess the completeness and quality of data currently available to conduct economic analyses of alternatives to an individual transferable quota program; and,

4. to recommend the appropriate analytical and methodological approaches that would be appropriate for analyzing the economic outcomes of alternative management regimes for red snapper.

3.2.2 Questions Addressed

The following specific questions were asked of the economics review panel:

1. Were the analyses which had been conducted the correct approaches to the issues?

2. When the Gulf of Mexico Fishery Management Council was considering implementing effort controls for the red snapper commercial fishery, were all reasonable effort management alternatives considered? In addition to ITQ management for red snapper, to what degree did the Council consider license limitation, multi-species effort management, management involving specific geographical areas or other relevant alternatives designed to limit overall commercial effort?

3. Are contemplated budgets and time frames sufficient for the tasks which need to be completed?

3.3 The Science and Management Review

The Science and Management Review was given the task of considering all aspects of the scientific and management basis for managing the red snapper stock in the Gulf of Mexico. The aim of the review was to consider the appropriateness of the scientific methods, information, and models used to assess the status and trends of the Gulf of Mexico red snapper stock and their usefulness as a basis for the fishery management plan for the Gulf of Mexico red snapper fishery. The review also considered the appropriateness and adequacy of the management measures in the fishery management plan for red snapper in the Gulf of Mexico for conserving and managing the red snapper fishery under the Magnuson-Stevens Act. The intention was for conclusions and recommendations from both the Statistics and Economics reviews to be also considered by the Science and Management Review Panel in formulating their reports. In fact, at the time of the Science and Management Review, the reports of the Economics Review were unavailable, hence only the reports of the Statistics Review were considered by the panel.

3.3.1 Goals of the Review

The goal of this review was to examine the available scientific data relating to the status of U.S. Gulf of Mexico red snapper and determine the best scientific advice to be derived from it and to determine whether the preferred management options are supported by the scientific advice. Specific objectives of this review were:

1. to evaluate the appropriateness of the goals and objectives in the fishery management plan;
2. given the available scientific information, evaluate the appropriateness of the management measures being pursued to meet those objectives;
3. given the available scientific information, evaluate whether the specific management regulations which have been implemented are likely to achieve those objectives;
4. to provide the most appropriate scientific advice in relation to the management objectives for red snapper in the U. S. Gulf of Mexico Reef Fish Fishery Management Plan (FMP);
5. to identify and evaluate weaknesses in present management procedures given the status of U.S. Gulf of Mexico red snapper;
6. to identify and evaluate weaknesses in the scientific data and information in regards to the determination of status and management procedures for red snapper; and
7. to identify and evaluate the uncertainty in the assessment of red snapper, the robustness of the scientific advice and the risk of present management policies given that uncertainty.

3.3.2 Questions to be Addressed

The overarching questions put to the panel were:

1. Is the available scientific evidence consistent with the conclusion that the red snapper stock in the Gulf of Mexico is biologically overfished as defined in the fishery management plan?

3. The issues for each review

2. If so, and the management objective is to prevent further overfishing and to promote rebuilding of depleted stocks, are the management measures in Reef Fish Fishery Management Plan appropriate to achieve the objective, or are they too severe or not severe enough?

3. Are the estimates of the biological parameters, model assumptions, and model specifications appropriate for the available data and the actual fishery?

4. Are the model results and conclusions from the assessments the most scientifically sound interpretation of all available information?

5. Are uncertainties in the assessments and their management implication adequately expressed to allow informed management decisions?

6. Is the current management of red snapper in the Gulf of Mexico and the scientific advice consistent with a precautionary approach to fisheries as expressed in the United Nations Food and Agriculture Organization Code of Conduct for Responsible Fisheries?

4. Consolidation of the reviewers' reports

This section presents a consolidation of the thirteen independent reviewers reports from the three review panel meetings, as described briefly in Section 1.4, and in accordance with the Statement of Work in Annex VIII. The results of the Science and Management Review are presented first, as these represent the major findings and conclusions of the whole review process. As explained in section 3.3, the intention was for conclusions and recommendations from both the Statistics and Economics reviews to be considered by the Science and Management Review Panel. In the event only the reports of the Statistics Panel were available at the time of the Science and Management Panel meeting, and the reports of the Economics Review were not considered by the Panel.

4.1 The Science and Management Review

4.1.1 Outline

The goals and objectives of the Science and Management Review Panel are explained in section 3.3 of this report. Numerous presentations were made to the panel. In addition, extensive briefing, scientific, regulatory and legal documents were provided. The review panel considered fishery independent data, fisheries data, stock assessment results, management advice from the assessments, and the implementation of the advice as reflected in the amendments to the FMP. T. Kevin Stokes (Stokes) describes the process in his report as thorough and open, with considerable input by NMFS personnel, consultants (LGL Ecological Research Associates), academics and the industry.

At the meeting the panel heard presentations from representatives from the NMFS Office of Science and Technology, Gulf of Mexico Fishery Management Council, NMFS (Southeast Regional Office, Beaufort Laboratory, Miami Laboratory, and Pascagoula Laboratory), the Gulf and South Atlantic Fisheries Development Foundation, the University of Massachusetts (Independent Red Snapper Assessment by Rothschild *et al.*), and the Texas Shrimp Association. C. Phillip Goodyear also gave a presentation on the 1995 Red Snapper Assessment (Goodyear, 1995).

Stokes explains that the various people involved in the process were all eager to contribute both during the meetings and during breaks. Alan Sinclair (Sinclair) remarks that the review process is to be commended for being comprehensive, open, and promoting a level of cooperation and data exchange uncommon in fish stock assessments.

Following the formal presentations, Phil Goodyear, Benny Gallaway (representing the Texas Shrimp Association) and Scott Nichols (NMFS Pascagoula Laboratory) provided considerable additional insight, materials and explanations to the panel during its deliberations. Reports from the earlier Statistics Panel were made available to the panel, but, unfortunately, the economics reports were not ready for distribution at the time of the meeting. Hence the Science and Management Review Panel was unable to consider fully the economics issues raised by the earlier meeting.

As with the two following sections, covering the statistics and economics reviews, the structure of this section is designed to provide an accurate and comprehensive consolidation of the individual reports of the five panel members. In most cases the reports include specific responses to the six questions set for the panel in the original Plan for the Peer Reviews (Section 3.3.2), using the questions as section headings. For ease of reference, this structure is used in the following section providing an overview of the responses, where they have been made. Following the responses to the questions, there are four further sections which present information and comments provided by one or more of the panelists which are outside the specific scope of the questions themselves. In cases where a reviewer has not responded on a particular point or question, this should not be construed as tacit

agreement or disagreement with the findings of the other panel members, rather it is simply that on these particular issues, the panelist made no comment.

4.1.2 Specific responses to the questions

Question 1 - Overfishing

> *Is the available scientific evidence consistent with the conclusion that the red snapper stock in the Gulf of Mexico is biologically overfished as defined in the fishery management plan?*

Murdoch McAllister (McAllister) succinctly summarizes the conclusion shared independently by all the panel members, when he states that all scientifically credible assessments of red snapper in the Gulf of Mexico very strongly support the conclusion that this stock is severely overfished. Stokes and Timothy Targett (Targett) explain that the overfishing definition is 20% transitional SPR. Stokes and Jon Sutinen (Sutinen) note that assessments which take account of all sources of catch, regardless of the assumed bycatch estimate or juvenile and adult natural mortality rates, indicate that transitional SPR is in the region of 1%. The most optimistic assessments indicate an overall SPR level in the region of 10%.

Several additional assessments were run by Goodyear during the panel meeting, at the request of the panelists, to examine the effects of a wider variety of assumptions than explored previously , particularly where uncertainty was greatest (see also responses to question 4). Sutinen explains that these re-runs, incorporated lower rates of shrimp bycatch, and higher juvenile and adult natural mortality rates, each of which reduces fishing impacts on SPR. He notes that under such favorable, yet plausible, conditions, the estimate of the current SPR is not above 5% and concludes that no set of plausible parameter values appears capable of raising the SPR above the overfishing level. According to Stokes also it is clear that regardless of the source of the bycatch estimate; regardless of the assumed juvenile natural mortality rates; and regardless of the discard survival values, the overall SPR is very low - well below the overfishing definition of 20% transitional SPR. Stokes further notes that regardless of the assumptions made, overall SPR has shown a gradual downward trend over the last decade.

Both Stokes and Sinclair note that the effects of the two main components of the fishery, by-catch in the shrimp fishery and the targeted fishery on the adults, may be considered independently because of the distinctness of the age groups taken by each. Partial SPR may be estimated for each component, and the combined SPR for the entire fishery is the product of the two components. Stokes attributes the gradual downward trend in SPR primarily to an increasing detrimental effect on the stock due to bycatch, resulting in a reduction in the SPR component by a factor of ½ to ⅓, more than offsetting "improvements" in the commercial component. Sinclair concludes that the current bycatch in the shrimp fishery alone is sufficient to prevent achieving the SPR target. Having considered the various analyses presented at and run during the panel meeting, he further concludes that the stock is biologically overfished and it would appear that closing either component completely would be insufficient to achieve the overfishing and stock rebuilding targets.

McAllister similarly reports that all the scenarios run during the meeting gave very pessimistic estimates of current stock status. In all cases results were as pessimistic or more pessimistic that Goodyear's (1995) findings (i.e., %SPR was less than 1% in all cases in 1992 - the most recent year in which a calculation was possible). Although the analysis undertaken by Rothschild *et al.* (1997) provided

estimates of current %SPR which were much larger than Goodyear's (Goodyear 1995), according to McAllister, this is largely because Rothschild *et al.* (1997) left out discard mortality and bycatch in computing *F*, assumed higher values for *M*, and used a static estimate of %SPR (equation provided in McAllister's report, Annex 1). In addition, McAllister points out that these estimates are likely to be positively biassed relative to transitional SPR and Rothschild *et al.* 's other estimates of stock status (e.g., stock size) using the ADAPT version of Virtual Population Analysis (VPA) could also be overly optimistic for similar reasons. Of the third main set of analyses, McAllister notes that all projections undertaken by Gazey, using the LGL estimates of bycatch and alternative values of *M* for age 0 and 1, indicated that the current status of the population was highly overfished with %SPR in 1997 well below 5%.

Whilst not advocating this as an approach, Sinclair points to the most optimistic and most conservative estimates of fishery wide SPR as evidence that the stock is clearly biologically overfished. The former he calculates to be 9% (35% for the shrimp by-catch times 25% for the adult fisheries) and the latter 0.4% (13% for the shrimp by-catch times 3% for the adult fishery).

Question 2 - Management measures

> *If so, and the management objective is to prevent further overfishing and to promote rebuilding of depleted stocks, are the management measures in Reef Fish Fishery Management Plan appropriate to achieve the objective, or are they too severe or not severe enough?*

In answering this question, the panel members provide two levels of response There are general summary responses, in which they all independently express their concern that to a greater or lesser extent, the management measures on the RFMP are not appropriate to achieve the objective. In all cases the concern is that the measures are not severe enough, and principally that they are not robust to uncertainty. In addition there are more specific responses relating to the management of the directed fishery for red snapper and the control of bycatch in the shrimp fishery, including suggestions for alternative approaches and recommendations for future action. These latter, more detailed responses are presented in sections 4.1.4 (by-catch) and 4.1.6 (management of the directed fishery).

General responses

Sinclair explains that he recommended additional runs of the catch projection simulation using alternative stock recruitment functions to further investigate the conclusion from Goodyear's deterministic simulations that the proposed management plan (a 44% reduction in juvenile red snapper *F* due to by-catch in the shrimp fishery and a TAC of 9.2 million pounds in the directed fishery) may achieve the SPR target in the required time frame (by 2019). However, regardless of the results of these additional simulations, he believes that it is unlikely that the management measures proposed to implement these changes are sufficient to achieve the management objectives.

At the outset, Sutinen writes that he considers that the controls on the directed commercial and recreational fisheries (referring to the TAC and minimum fish size for red snapper) are appropriate, but that the approach used to reduce and control red snapper and other finfish bycatch in the shrimp fishery is not appropriate. However, he later concludes generally that there is a risk that current management measures will not achieve the objectives of prevention of further overfishing and promotion of rebuilding of the stock. Referring to the analyses run during the meeting by Goodyear, Sutinen concludes that, under the plausible conditions assumed in those reruns, only far more severe

restrictions on red snapper mortality would raise SPR to, or above, the target of 20% by 2019. Current measures, he believes, carry too much risk of failing to rebuild the stock.

Targett concludes that the *status quo* (i.e., current management measures), even under varying assumptions of bycatch mortality rate and early mortality rate, will not allow the stock to recover. Consequently, fishing mortality, in his opinion directed and/or bycatch, must be reduced. He concludes from the stock recovery simulations run during the panel meeting, however, that given it is unlikely that bycatch in the shrimp fishery can be eliminated, mortality from both the directed fishery and bycatch will have to be reduced below current levels, to provide for red snapper stock recovery by 2019.

Sinclair also concludes that closing either component of the fishery completely would be insufficient by itself to achieve the stock rebuilding targets. In accordance with this, Stokes stresses throughout his report that an increase in transitional SPR will only be brought about by reducing fishing mortality on both juveniles (the by-catch) and adults (the directed fishery). He explains that the age structure is primarily influenced by action on the spawning component of the stock, which is exploited by the directed fishery, but the material on which that fishery can operate is dependent on the numbers of juveniles that can pass through the gauntlet of the bycatch in the shrimp fishery (which takes upwards of 90% of potential recruits to the commercial fishery). He believes the reduction in juvenile mortality needs to be at least 50% and in this case, the commercial TAC could potentially be as high as 6 million pounds. Lesser reductions in juvenile mortality would require lower commercial TACs. Furthermore, the 6 million pound TAC in the commercial fishery is an upper bound that would reduce depending on the required degree of certainty that SPR will recover to 20% by 2019. He believes, as does Sutinen (see above) that current management plans to reduce juvenile mortality by using BRDs may be insufficient.

McAllister is also of the opinion that the current stock rebuilding plan does not appear to be robust to uncertainty and does not appear to ensure that the stock has a reasonable chance of recovery from its overfished status within the desired period of 1.5 generations, although he concedes that the evaluations carried out to date do not enable him to properly answer this question quantitatively. He notes that a variety of policy projections have been carried out under a variety of assumptions and that some of them indicate that the stock rebuilding target will be achieved, whilst others indicate that there will be no net increase in %SPR over the time period (i.e., up to 2019). McAllister believes he has no basis on which to weight these various trajectories, and it is therefore not possible to evaluate the likelihood that stock rebuilding will occur. However, in his opinion, the finding that some plausible projections suggest that no rebuilding will occur casts reasonable doubt on the effectiveness of the current management regime. He therefore feels unable to conclude from the scientific analyses that the current plan has a reasonable chance of promoting stock rebuilding such that 20%SPR is reached by 2019.

Question 3 - Estimates of biological parameters, model assumptions, and model specifications

> *Are the estimates of the biological parameters, model assumptions, and model specifications appropriate for the available data and the actual fishery?*

Several of the panelists provide detailed comments and information in direct or indirect response to this question. In addition to biological parameters, model assumptions, and model specifications, comments are also provided on related topics of data and information, including landings data, surveys, observer programs and shrimp effort data. For ease of reference these are also summarized in this section.

McAllister notes that the issue of data and available information - on which the biological parameters and model assumptions are based primarily - is thoroughly dealt with by the statistics panel. He further notes that they appear to concur over most of the data sampling issues and where he has managed review relevant reports, he states that he also for the most part concurs with their findings. The main issue in which their findings did not entirely concur was that of bycatch estimation, which for the purposes of the Science and Management Review is dealt with under section 4.1.4.

In his summary response to this question, Stokes expresses the view that there are a number of weaknesses that can and should be attended to, including the wider incorporation of uncertainty into the assessment (see also responses to question 5), but he concludes that, nevertheless, the assessments conducted by NMFS are an excellent example of a comprehensive approach to fisheries assessment work. In his view they constitute a sufficient basis for sound management decisions to be made.

Biological parameters

- *Growth and size at age*

Sinclair notes the importance of estimates of red snapper growth rate and size at age for the assessment and the problems associated with the available material. For example, none of the sampling programs provide random samples of the age composition of the population. A pooled dataset was used, combining all data to arrive at a single growth curve, which makes the implicit assumption that the sampled lengths were a random representation of the size distribution at age in the population. He also notes the agreement between Goodyear and Rothschild *et al.* on the interpretation of the growth and size at age data, arriving at similar von Bertananffy parameters, although Goodyear used a lower coefficient of variation compared to Rothschild *et al.* His main criticism is that asymptotic length estimates are strongly influenced by the oldest age fish and their inclusion produces a strong residual pattern indicating the size at age 7-15 is under-estimated. He makes several recommendations for potential improvements in parameter estimates (see Section 4.1.6), which he thinks might be useful, but makes no suggestion that the parameters used in the present assessments are inappropriate.

McAllister also notes the problems associated with reading the otoliths of red snapper, particularly the possibility the opaque rings fail to form in some years between ages 1 and 5. There may therefore be a negative bias in the ageing of all individuals, and the percentaqe bias will be greatest for the youngest aged individuals. He explores the potential significant and extensive ramifications of the effects of ageing error on the stock assessments and evaluations of management strategies, with possible secondary effects on:

- growth curve parameters;
- fecundity at age estimates; and
- age frequency distributions, and hence total and natural mortality estimates.

He concludes the possible extent of the bias needs further attention and acknowledges the positive step of attempts to use the effects of past atomic bomb tests to verify current otolith readings. As with Sinclair, he makes no suggestion that the parameters used in the present assessments are actually inappropriate.

Stokes comments on the 'considerable argument' which has emerged over the interpretation of otoliths and subsequent estimates of adult mortality (see also later section on mortality estimation) which arise from different interpretations. He believes that the work on otoliths at the University of Louisiana has

been conducted in a professional and expert manner and probably represents the best scientific interpretation at present. He considers that the inter-reader comparisons presented by Rothschild *et al.* are not compelling, although acknowledges that there remain concerns regarding the inconsistency with other Lutjaniids over longevity, which could be investigated further.

Targett and Sutinen make no specific comment regarding the estimation of growth parameters and size at age.

- *Length frequency data*

Only McAllister and Sinclair comment specifically on the estimation of length frequency distributions. Their comments are summarised here, but this is should not be construed as tacit acceptance of their conclusions by the other panel members.

McAllister comments on problems with the sampling of length frequency data associated with:

- size selective properties of various fishing methods;
- minimum size limits and potential discarding; and
- opportunistic sampling (see statistics section - 4.1)

and the attendant potential for bias in growth and fecundity-at-age estimates. He notes Goodyear's exclusion of tournament data in recognition of these problems, and although he expresses concern, he makes no suggestion that the parameters used in the present assessments are inappropriate. Sinclair states that he has no particular problem with the way in which the size frequency of the commercial and recreational catches were estimated.

- *Natural Mortality*

Sinclair comments on the considerable disagreement between Goodyear and Rothschild regarding the natural mortality (M) rate of the adult stock (as does Stokes - see earlier section on growth and size at age). Goodyear performed an assessment using 3 values of 0.1, 0.15, and 0.2, and favored the lower value. Rothschild *et al.* (1997) used values of 0.2, 0.25 and 0.3, and favored the higher value. Sinclair notes that all other things being equal, a higher M leads to a higher spawning potential ratio (SPR). He goes on to compare the longevity of red snapper (through the frequency of older fish in the otolith samples) with that of data he has on the cod stock from the southern Gulf of St. Lawrence, for which the generally accepted value of M is 0.2. He concludes that, given the data presented on red snapper, he favors estimates of M lower than 0.2, and he states that he finds it difficult to accept estimates in the range proposed by Rothschild *et al.* With respect to dealing with uncertainties in M, Sinclair notes the difficulties in estimating M directly and concludes that the best approach may be that taken in the assessments - i.e., to examine the implications of a range of possible values on management decisions, and ask the question "what happens if we assume M = X when in fact M = Y".

Balancing Sinclair's comments, McAllister notes that one of the methods used to estimate total mortality rate Z (and by inference an upper bound on the value of M) - that of Hoenig *et al.* (1983) - can lead to negative bias in the estimated value, if the assumptions of the method are invalid. According to the method, using the oldest observed age of 53 years and the total number of fish sampled of 6803, the estimate of Z came to 0.18, implying that M must be smaller, say around 0.1. The method assumes that samples of individuals are taken randomly from the population, and that

recruitment and total mortality are constant. Goodyear (1995) acknowledges that none of these assumptions are valid for red snapper. McAllister explains that sampling of individuals in the population by commercial and recreational gear is nonrandom. The estimate of total number sampled ignores any of the fish (i.e., the smaller and undersized individuals) that were discarded by fishermen in each of the samples and the possibility that commercial and recreational gear may be biased towards sampling older individuals. Thus, sample size may be underestimated. If this is so, then estimates of natural mortality based on this method may be negatively biased and the true value for the rate of total mortality, *Z*, could be considerably larger than 0.18.

According to Stokes, the most important aspect of *M* is that of juveniles. It is the combined effect of juvenile *M* and bycatch mortality, which determine the level of recruitment to the mature component of the stock. He notes that transitional SPR is critically dependent upon the level of recruitment remaining available to the commercial fishery and concludes, therefore, that if juvenile mortality is poorly determined, then efforts to obtain precise estimates of bycatch mortality may be somewhat futile. He expresses concern that despite the critical nature of estimates of juvenile *M* the forecasts and possible decision making, there is no strong scientific evidence for an appropriate level. He believes that the levels used by Goodyear and Galloway and Gazey are all speculative and warrant urgent refinement.

Sinclair also notes the importance of the estimates of juvenile *M* and the effect on recruitment. He suggests that it would be worthwhile considering a range of *M* for juveniles (see also section on Sequential Population Analysis), in a similar way to the adults. He also suggests a possible experimental approach to estimating *M* for juveniles, which involves closing a limited number of areas to shrimp trawling and other potential forms of juvenile red snapper mortality, and conducting quantitative abundance surveys over these areas. The existing SEAMAP and groundfish surveys could serve this purpose. The objective would be to compare estimates of total mortality (Z) for these areas before (current) and after the closed areas were implemented. Sinclair acknowledges that the closures would have to be large enough to preclude immigration / emigration of red snapper.

Targett makes no specific comment regarding the estimation of mortality rates, nor does Sutinen, except in relation to uncertainty, in his specific response to question 5 (see later in this section).

Landings

In relation to the programs for recording landings statistics, of the five panel members only McAllister includes comments in his report. His comments are summarised here, but this is should not be construed as tacit acceptance of his conclusions by the other panel members.

McAllister concurs with the findings of the Statistics Panel the procedures for estimating total commercial landings appear to be adequate (see also section 4.1.2, this report). He is concerned, however, about the uncertainties associated with:

- illegal landings by Mexican vessels, taken from US waters, which in some years have been quite substantial, up to 1 million pounds; and
- dock and road side sales and sales made directly to restaurants which are not accounted for and he believes should be evaluated.

McAllister also reiterates and concurs with the findings of the Statistics Panel regarding the charter boat and headboat landings, in particular:

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- the charter boat program operated from the Panama City Laboratory is voluntary, with a small number of participants;
- sparse coverage of the charter boat fleet;
- failure of operators to cooperate in supplying information; and
- requirement for a more effective sampling program.

In relation to the problems associated with charter boats, McAllister concludes that the suggestion by Kaiser (1997), that, for sampling purposes, this fleet be treated as a commercial fishing fleet, should be taken seriously (see also section 4.1.3, this report). In his view, a sampling program that included the installation of observers on charter boat operations to record catches and discard numbers and fish sizes would be a reasonable alternative to the present system. As another possibility he also suggests is the introduction of a law that requires charter boat fishermen to accurately fill out and submit logbooks in a timely manner under threat of loss of their right to operate.

Discard mortality

Of the Science and Management Panel members only McAllister and Stokes discuss the issue of discard mortality rates for red snapper. McAllister briefly reviews the experimental results from which estimates of mortality were obtained. He notes that release mortality studies yielded highly variable estimates between 1% and 44%, and that, by contrast, a graph of the disposition of red snapper from handline catches suggests that at least 80% of discarded individuals appeared to be stressed (Fig. 56, Goodyear 1995). He takes this latter result to indicate that the discard mortality rate at least for commercially landed red snapper may be under-estimated. He concludes that in view of the relatively high percentage of the catch discarded in recent years (30%-40%) in both the commercial and recreational fisheries, it would be appropriate to attempt to apply as accurate as possible an estimate of discard mortality rates. Stokes and McAllister record that a higher discard mortality in the commercial fishery (80% as opposed to 25% and 33% in the directed and recreational fisheries) was used in the four forecasts run for the panel at the meeting. Stokes also notes that discard mortality rates are seen to be influential on possible levels of TAC given a particular bycatch reduction (with particular bycatch estimates)

Surveys and observer programs

In relation to the summer SEAMAP and fall groundfish surveys, McAllister notes the advice of certain members of the Statistics Panel that :

- the geographic range of these surveys should be expanded in response to the many new detections of red snapper in the last year made on the periphery of the range of the survey (see section 4.1.4, this report);
- the surveys be restratified, to enable the estimation of precision in survey estimates of snapper abundance (see section 4.1.4, this report); and
- efforts be made to ensure that the relative catchabilities of different vessels (e.g., by vessel intercalibration studies) are accounted for if research survey vessels are to be changed in future surveys (Hayes - see section 4.1.4, this report).

Both McAllister and Sinclair stress the need for a permanent observer program in the shrimp fishery for the empirical monitoring of the bycatch of red snapper (see section 4.1.7, this report). Sutinen also mentions the use of this approach for monitoring bycatch in Canadian fisheries. Issues related to bycatch are further covered under section 4.1.4.

McAllister notes suggestions made by all of the members of the Statistics Panel regarding the MRFSS; specifically that the survey is adequately designed and implemented, but that there was a need to increase the sample coverage in some way to improve the precision of estimates of catch and effort. He also notes the doubts about the feasibility of increasing sampling effort due to excessive cost and the suggestions to compare the results of the MRFSS with the Texas Marine Sports Harvest Program. He does not indicate whether he concurs with these suggestions.

However, McAllister does concur with recommendations of two of the Statistics Panel regarding the need to maintain on an annual basis an observer program in the commercial red snapper fishery to:

- estimate the number and length frequencies of discards in future years (Hayes, section 4.1.2, this report); and
- obtain more accurate, representative samples of length frequencies of actual landings, since shore-based sampling programs appear to be flawed (Kaiser, section 4.1.2, this report).

McAllister explains that obtaining an accurate annual estimate of discards is important because of the large proportion of discards in fish brought on board, the discrepancy between observer and logbook records of discards (e.g., 40% and 30%, respectively), and the potential interannual changes in discards as a result of future changes in regulations and shifts in the age structure of the population.

Model specifications and assumptions

Of the five members of the Science and Management Panel, only three provided detailed comments on the specifications and assumptions of the various models used to assess the status and potential of the red snapper stock. These comments are presented here, but, as before, they should not be taken as giving any indication of the views of the panelists who did not comment on these specific issues in their reports.

Several points were raised by the reviewers with regard to the detailed implementation of the analyses. However, they also all express caveats at some stage in their reports in relation to their ability to comment on the detail of the assessments. Stokes explains that overall, he would only be willing to comment on the detail of the assessments if he were to undertake the analyses. In his view, the only way to evaluate assessments is to have the data and do the analysis, producing all the detail for full consideration. In the introduction to his report, McAllister writes that in the time available he was not be able to address the questions in as much detail as he would have liked and instead focused in on key areas that he believes warrant attention. Likewise, in his response to question 4 (see below), Sinclair considers that to evaluate whether the model results and conclusions are the *most* sound would require a careful assessment of the data, which in his view was beyond his mandate. Nevertheless, the following sections cover points were raised with respect to the models themselves and their implementation in the assessment of red snapper.

- *Assessments presented to the review panel*

Goodyear's assessment (Goodyear 1995) included an application of the modified version of the ADAPT procedure for Virtual Population Analysis (VPA) known as Sequential Population Analysis (SPA). He also evaluated the potential consequences of alternative management regimes for red snapper using a projection analysis (LSIM - Goodyear 1989).

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Dr. Brian Rothschild's group at the University of Massachusetts was commissioned by NMFS to perform a stock assessment of red snapper independent from Goodyear's (1995) (Rothschild *et al.* 1997). Rothschild obtained raw data and reworked it using differing methods and assumptions to those of Goodyear. They provided independent estimates of growth rates, total mortality rates, fishing mortality rates, stock biomass, bycatch, and measures of relative spawning potential, among other things. They did not quantitatively evaluate the potential adequacy of the current management measures in achieving the management targets in the FMP. No management strategy projections were carried out as in Goodyear's (1995) analysis.

Bill Gazey provided projections of alternative management scenarios using Goodyear's projection method (LSIM), incorporating the results of an alternative approach for estimating bycatch in the shrimp fishery presented by LGL and and alternative values of *M* for age 0 and 1.

- *Sequential Population Analysis (Goodyear and Rothschild et al.)*

Stokes, Sinclair and McAllister all independently express the opinion that the Goodyear's SPA was in general appropriate for the assessment of red snapper, given that a construction of catch-age data was available and data series existed to which the procedure could be tuned.

Stokes views the residual plots of CPUE for the tuning indices in Goodyear's analysis as indicating that the assessments are sound for the values of adult natural mortality tested. He notes, however that the way in which juvenile catch (as bycatch) was accounted for post-assessment is unusual. He believes the approach is sound, but would have preferred to see a direct seasonal analysis with all catch components considered within one integrated model. He suggests this would provide a more convenient basis for direct production of error estimates to feed into forecasts.

Overall he describes both the assessments by Goodyear and Rothschild *et al.* as impressive in their scope. He regards the Goodyear assessments as comprehensive, taking account of all available material and knowledge in such a way as to provide a solid foundation for decision making. He notes that the alternative assessment intentionally takes a critical view of the assumptions used in Goodyear's assessment. It highlights important areas of uncertainty and attempts to point out implications for the assessments that might result. In his view, however, the details of the Rothschild *et al.* assessments are lacking relative to the critique of the assumptions, and the implications for forecasting and decision making and are not addressed. More specifically, he explains that it is brief in its report of the analytic treatment of the VPA, does not include bycatch and is effectively untuned. He explains that comparison and evaluation is consequently difficult.

Reviewing Goodyear's analysis, McAllister regards the CPUE series derived from the MRFSS program as the best CPUE series available since it comes from a well designed and implemented survey program. However, by contrast, he believes that the other tuning index, the age 1 CPUE series constructed by combining two different series - the Fall Groundfish Survey (1971 to 1981) and the Summer SEAMAP series (1982 to 1994) - could be very imprecise and biased. He cites possible sources of imprecision and/or bias as follows:

- the two stage procedure, in which conversion parameters estimated in one period were applied to data in another period, used to make the two series comparable (see McAllister's report for details);
- prediction error: the values of r^2 in the two regressions used to estimate the conversion parameters between the two survey series were 0.70, and 0.62, respectively; and
- any trends in growth or survival rates over the period of the surveys 1971-1994.

McAllister further notes that distributions of age frequency could be biased due to ageing error and sampling bias giving rise to bias in growth rates and CVs of length at age. Sinclair also notes that the calibration process relies heavily on the estimated growth function to obtain length at age and its variance, and on the recruitment index to set year-class strength. He suggests that it would be informative to perform a retrospective analysis where the calibration is done on successively shorter data sets, e.g., to 1994, to 1993, to 1992, etc. Trends in *F* and recruitment could then be investigated for variation and bias.

McAllister expresses concern that no sensitivity analyses were conducted on *M* for ages 0 and 1, despite the considerable uncertainty in these two quantities, whilst a range of values were investigated for ages 2 and greater. Furthermore, no empirical analysis was presented to support the values used (0.5 and 0.3 for ages 0 and 1 respectively in Goodyear's 1995 forecasts), and during the panel meeting, Benny Gallaway presented one laboratory study to indicate that the two values could be much larger. McAllister suggests that reasonable alternative could perhaps be 1.0 and 0.5 and considers that more work is needed to attempt to obtain better estimates for these quantities. In conclusion he expresses the view that there could potentially be a large set of covarying biases in the various inputs to the assessment - including assumed values for fecundity, *M*, and growth rate, and the age frequency distributions.

Sinclair also stresses that at the time of the panel meeting Goodyear's assessment was 2 years out of date. In his view it will be very important for NMFS to continue the assessment work and stock monitoring, particularly given the importance of the stock and the volatility of the fishery. He suggests that future work on the assessment should investigate ways of estimating the variance of the simulated population state variables, specifically the estimates of year-class strength in the final year of the assessment. This information is essential for undertaking risk analysis of management alternatives.

Sinclair had difficulty in comparing the alternative analyses undertaken by Rothschild *et al.* (1997) with those of Goodyear, as did Stokes (see above). He found the SPA presented by Rothschild *et al.* difficult to accept and includes a detailed explanatory commentary in an annex to his report. In summary he cites the following problems:

- the assessment appeared to be unfinished, probably due to the complexity of the task and the time frame available;
- major disagreement in the value of *M* assumed for the adults (see section on natural mortality), giving rise to the main difference between SPR estimates;
- use of a combined age-length key across all years to calculate catch at age for the SPA, effectively smoothing out variations in year class strength and giving rise to inconsistency with the treatment of the age specific tuning data;
- difficulty in interpreting the SPA diagnostics and the calibration procedure;
- no account was made of the influence of variations in juvenile by-catch mortality on the relationship between the recruitment indices and the SPA estimates;
- the assessment basically ignores consideration of by-catch mortality; and
- the authors may have misinterpreted the meaning of SPR.

He concludes that their estimates of SPR are questionable given the problems with the VPA calibration and they should not be accepted until the tuning procedure is better explained.

McAllister concludes that Rothschild *et al.*'s estimates of %SPR are larger that Goodyear's largely because they left out discard mortality and bycatch in computing *F*, assumed higher values for *M*, and

used a static estimate of %SPR. He also reviews the different measure of spawning potential used by Rothschild *et al.*, which differs significantly from Goodyear's transitional SPR. He notes that it is more like a static SPR because it uses the estimated constant value of *F* rather than that estimated for each age class.

- *Management Strategy Projections (Goodyear, Galloway and Gazey)*

McAllister summarizes the procedure used by Goodyear (LSIM, Goodyear 1989), by which the potential consequences of alternative management regimes for red snapper are evaluated. He explains that this type of analysis is essential to a rational, objective protocol for providing scientific advice to fishery management. It provides the Council with an objective quantitative means of evaluating the potential trade-offs of the alternative stock rebuilding options. In Sutinen's view, the model developed and applied by Goodyear is structurally sound. However, but both he and McAllister express concern that slight changes in the model's input parameters result in very different stock recovery outcomes. These parameters include assumptions about the form of the stock-recruitment relationship and how it was estimated, and the values assumed for *M*, *F*, fecundity-at-age, discard mortality rates, discard rates, and bycatch in the shrimp fishery.

Both McAllister and Sinclair raise the same concern regarding the method used to estimate the stock-recruitment function. In the fitting procedure, the largest historic observation of recruitment is assumed to be the value for the asymptote of the stock-recruit relationship. McAllister considers this to be a rather arbitrary step which could potentially bias the stock-recruit parameters. Both he and Sinclair also note that the largest observed recruitment comes from a period in which there are no spawning stock observations. Sinclair comments that as a result of the fitting procedure, the relationship would predict that the average recruitment at large stock size would be equal to the largest ever seen. He warns that this extremely optimistic relationship could be very misleading. Since the catch projections include an assumed reduction of juvenile red snapper by-catch in the shrimp fishery, these fish are projected to recruit to the spawning population and subsequently generate increased production of young fish. He concludes that the predicted success of the fixed adult TAC management plan is almost entirely due to this projected increase in recruitment.

Sinclair suggests that, as has been done with *M* on the adult stock, it would be informative to repeat the catch projections using alternative stock/recruitment functions. One option he proposes would be to assume that recruitment is essentially a random event and the distribution of possible recruitment is restricted to those previously observed. Both he and McAllister express concern that there is a serious possibility of a depensatory stock-recruit function, one in which recruitment reaches an extremely low level well before spawning stock size is completely depleted (referring to the patterns of stock-recruit observations in Figures 39 and 40 of Goodyear (1995) which show negative Y-intercepts, when a straight line is fitted through the observations). McAllister warns that if this is the case, then use of the Beverton-Holt stock-recruit function without depensation would provide overly optimistic forecasts of recruitment at low stock sizes. He recommends that, along with uncertainty in stock recruit parameter estimates generally, this serious possibility of a depensatory stock-recruit function should be incorporated in future policy projections. He notes that the stochastic approach to projecting recruitment presented in Goodyear (1995) provides slightly more pessimistic forecasts than the deterministic version and that Goodyear agreed at the panel meeting that the stochastic approach was more defensible. Thus he recommends that future evaluations should continue to incorporate stochastic recruitment.

Stokes, however, points out that the stochastic runs only take account of a small degree of uncertainty (i.e., that in recruitment). No account is taken of estimation error of numbers-at-age, fishing mortality

rates and SPR in the assessments, of uncertainty in juvenile or adult natural mortality or of alternative bycatch or discard estimates. Sutinen concludes that since there is considerable uncertainty about the true parameter values, management measures should be set such that the odds of stock recovery are high and the risk of stock recovery failure low. With this in mind, he reiterates that, in his view, the current set of management measures have an unacceptably high risk of failure. The issue of uncertainty is covered in more detail in the responses to question 5.

Sinclair notes that there are no comments in the assessment regarding the potential biological interactions between red snapper and other fish species that would potentially survive if the fish by-catch in the shrimp fishery was reduced. He cites the North Sea multispecies VPA and interactions between seals and two species of hake off south west Africa as examples of assessments where this type of information is incorporated. He explains that he has no reason to believe that this would be a significant issue in the Gulf of Mexico, but in his view it is worth considering, given that red snapper constitutes less than 1% of the by-catch in the shrimp fishery and that over 300,000 t of fish are taken annually as by-catch. He poses the question - are any of these other fish species potential predators on red snapper juveniles?

McAllister makes several comments on the alternative approach to estimating bycatch in the shrimp fishery presented by LGL. Although the estimation still suffers from having to use data collected in a far from ideal sampling design, he believes that the alternative presented provides some significant improvements over the current NMFS approach. Specifically:

- the stratification used appears to be more sensible and reduces the some of the serious problems in the NMFS analysis;
- the creation of larger strata by summing catches over weeks rather than dealing with catches per tow reduces considerably the number of units with zeros for observations and the resulting biases from having a large fraction of units with zero catches;
- the north and south stratification of units for inference are also based on several sensible criteria; and
- separation of the data sets into two time periods of 1972-1984 and 1985-1996 lowers the extent of extrapolation required to years without observer data.

None of the other panel members commented specifically on the approach taken by LGL, confining themselves to consideration of the results of using the alternative estimates in the assessment (see responses to question 4).

Question 4 - Interpretation of all available information

> *Are the model results and conclusions from the assessments the most scientifically sound interpretation of all available information?*

Stokes and Sinclair share the same problem with the wording of this question. Stokes believes that whether or not the results and conclusions are *the most scientifically sound* is endlessly debatable. Sinclair would prefer to rephrase the question to ask if the conclusions are scientifically sound. He believes that to evaluate whether they are the *most* sound would require a careful assessment of the data, which he considers is beyond his mandate.

Stokes explains that the uncertainties associated with fisheries science can only be reduced by substantial research and monitoring. Consequently it is always possible to produce new models and

new interpretations. Sinclair shares much the same view, referring to the way in which progress is made in increments by developing new methods, beginning new data collections, exploiting old data sources, and investigating the effects of specific management initiatives. Stokes concludes that the important point is that the models used by NMFS for red snapper assessment work are sufficient to provide advice that is robust to the uncertainties and which can hence lead to management decisions which are similarly robust. In his opinion the results are robust with respect to the resulting advice and decisions which need to be taken, although this is tempered by his comments on the results of the projections presented to and undertaken during the meeting (see below)

Sinclair shares this view, and makes the following specific comments on the assessment:

- The Goodyear assessment is a reasonable and sound treatment of the data.
- The analysis of biological parameters was consistent.
- Using a range of adult *M* from 0.1 t 0.2 was a good idea.
- The various scenarios of *M* and by-catch were taken to the end point of asking whether the proposed management actions were likely to result in reaching the management objective.
- A juvenile *M* of 0.5 and 0.3 for ages 0 and 1 respectively seems a little conservative, but the committee requested and received runs with Ms much higher (1.5 and 0.75 respectively);
- The estimates of red snapper by-catch [resulting from the 'low' estimates of juvenile mortality] were high, but using the lower LGL estimates had little effect on the main conclusions.

In addition to the extra projections (see below), Stokes notes that Goodyear re-ran the assessments (but not projections) under a variety of conditions:

- two levels of juvenile natural mortality (1.5 and 0.75 or 0.5 and 0.3 at ages 0 and 1 respectively);
- LGL or NMFS bycatch estimates; and
- higher and original discard mortality.

The static SPR was decomposed under the various assessments into contributions from commercial and bycatch fisheries and Stokes provides the results for 1984 and 1991 in the following table.

Static SPR		**Low Discard Mortality**				**High Discard Mortality**			
Bycatch →		**NMFS Estimates**		**LGL Estimates**		**NMFS Estimates**		**LGL Estimates**	
Juvenile *M* →		**M low**	**M high**	**M low**	**M high**	**M low**	**M high**	**M low**	**M high**
Commercial	**1984**	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%	2.7%
	1991	5.1%	5.1%	5.1%	5.1%	4.1%	4.1%	4.1%	4.1%
Bycatch	**1984**	24.5%	35.4%	31.2%	46.9%	25.5%	36.5%	32.3%	48.1%
	1991	8.4%	17.1%	12.3%	25.6%	7.3%	15.0%	10.8%	22.9%
Total	**1984**	0.7%	0.9%	0.8%	1.3%	0.7%	1.0%	0.9%	1.3%
	1991	0.4%	0.9%	0.6%	1.3%	0.3%	0.6%	0.4%	0.9%

He concludes from these results, as did the other panel members (see also responses to question 1) that regardless of the source of the bycatch estimate, the assumed juvenile natural mortality rates and the discard survival values, the overall SPR is very low - well below the overfishing definition of 20%SPR.

Sutinen also considers that the assessments of current red snapper stock status are scientifically sound, but in his view, the assessments of stock recovery under the management measures (a TAC of 9.1 million pounds and the use of BRDs in the shrimp fishery) are not. He notes again the considerable uncertainty with regard to

- the true parameters governing red snapper productivity;
- the effectiveness of BRDs to reduce red snapper bycatch; and
- the amount of bycatch in the shrimp fishery.

Therefore, he believes that the conclusion that the stock will recover by the target date of 2019 is not sound. The risk that the stock will not recover is very high and the management measures are too risk-prone to be scientifically sound. He also believes that the assessments of the economic consequences of the proposed and alternative management measures are inadequate. He defers to the Economics Panel on the soundness of the analysis undertaken by Ward (see section 4.2), but would like to see a comprehensive economic analysis of alternative stock rebuilding programs. He also raises the issue of what he refers to as the allocation of fishing mortality among user groups. He points out that no scientifically sound evidence was presented to the panel showing that the 9.1 million TAC to the directed fisheries and use of BRDs in the shrimp fishery is an economically sound allocation among the user groups.

Stokes summarizes briefly the projection runs made from which the review panel was able to draw its conclusions. He explains that in his 1995 assessment, Goodyear ran eight quota and bycatch reduction scenarios at each of three natural mortality levels. These 24 scenarios were run deterministically but also stochastically, 500 times each, with lognormally distributed recruitment. Gazey presented a number of deterministic projections to the panel in which alternative bycatch estimates (LGL), juvenile natural mortality rates and a stock-recruitment formulation were used. A total of twenty deterministic projections were made. Goodyear ran a further four deterministic projections for the panel.

Both Targett and McAllister explain the background and inputs into the additional projection scenarios run at the panel meeting. In summary:

- discard morality was increased to 80%;
- age 0 and 1 rates of natural morality were increased to 1.5 and 0.75, respectively;
- the LGL estimates of bycatch replaced the NMFS estimates; and
- the age 2+ value for M was held at 0.1.

Several panel members provide tables of the results of these projections in their reports, and conclude from them that mortality from both the directed fishery and bycatch will have to be reduced below current levels, to provide for red snapper stock recovery by 2019.

Stokes makes a number of general points on the strength of the projection results:

- The forecasts are sensitive to a number of inputs - bycatch estimates, juvenile and adult natural mortality and possibly discard mortality in the commercial fishery are all important and a better knowledge is required of these factors (as noted by both Sutinen and McAllister in the previous section);
- Regardless of these sensitivities, errors in estimation fed into stochastic forecasts would likely lead to far more pessimistic advice and management action than the range of deterministic forecasts indicate; forecasts taking account of uncertainty need to be made; and
- If SPR is to be increased, real reductions in bycatch will need to be brought about.

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Several panel members focus on a projection in which the current policy (50% reduction in bycatch mortality by 1997, Goodyear's (1995) estimates of discard mortality) was evaluated and the rates of juvenile mortality were set to 1.5 and 0.75 (as above) and the LGL values for bycatch were used. Targett notes that under these circumstances a TAC of 8 million lb. would not permit stock recovery by 2019. McAllister notes that only when the TAC was lowered from 9 million to 6 million pounds did %SPR exceed 20%SPR by the year 2019. Both he and Targett independently conclude from this that if uncertainty is to be accounted for, the TAC must be reduced to 6 million pounds or less if the rebuilding target is to be reached in the desired time.

Stokes also concludes that bycatch reduction in the shrimp fishery should be at least 50%, from current levels, and with a 50% bycatch reduction, the commercial TAC should be set no higher than 6 million pounds. He further notes that if bycatch is not reduced by 50% or more, the commercial TAC will need to be set at a lower level; perhaps as low as zero if no bycatch reduction can be achieved. He regards these conclusions as robust, but notes the need for more work on incorporating estimation error into the projections, refining estimates of bycatch and natural mortality and investigating scenarios with a realistic range of potential bycatch reductions to find appropriate commercial TACs which will permit SPR to recover to 20% within the specified time frame.

Targett similarly notes that even these results may be over optimistic since the release mortality rates (20% in the recreational fishery and 33% in the commercial fishery) used in the Goodyear (1995) assessment model are probably underestimates of actual release mortality and regulations to reduce bycatch mortality in the shrimp fishery were not begun in 1997.

Question 5 - Expression of uncertainty

> *Are uncertainties in the assessments and their management implication adequately expressed to allow informed management decisions?*

The treatment of uncertainty in the various assessments presented to the panel is discussed throughout all the panelists' reports and indeed forms a central theme in the evaluation of management strategies aimed at achieving the stock rebuilding target. This section provides summary responses to this question as they appear in the reports. For additional detail on the possible effects of uncertainty, and suggestions for ways in which it could be better accounted for, the reader is referred to responses to all the previous Questions, and to section 4.1.5.

Uncertainties in the assessments are addressed in a simple manner through sensitivity analyses and stochastic forecasting. All the panel members express in various ways the opinion that as a basis for management advice, insufficient account has been taken of the large amount of uncertainty in the assessments and input assumptions. In particular, several panelists specifically suggest that more account needs to be taken of uncertainty in bycatch estimates and juvenile natural mortality. Stokes explains that uncertainty is a major factor in what decisions will need to be taken with respect to the management of red snapper and interacting fisheries. In his view, it is likely, given the large amount of uncertainty in assumptions and data that flow to the assessments from a variety of sources, that only scenarios with much more stringent TAC reductions and/or bycatch reductions could possibly lead to recovery to 20%SPR within the desired time frame.

Stokes goes on to point out that even if uncertainty were eliminated in the biological inputs, the forecasts are still all optimistic. For example, they all assume constant quotas, which in his view are untenable. Both he and McAllister explain that as SPR rises, so too must CPUE. As a result, either the

TACs would rise (and SPR recovery would be delayed) or the take up of quota in the "Derby fishery" would be faster and faster. McAllister also believes there will be added incentives to under report catches. Stokes points out that as red snapper fishermen all operate under a Reef Fish Permit, effort would presumably be redirected to general reef fisheries where red snapper would still be caught as a non-target species. Additionally, high-grading might occur. Again, the recovery of SPR would be delayed. Both Stokes and McAllister also note that the assessment assumes that BRDs will work as planned and produce the modeled reductions in bycatch mortality rates. 50% reductions may not in fact be feasible through technical measures - and as shrimp effort is apparently increasing, technical bycatch reductions of greater than 50% may be necessary. Stokes notes, however, that if an alternative licensing regime were to be adopted, these aspects might be less important.

Sinclair is also of the opinion that uncertainties are not adequately expressed. He considers it was informative to see runs with different assumptions of *M* and by-catch estimates, but in his view, this was not an adequate exploration of the assessment uncertainties. He explains that managers may be interested in an evaluation of the probability that a given management action will produce the desired result. If the emphasis is on resource conservation, they may wish to have a relatively low probability that the objective will not be achieved. By presenting only the point estimates of population size and *F*, the managers cannot consider anything other that the average or median outcome. In this regard, Targett states that it is necessary to use the best estimates available, while clearly recognizing the uncertainties, and be certain to err on the side favoring the fishery resource.

In summary Sutinen states that:

- the extent of sensitivity analysis is too limited;
- none of the assessments adequately expresses the risk of not achieving recovery associated with the management measures; and
- some indications of likelihoods need to be expressed in the assessments and explicitly accounted for in the management decisions.

McAllister provides a useful listing of the key uncertainties in the management of red snapper:

(1) Bycatch of red snapper in the shrimp fishery

(a) The magnitude of snapper bycatch in historic years.
(b) The effectiveness of certified BRDs in reducing bycatch mortality rates.

(2) Aging error and life history parameter estimates.
(a) The extent of ageing error and its implications for estimation of life history parameters and age frequency distributions used in VPA.
(b) Estimates of life history parameters for the rate of natural mortality-at-age, growth, fecundity, variance in length-at-age.

(3) Discards
(a) Discard mortality rates for the recreational and commercial fisheries.
(b) The effect of different minimum size regulations on the rate of discarding.

(4) The stock-recruit relationship.

(a) The true level of replacement %SPR.
(b) The functional form of the stock-recruit relationship (e.g., is it depensatory?).

(c) Estimates of the stock-recruit parameters
(d) The effect of historic and future changes in the marine environment on the stock-recruit relationship.

(5) Stock Structure

(a) what is the spatial extent of the red snapper stock?
(b) are removals for the current stock accurately estimated? (e.g., are the Mexican illegal takes of red snapper in U.S. waters)?

(6) Economic responses to new fishing regulations

(a) how will the incentives for under reporting, illegal fishing, and overcapitalisation change with the changes in fishing regulations?
(b) how will the value of landings be affected by new regulations?

He views that the scientific advice supporting the current management regime is not robust to uncertainty, and speculates that there is a non-negligible risk that stock rebuilding will not occur as desired because of uncertainties in the scientific assessment.

Question 6 - Consistency with the Precautionary Approach

> *Is the current management of red snapper in the Gulf of Mexico and the scientific advice consistent with a precautionary approach to fisheries as expressed in the United Nations Food and Agriculture Organization Code of Conduct for Responsible Fisheries?*

The FAO Code of Conduct sets out principles and international standards of behavior for responsible practices with a view to ensuring the effective conservation, management and development of aquatic living resources, with due respect for the ecosystem and biodiversity. In responding to this question, the panelists have chosen to focus on particular aspects of the FAO Code, which they see as the most applicable in this case. Once again, not all panelists have chosen to comment on all aspects, and where no comment is made, this should not be taken as tacit agreement with the comments of the other panel members.

Management decision processes and management objectives

Stokes believes that in terms of management decision processes and inclusion of interested parties, the management process is consistent with the FAO Code. In his view, the legal framework in the USA (the Magnuson-Stevens Act), and the system of management through the Councils, is reasonably consistent with the principles of Fisheries Management set out in Section 7 of the FAO Code. He believes that the provision of Guidelines by NMFS for defining Optimum Yield (OY) and overfishing attempts to emphasise a practical, scientifically based, support for strategic management. He notes that these Guidelines are the subject of frequent, but thoughtful, review and form the basis for fully fledged management plans as called for in Section 7.3 of the FAO Code.

Stokes does, however, express concern over the specific definitions of OY and overfishing for red snapper (see section 4.1.3 for details). He believes that if the reference points for red snapper are to be set on a single species basis, consideration should be given to raising the OY to 30-35%SPR. He

notes that published studies have indicated that such a level is likely to be closer to MSY for many stocks. Sinclair shares this view. In his experience, SPR in the range of 20% will produce fishing mortalities in excess of that needed to produce MSY. He believes that SPR in the range of 30% to 40% are more likely to produce fishing mortality consistent with MSY. In addition, he notes that it will take much longer for a stock to recover to a state capable of producing MSY if the target fishing mortality is MSY than it will if the fishing mortality is set much less than MSY, for example 0.5 or 0.25 F_{msy}.

McAllister also expresses concern regarding the management objectives. He notes that, as required by the precautionary approach, the regulations include provision for biological reference points for management, and stock conditions and management actions with respect to these reference points. However, he points out that the management regulations ignore empirical uncertainty in the reference points selected. In summary:

- He questions whether 20%SPR is close to the replacement SPR and suggests that the regulations could require a re-evaluation of the appropriateness of the 20%SPR overfishing reference point once more stock recruitment data become available.
- He suggests that the same applies to the suggestion of 30%SPR as OY. In his view this appears to be completely arbitrary and an estimate of MSY, based on S/R observations for red snapper, once more observations become available, seems more appropriate.
- He notes that uncertainty in the 1.5 generation time horizon is also ignored with the adoption of the year 2019 as the target date for stock recovery from the overfished state. He points out that if, for example, the rate of natural mortality is higher than the current assumed value of 0.1, then this date is too distant.

Sutinen comments that whilst the fishery management plan does have a 'stock-specific limit reference point,' (20%SPR), measures have not been taken 'to ensure it not be exceeded' (paragraph 7.5.3.b, FAO Code).

Excess fishing capacity and bycatch

Both Stokes and Sinclair regard excess fishing capacity and other conditions set out in Sections 7.2.2 and 7.2.3 of the Code as a remaining problem for the red snapper and associated fisheries. Sinclair believes that it is clear from the development of the derby fishery that resulted from the imposition of TACs that the fleet capacity far exceeds the resource potential and steps are needed to reduce it.

In Stokes' view, excess capacity in the Gulf of Mexico shrimp fishery, with its associated large bycatch of red snapper and other species, is also a problem which needs to be tackled. He believes that bycatch is the one area in which management which affects red snapper is not yet consistent with the FAO Code. Bycatch of juveniles is a major source of juvenile mortality and has a profound effect on SPR. Although investigations are being undertaken to develop gears which might reduce bycatch rate, he believes there is no evidence that sufficient thought has been given to reducing total bycatch of red snapper and other reef fish. He notes that paragraph 7.2.1g of the Code calls for reductions in catch of non-target species using selective gears, although this is *to the extent practicable*. He believes that the problem of red snapper bycatch is sufficiently large that besides the use of selective gears (BRDs), more direct means of reducing bycatch should be investigated (effort/capacity reduction and or re-location of effort), along with their associated economic implications. In his view, this would be consistent with both Paragraph 7.6.9 of the FAO Code and the recent National Standard Guidelines on National Standard 9 (*Federal Register* Vol. 62 No. 149), which require Councils to prioritize bycatch programs in their fisheries monitoring.

Data collection and scientific input into the management process

Stokes views the apparent general weakness in the quality of the basic data which flow into the assessments and forecasts as perhaps the greatest weakness of the red snapper management process. He notes that this is at odds with the conditions set out in much of Section 7.4 of the FAO Code. Nevertheless, in his view, the science carried out by NMFS for many years has been good, and proper attempts have been made to ensure that science has fed into the decision making process. This is fully in accordance with Para. 7.4.1 of the FAO Code. He also notes that the data gathering schemes set up by NMFS are expensive and extensive, and whilst they could in theory be improved, as suggested by members of the Statistics panel, this would be at great cost. He considers the problem in data collection and consequent data and assessment quality, is that the fisheries themselves are widely distributed and prosecuted by a large group of fishermen switching activities in time and space. In his view, the mixture of small and industrial scale operations and the economically important shrimp and recreational fisheries, conspire to create an exceptionally difficult data collection problem. He therefore suggests that criticism should perhaps be qualified with praise that so much has in fact been achieved.

The Precautionary Approach

The issue that most of the panelists focus on in relation to the FAO Code is the application of the Precautionary Approach to Fisheries (Section 7.5). In particular, Sinclair notes that *The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures* (FAO Code, paragraph 7.5.1). In his view, while there remains considerable uncertainty about the current status of the resource and the expected outcomes of reducing the juvenile by-catch and adult fishing mortality, it is abundantly clear that the stock is seriously overfished. He states that these uncertainties should not be used as a reason for inaction.

Stokes also advocates action on the basis of available information. He notes again the considerable uncertainty in many of the inputs used in the forecasts, but in his view NMFS have attempted to use best estimates which, in all cases, also result in the most cautious forecasts. He suggests that, unless it can be demonstrated that bycatch estimates used by NMFS are too high, or that natural mortality rates are higher than assumed, a precautionary approach demands that the currently used best estimates are the forecast inputs of first choice.

In order to be consistent with paragraph 7.5.2 of the Code, Sinclair believes that more use is needed of the uncertainties in point estimates of stock status and catch projections used as the basis for management decisions. He suggests that the council needs to solicit risk analyses of its decisions and adopt procedures that err on the side of conservation. With respect to risk, Targett believes that the Precautionary Approach would dictate reduction in the fishing mortality (directed and/or bycatch) to achieve the goal of 20%SPR by 2019. Sutinen also believes that more conservative, less risk-prone measures are required. Targett suggests that various options be explored to reduce F such that conservative stock recovery projections indicate a high probability of achieving the goal of the fishery management plan. Sinclair also notes that the setting fixed TACs for extended periods of time (15 - 20 years) is not consistent with the Code. In his view, it is important to monitor stock status and adjust TACs accordingly.

Socio-economic conditions

Sutinen notes that the management measures do not take into account the uncertainties relating to socio-economic conditions. He concedes that analyses of socio-economic conditions have been conducted but notes there is little indication that the conditions have been properly considered when formulating management policy. He also notes that the analyses have not characterized the uncertainties relating to the possible socio-economic impacts of the management measures. McAllister concurs with this view, and points out that the regulations appear to create fishing derby conditions and encourage a race to catch the fish, overcapitalisation, and fishing when weather conditions may not be safe.

4.1.3 Objectives of the Reef Fishery Management Plan

At various points in their reports the panel members make comments on not just the conduct and the results of the assessments, but also the actual objectives of the Reef Fishery Management Plan (RFMP). For the most part these comments are relatively brief and are integrated in the responses to the Questions (see in particular responses to question 6). However two panelists, Stokes and McAllister, provided more detailed comments on the definitions and objectives used in the RFMP which fall outside the scope of answers to the questions themselves. These comments are summarised in this section. As before, the fact that other panel members have chosen not to comment in such detail on these issues should not be taken as tacit agreement with the views expressed by Stokes and McAllister.

Stokes notes, for the record, that overfishing for red snapper is defined as harvesting at a rate inconsistent with maintaining, or rebuilding, to a level of 20% transitional SPR. He also notes that, somewhat awkwardly, the definition of OY for red snapper is a harvest rate which maintains at least 20%SPR. These definitions have arisen from published studies which were considered by the NMFS Overfishing Reviews and they have been further commented upon, and reaffirmed, by the Gulf of Mexico SPR Management Strategy Committee (1996). Stokes choses not to question these definitions for this review, but he raises one concern with the definition of OY, which at present does not influence any of the conclusions he reaches in his report. In his view, OY is a "target reference point". The definition of the stock being overfished, however, is a "limit reference point". The former is a point which is aimed at (and which one would expect to over and under shoot with roughly equal probability). The latter is a threshold which one would seek to avoid reaching from above with high probability. If a target is chosen wisely, the threshold should be avoided. From below the threshold (the current state for red snapper), one would seek to reach it with high probability within a reasonable time frame (currently taken as 1.5 generations for red snapper- i.e., by 2019). The current low percentage SPR estimates means that the optimum yield definition requires less than immediate attention at present, particularly given the more immediate concerns over the requirement to more fully account for uncertainty in the assessments. In Stokes' opinion, however, it should, nevertheless, be reconsidered.

McAllister provides detailed comments on the choice of 20%SPR as an overfishing threshold (see his full report in Annex 1 for more details). He notes that recent evaluations of the appropriateness of this target for red snapper in the Gulf of Mexico have supported its application (Anon 1996a; Anon. 1996b). However, in his view there remains considerable uncertainty over whether 20%SPR is an appropriate overfishing reference point for the management of red snapper. He explains that the value of 20% was presumably chosen to reflect the "replacement %SPR" (%SPR_{rep}) (Mace and Sissenwine 1993). %SPR_{rep} has recently been defined as an overfishing threshold and reference point for fishery management in the US and has been applied in several different FMPs (Anon. 1996a, Anon 1996b).

He goes on to explain briefly the derivation of this threshold, and notes that it appears that $\%SPR_{rep}$ is known only very imprecisely for red snapper and the value of 20%, assumed in the FMP, could be very inaccurate. In his view there does not appear to be much empirical support from other species to suggest that $\%SPR_{rep}$ for red snapper is 20%. The actual value could be quite different. However, he notes that the value chosen appears to be conservative since the S/R line that corresponds to it falls well below all of the S/R observations. Having said that, he comments that the calculation of annual %SPR requires accurate estimates of the various quantities such as *M*, fecundity-at-age, and depending on the measure of SPR, *F* for each of the cohorts present in the fishery. For red snapper, estimates of fecundity-at-age and natural mortality rate and thus fishing mortality rates-at-age are only imprecisely known. Finally he presents a brief comparison of the applicability of different measures of SPR and concludes that the unweighted transitional SPR (used by Goodyear 1995), appears to be the most appropriate type of SPR to apply as an indicator of relative spawning potential and an overfishing definition.

In summary, McAllister believes that the weak empirical basis for defining reference points for fishery management of red snapper based on values for %SPR, will improve as more years of S/R data become available as the red snapper stock rebuilds. He suggests that it would appear appropriate to quantitatively evaluate the relative trade-offs between using an empirical estimate of MSY versus $\%SPR_{rep}$ before one or the other was chosen as a reference point for OY.

4.1.4 Bycatch issues

The issue of bycatch of red snapper in the shrimp fishery and its importance for the assessment has already been raised in relation to answers to the Questions in section 4.1.2. This section provides additional detail included in the panelists reports.

In reiteration, Stokes believes that bycatch undoubtedly has a major impact on the red snapper stock and the estimation of the SPR level. In combination with varying assumptions of juvenile natural mortality, the estimated bycatch levels can have a non-trivial effect on forecast levels of SPR. The bycatch of red snapper is composed of 0 and 1 groups. Estimated fishing mortality rates indicate a loss in the order of 90% of potential recruits to the shrimp fishery. Stokes concludes that the results of deterministic forecasts clearly indicate a need for the best possible characterisation of the mortality caused by shrimp fisheries.

Estimation

Stokes notes the considerable effort that has been expended by NMFS and LGL Ecological Research Associates on deriving bycatch estimates of red snapper in the shrimp fishery. Much of the debate seems to have centred on the choice of an appropriate linear model for analysing the bycatch per unit of effort using a variety of covariates, with or without interactions. He notes that both sets of analyses have been criticised and members of the Statistics panel have made useful suggestions for improvements to the models and for alternative estimation schemes and monitoring programs. Stokes stresses the need to resolve issues relating to existing datasets, for example through agreement on how to pre-process the data, and to institute a well designed bycatch monitoring program for the future. This latter initiative should aim to provide unbiased bycatch estimates with associates variance estimates.

Sinclair also remarks on the problems with the quantification of bycatch. He recommends following up on the two options for achieving more precise and justifiable estimates offered by Kaiser (see section 4.1.7). Despite these problems, he believes, as does McAllister that the level of by-catch is

likely to be of sufficient magnitude to have an important effect on red-snapper productivity, and notwithstanding the difficulty in determining the result of any management action to reduce the by-catch, he believes it is clear that no progress can be made on meeting management objectives if the by-catch is not reduced.

McAllister raises the concern that the estimates of the amount of shrimp fishing effort by location and depth used in the estimation of red snapper bycatch are likely to be biased and imprecise because of non-randomness in the protocol used to sample shrimp fishing vessels for fishing effort and catch. He notes the comment of Fanning (see section 4.1.7) that recommendations of recent reviews of shrimp fishery data collection programs have provided some reasonable suggestions for alternatives including shrimp fishing permits and trip tickets that could help to provide better information on the actual amount of shrimping effort.

Reduction

In Stokes' view, if there are no practical means of reducing bycatch, the major management issue is whether or not to reduce effort in, or even to close, the bycatch fishery. Whilst acknowledging that given the social and economic value of the shrimp fishery, this is presumably politically untenable, he points out that National Standard 9 and the FAO Code of Conduct are clear that bycatch reductions and minimisation of wasteful practices are a priority. He stresses that account needs to be taken not just of red snapper but of the plethora of other bycaught species and potential ecosystem damage. He also specifically points out that any reductions must relate not just to bycatch rate but to total bycatch in the fishery - a function of rate and effort.

Regarding the bycatch reduction target of 44%, McAllister notes that considerable uncertainty in the values for some of the parameters and assumptions used in this evaluation, for example in the rate of natural mortality for age 0 and 1 red snapper, were largely ignored was ignored. Thus, he believes that without further analysis, it is not clear whether the modeled rebuilding consequences of this target of 44% are robust to uncertainty. He also expresses concern over the extent to which the target is achievable with the use of BRDs. He regards this as uncertain mainly because of the use of relatively few replicates and extremely high variability in test results for candidate BRDs, and uncertainty over the extent of effective deployment of these devices once they are certified and required to be used in the shrimp fishery (see comments of Sinclair and Sutinen below). Moreover, in his view, the survival rates of red snapper that encounter and escape from the net is uncertain. He cites a European study (e.g., by Petri Suronen, Director of the Marine Laboratory in Helsinki) which indicates that such survival rates can be quite low.

Sinclair also expresses concern regarding the use of BRDs to solve the bycatch problem. Based on the research results to date, he believes that it is not clear that an effective BRD can be found (i.e., one which can achieve the required reduction in bycatch). Stokes regards the results to date of testing the efficacy of various devices as inconclusive.

Sinclair specifically notes that:

- only 1 BRD has met the selection criteria;
- the sample size for testing is very small;
- the uncertainty associated with their performance is high; and
- the industry is very skeptical that these devices will work and they fear substantial losses of valuable shrimp by using them.

Consequently, he believes that it will be difficult to deploy the BRDs into the fishery and as a result, there is a high probability that the desired reduction will not be achieved. As an alternative, he suggests that it may be necessary to consider indirect or direct restrictions on the shrimp fishery such as imposing a red snapper by-catch quota in the shrimp fishery or restricting shrimp fishing effort.

Stokes notes that, although technical measures may be appealing to managers and to fishermen, bycatch is a product of bycatch rate and effort. He therefore also believes the most direct route to reduction of total bycatch is reduction of effort; either *in toto* or using closures in space and time. In his view, this has the added advantage that effort reduction is more easily regulated, monitored and enforced than continually monitoring the changing effectiveness of technical devices. Having said that, he concedes that if technical bycatch reduction devices can be devised which genuinely reduce bycatch levels by 50% or more in all areas of the red snapper range, and which do not compromise shrimp catch and operating conditions aboard ship, they should of course be used. He warns, however, that their use should be carefully scrutinised and total bycatch will still depend on effort expended, so if total bycatch rather than bycatch rate is to be reduced by 50%, effort in the shrimp fishery must not increase further.

Sutinen specifically cites four main reasons why he believes the proposed bycatch reduction measures are inappropriate, and provides a number of possible solutions:

- The management approach is too focused on a single species, red snapper. An appropriate approach would address all bycatch species. Red snapper is thought to account for less than 1% of the total finfish by-catch, which includes Atlantic croaker, sea trouts, longspine porgy, spot, Gulf butterfish, Atlantic cutlassfish, hardhead catfish, Atlantic bumper, Spanish mackerel, king mackerel and red drum. (Amendment 9 of the FMP for Gulf of Mexico shrimp.)

- The focus on a single technological solution, applied across the board, has a high risk of failure. Fishing is far too complex to expect a single technological device (the BRD) to be the best solution to the bycatch problem. BRDs are unlikely to be appropriate under all circumstances. Other measures in combination with BRDs may improve the effectiveness of bycatch reduction, and achieve the reduction at lower cost to and with wider acceptance among the industry.

- There were indications during the review that the shrimp industry has not been sufficiently involved in finding solutions to the bycatch problem. Management authorities should work closely with the shrimp industry to solve the bycatch problem since it is in the industry's interest to solve the bycatch problem comprehensively (i.e., all bycatch species), and it's in the government's interest to gain widespread acceptance of a solution.

- The onus for controlling bycatch is not properly placed. The onus for controlling bycatch should be shifted entirely to shrimp harvesters. That is, shrimp trawlers should be held responsible for maintaining their bycatch below acceptable levels and proving that they have done so. In exchange, shrimp harvesters should be allowed to use any environmentally sound method for achieving their bycatch limit. An effective way to achieve this shift in onus would be to implement bycatch quotas on the shrimp fishery. Shifting the onus to the industry will provide the incentives to find multiple low-cost ways to reduce bycatch.

Targett also advocates working with the shrimp industry to develop a workable framework for red snapper bycatch reduction. In his view this would include the consideration of alternative options to BRDs (e.g., area and/or time closures and annual bycatch quotas).

With regard to effort reduction, Sutinen notes the analysis by Ward (1997) which shows that a shrimp fishery operating at maximum economic yield would significantly reduce the fleet size and total effort below current levels. He notes that the use of ITQs to achieve Maximum Economic Yield (MEY) in the shrimp fishery has been rejected, but suggests that an alternative approach would be to use individual effort quotas, in which individual fishing units would be allocated a fixed number of days to fish. He envisages that over time the total number of days fished would be reduced to approach MEY and to reduce the bycatch of juvenile snapper (and other bycatch species).

Sutinen cites two examples where bycatch quotas are applied in existing fisheries - the Alaska groundfish fisheries and the Sotia Fundy groundfish fisheries. He suggests experience with these and other examples should be investigated. He explains briefly how bycatch quotas work - very much like a standard total quota - but notes the major difference is that not all of the bycatch is landed. There is therefore a need either for monitoring at-sea using observers and/or, as in Canada, having mandatory landings of all catch. He suggests that If ITQs are eventually implemented in the red snapper fishery, the shrimp fishery with a bycatch quota, could be allowed to acquire quota in a given year in order to meet their shrimp landing goals

In Sinclair's view, whatever management approach is selected, it seems imperative that a permanent fisheries observer program be developed to monitor by-catch in the shrimp fishery. Given that all the fish by-catch is discarded, he sees direct estimation at-sea as the only practical approach to monitoring and estimating its level. He notes that deployment patterns and coverage levels would need to be carefully determined in order that inferences may be made about the overall levels of fish by-catch.

4.1.5 Recommendations for research

This section summarizes the recommendations for further research made in the panelists reports, which all relate to a greater or lesser extent to ways in which uncertainty can be more effectively dealt with in the assessment.

McAllister suggests a revision of the stock assessment and projection procedures to more fully account for uncertainty should include adoption of the Monte Carlo approach, such as that presented int he appendix to Kaiser's report (Annex 1). He notes that the the current projection does include a Monte Carlo option to incorporate uncertainty about future recruitments, but this procedure needs to be made more thorough to account for the full range of uncertainties in, for example,

- M;
- bycatch estimates;
- discard mortality rates;
- discard rates;
- the stock-recruit function;
- fecundity-at-age;
- growth rates; and
- the effectiveness of BRDs.

In his view, the acceptability of alternative management regimes could then be evaluated in a probabilistic framework in which uncertainties could be readily identified and dealt with. In addition he suggests that the bootstrap procedure of Restrepo *et al.* (1992) would also appear to apply well to red snapper policy evaluation and, in contrast, a more formal Bayesian statistical approach could also be considered (McAllister and Ianelli 1997; McAllister and Pikitch 1997; Punt and Hilborn 1997). Stokes also suggests the possible use of Bayesian approaches in which prior agreement on the

probability to assign to the various inputs is used. The outputs would then be in the form of probability distributions which could be used in the decision making process. He notes, however, that argument will continue over the priors to assign.

Stokes also suggests that estimation error could be addressed by bootstrapping the assessments and forecasts. Each bootstrapped assessment would form the basis for a single forecast; the suite of bootstrapped forecasts would give a clearer impression of the probability of achieving in recovery to 20%SPR by 2019. He reiterates that If credible management decisions based on recovering SPR are to be based on forecast work, account will need to be taken of uncertainty in the forecasts.

He believes that the only way, ultimately, to reduce uncertainty is to learn through data gathering and analyses. In summary he recommends the following approached for reducing uncertainty in various components of the assessment:

Bycatch estimation	He places a high priority on estimating bycatch as best as possible from existing data, whilst recognising that the estimates are likely to be imperfect. For the future, the imperative is for a well designed and implemented bycatch monitoring program, set up to facilitate future analyses. He recommends a carefully conducted workshop comprising all protagonists and a few independent analysts. He suggests clearing up this controversial area would reduce considerably the overt scientific antagonism and provide a sounder basis for forecasting and decision making.
Juvenile M	He recognises the problems involved in reducing uncertainty in *M* and makes no specific recommendations for how it should be approached. He suggests that unless and until credible analyses can be used to estimate natural mortality and associated variances, the use of low levels is again the route to cautious forecasts and is most consistent with the FAO Code.
Otolith readings	He recommends trusting in the knowledge and judgement of experts. If alternative age reading programs by scientists with expertise in Lutjaniids can be commissioned, this may resolve the issue. In his view, in the absence of such research, the work at the University of Louisiana should be accepted as the best current basis. The resulting low adult mortality rates lead to cautious forecasts and should be used.
Constant catch	He suggests that the assumption of constant TACs must be questioned and suggests carrying out forecasts in which the TAC either responds to changes in SPR or the catch is governed by a control rule for actual take set between the constant TAC and the TAC that would be set under a constant (current?) effort rule.
Stock-recruitment	He notes that red snapper recruitment history is unusually "constant" with a maximum to minimum ratio of the order of five. Consequently the stochastic forecasts already carried out by Goodyear show relatively little degradation in performance. Correct characterisation therefore appears less influential than, for example, bycatch or juvenile natural mortality rates, which have major impacts on deterministic outcomes. Nevertheless, he recommends that if the range of uncertainties for all factors are more adequately brought into the forecasts, recruitment should be properly characterised. This is especially the case given the strong and compelling evidence for possible depensatory effects

shown in Goodyear's assessments. A full analysis of recruitment variability should therefore be continued.

McAllister and Sinclair also recommend that the possibility of depensation in the stock-recruitment relationship be investigated.

With regard to growth parameters, Sinclair recommends that a comprehensive program for determining annual catch at age in all components of the fishery be implemented. Such a program would allow investigation of interannual variation in size at age and provide more precise estimates of year-class variation by tracking their abundance through the adult ages. The current assessment relies heavily on the SEAMAP and groundfish surveys for estimates of year-class strength. Having age composition data from adult catches would provide additional abundance indices

Sinclair also recommends that future development of the assessment should include risk analysis of the probability of achieving specific management objectives (e.g., 20%SPR) as a result of specific management actions (e.g., use of BRDs, adult fishery fixed TAC). He proposes that uncertainty estimation must be integrated into the SPA so that the variance and distribution of key population state parameters may be included. In his view, these include *M*, abundance at age, future recruitment, and weight at age. Variance in the management process will also need to be considered, for example, the distribution of expected reductions in red snapper by-catch in the shrimp fishery, the actual adult catch vs the TAC.

4.1.6 Recommendations for management

The general conclusion, reached independently by all the panel members is that if red snapper is to be recovered to above the overfishing definition of 20%SPR, the fishing mortality rate on both juveniles and adults needs to be reduced. Precise levels of reduction will depend on the degree of certainty required for recovery by the specified date of 2019. The values most commonly referred to in the text of the panelists reports are that if total bycatch can be effectively reduced by 50%, the commercial TAC could be set as high as, but no higher than, 6 million pounds. This level would reduce further in the event that:

- effective bycatch reduction decreases, and
- if full and proper account is taken of estimation errors and uncertainties in critical forecast inputs.

Stokes summarizes some of the problems which potentially undermine the successful management of the red snapper fishery as follows:

- if the large bycatch fishery is effectively open, with excess capacity and less than adequate data collection, the assessments will be substandard;
- if data from Mexican fisheries are missing, the assessments will always be open to criticism; and
- if red snapper catches under reef fish permit are less well recorded, or discard survival rates inaccurate, the assessments may be compromised.

He suggests that the complex, inter-acting fishery system and means of regulation (lack of transferable quotas; producer organizations etc.) perhaps point to the need for consideration of a simpler management regime. In his view, laudable as the single species overfishing definitions are, it may be that a multispecies approach would offer the prospect of simpler, more effective management, with

less need for complex and expensive data collection. Robust and adequate might be better than complicated but fragile.

McAllister summarizes similar problems in his report and adds the following:

- If catch rates rise substantially as the stock rebuilds, it is likely that there will be increased pressure from fishermen for increases in the TAC. It is unclear whether catches can effectively be held down under such a scenario.
- difficulties in keeping track of the sports landings during each season in order to determine when to close the season once the recreational quota has been caught.

Despite the existing prohibition on proposals to implement individual quotas, Stokes recommends that consideration be given to how ITQs might be utilised after 2000 in order to control effort in the bycatch fishery. McAllister also suggests that this would be a more attractive approach to management than the current license system, citing, among others the advantages of alleviation of the derby fishery, avoidance of overcapitalisation and problems of safety.

Sinclair notes that the management plan calls for fixing the adult fishery TAC over a 15-20 year period in order to meet the SPR target for this fishery. He believes, as do other panel members, that fixed catch management plans have several pitfalls and comments that they are not favored in the fisheries management literature. In this case, he envisages the following problems:

- fishers will have to fish harder when stock size is low and less when stock size is high;
- the highest exploitation rates would occur at the lowest stock sizes;
- it will be difficult to restrain fishing effort when stock sizes are high; and
- the projected success of the fixed TAC in achieving the SPR target is largely based on the highly optimistic stock/recruitment function used in the catch projections (as described in his response to question 3).

He strongly recommends an alternative approach, to be investigated through simulations, which would be to determine a target *F* for the adult fishery based on the expected mix of quota sharing between the different fleets (commercial, recreational, etc.) and set annual TACs based on stock assessments. He explains that if improved recruitment is not realized, there is security in not promoting too high a catch. Since SPR depends on fishing mortality, the objective might be achieved at lower risk of stock failure.

Both Stokes and McAllister also comment on the non-feasibility under the current management regime of constant catches as the stock recovers and CPUE increases (see above).

In order to improve the efficiency of dealing with complex management problems that involve more than one species and resource user group, McAllister suggests that the RFFMP could be modified to incorporate more of a systems approach and multispecies approach to dealing with fishery management. For example, as the bycatch problem extends across several commercially and ecologically valuable species, it would seem that the most desirable solutions to the bycatch problem could be found if the problem was considered in total rather than one species of a time. As part of such an approach, McAllister also recommends that the issue of allocation of fish resource across different resource user groups be dealt with more explicitly in Reef Fish Fishery Management Plans to promote and maintain a fair and equitable allocation of the access to resources among the various resource user groups.

In closing, Sutinen comments that it is becoming increasingly evident that a critical necessary condition for successful fishery management is industry support for the program. He provides a summary of evidence supporting this view and suggests ways to obtain industry support for the regulations, including:

- meaningfully involving fishermen in the development and implementation of regulatory policy;
- keeping regulations simple with a clear connection to conservation goals; and
- equal application of regulations and enforcement.

(Sutinen, 1995).

He believes this constitutes an argument for heavily involving shrimp harvesters in the process for finding a solution to their bycatch problem. In his view, if they are not so involved, there is significant risk that the resulting measures will fail.

4.2 The Statistics Review

4.2.1 Outline

The Statistics Review Panel was presented with a package of information on the series of data collection programs used to characterize the total removals of red snapper by fisheries in the Gulf of Mexico. Removals comprise both the targeted catch and incidental bycatch in the shrimp fishery. Data collection and estimation procedures were explained in detail in background material and in presentations during the meeting, providing the panel members with information on which to base their responses to the five questions to be addressed:

1. *Are the designs of the data collection programs appropriate?*
2. *Does the estimation protocol for each program take into account the design aspects of the data collection programs?*
3. *Is sampling level and coverage sufficient to adequately describe the target population?*
4. *Are there identifiable biases in the results of the surveys?*
5. *Is the precision of the estimates appropriately expressed?*

The data collection programs were subdivided into five principal categories. The first four each comprise a number of on-going programs of differing scope and design. The fifth is a collection of special studies, rather than a single program. A brief summary is given below. Additional detail is provided in Annex 1 (Appendix B of Christman 1997)

1. Commercial Red Snapper Fisheries Data Collection Programs

   - Total landings census - data collected by port agents from seafood dealers either under Federal (NMFS) or state (in Louisiana and Texas) supervision
   - Logbook program for catch and effort data - mandatory since 1992 for all vessels with a federal vessel permit, collected directly from the fishers
   - Trip interview program (TIP) - focusing on size composition of the landed catch, data collected by port agents from co-operative fishermen
   - Brief commercial observer program in 1995 to study mortality or discarded fish, covering about 20 to 30 vessel trips

2 Recreational Red Snapper Fisheries Data Collection Programs

   - Marine Recreational Fishery Statistics Survey (MRFSS) - national (except Texas) telephone and on-site interception survey, covering private/rental, shore based, charter and headboat components in all coastal counties
   - Texas Marine Sport Harvest Monitoring Program - analogous to the MRFSS, administered by the Texas Parks and Wildlife Department, in place since 1983
   - NMFS Charter boat survey - voluntary (since 1989) logbook program aimed to augment inadequate coverage of charter boats by MRFSS, administered by NMFS Panama City Lab, covers eastern Gulf only
   - NMFS Headboat survey - logbook (75% returns) started in 1986, designed as complete census of fishing effort and sample of catch per unit effort collected by port agents, aimed to augment inadequate coverage of headboats by MRFSS, administered by NMFS Beaufort Lab

3. Fishery Independent Data Collection Programs

   - Summer South East Area Monitoring Assessment (SEAMAP) - groundfish trawl survey, started in 1982, providing estimates of relative abundance, recruitment patterns and species composition
   - NMFS Fall groundfish survey - annual groundfish trawl survey, started in 1972, providing estimates of relative abundance, recruitment patterns and species composition, since 1985 covering the same areas as the SEAMAP survey, adopted formal SEAMAP protocols in 1987

4 Commercial Shrimp Fisheries Data Collection Programs

   - General canvas landings program - collection of total landings data collected by port agents from seafood dealers, during monthly visits, under Federal (NMFS) supervision
   - Trip Interview Program (TIP) - opportunistic sampling for catch and effort data from individual trips
   - Voluntary at-sea observer programs - three conducted in the periods 1972 to 1982, and Regional Bycatch Research Program from 1992, to collect discard data, evaluate post-release mortality, and the performance of BRDs

5. Biological characteristics, morphometrics, fecundity and post release morality

   - Morphometric study from Louisiana (Wilson, Render and Neiland 1994)
   - Age-Length Study by Panama City, FL Lab (Allyn Johnson, 1996)
   - Release Mortality (Cage Studies)
   - Release Mortality (Headboat Studies)
   - Release Mortality (Commercial hook-and-line Studies of discard fish)

The four panel members responded to the specified tasks in different ways, each using a different report structure to present their findings. However, each of the reports covered the major issues within the four data collection programs, providing specific comments on performance to date and recommendations for the future. There was a relatively high level of consistency between the comments and recommendations of the panel members, although particular issues received different levels of attention in each report. In cases where a reviewer has not responded on a particular point or question, this should not be construed as tacit agreement or disagreement with the findings of the other panel members, rather it is simply that on these particular issues, the panelist made no comment.

In order to provide a consolidated report of the individual conclusions of the panel members, this report mirrors, in part, a structure used by some of the panelists; that is considering the five basic questions set by NMFS in relation to each of the data collection programs listed above. This provides a convenient framework for an overview of the strengths and weaknesses of the data sources as they are viewed by the panel members, and the recommendations they make for future actions. There are a number of additional general comments, which could be regarded as cross-cutting issues, that are best considered outside of this basic framework and these are discussed below.

At the end of the main section dealing with the Statistics Review there are four tables (Tables 4.1 to 4.4), which present a tabular summary of the responses to the five questions as they relate to the various components of the four main data collection programs (commercial red snapper, recreational red snapper, fishery independent and commercial shrimp). These tables include specific responses by the panel to the questions, some of which comment on performance or otherwise make judgements about the data collection programs. These tables are intended to provide an overview, and as such,

these responses are not attributed to specific reviewers. As indicated previously, however, this should not be construed as indicating that there was consensus on these issues. For a detailed information on the responses of individual panel members, the reader is referred to the main text of the report.

Use of scientific information

Early in his report, Mark Kaiser (Kaiser), raises the issue of the characterization of the overall manner in which scientific information is produced and used in management of the red snapper fishery. He explains that it is impossible to address the adequacy of a data collection program without knowledge of the purpose for which the data are being collected, and expresses concern that the lack of contextual information presented at the New Orleans meeting is a major impediment in assessment of the programs under study. Kaiser further explains that the design of a data collection program is not simply appropriate or inappropriate, but rather is appropriate or inappropriate only within the context of an intended use. The same is true of a statistical estimation procedure. For example an assessment of potential bias in estimated quantities is of little value unless it is known that the use made of those quantities renders bias an important property.

The point is further made by Daniel Hayes (Hayes) that evaluation of the adequacy of sampling level and coverage of the various sampling programs was hampered by the fact that measures of precision were not computed or presented in many cases. Also the lack of external checks for many of the quantities estimated made identification of potential biases from the results themselves difficult.

General comments on sampling, precision and data treatment

Kaiser suggests that the current programs attempt to mitigate questions of uncertainty through the use of overwhelming sample sizes. He considers that properly expressed measures of uncertainty could lead to greater efficiency in the combined data collection and estimation procedures. That is, if uncertainty in the estimation of quantities relevant to the assessment of the red snapper resource can be appropriately quantified, then there may be less of a need to gather massive amounts of data in the first place. He notes that smaller samples may leave estimation more vulnerable to adverse effects of bias. If sampling is truly haphazard, lacking systematic sources of bias, then large sample sizes may provide some protection against bias. But, he explains that, if systematic sources of bias are present, then large sample sizes simply produce estimators that are precisely biased. If proper methods for variance estimation are implemented, a totally analytical exercise using sub-sampling and cross-validation methods with existing data could provide an excellent indication of whether adequate precision is obtainable with smaller sample sizes than currently used.

Hayes reports that the only case where reasonable estimates of sampling precision are made is for the Marine Recreational Fisheries Statistical Survey (see section 4.2.3) and for programs designed as a census. Even though virtually all other programs rely on some statistical design and analysis, there is little in the way of reporting variance estimates for most quantities. He considers that much more work is needed to appropriately express the uncertainty associated with point estimates reported.

With respect to estimation protocols, Hayes suggests that in the programs where data are collected opportunistically or with the voluntary consent of the fishermen, the primary consideration is whether the estimation appropriately uses blocking factors (e.g., spatial or temporal characteristics of the data) to reduce the variance of estimates and to minimize the potential for unknowingly introducing bias by combining data into inappropriate groups. He explains that the choice of blocking factors and cut off points within these factors is largely subjective, and there is little or no external means to evaluate the

validity of particular choices. Specifically, he mentions that the estimation protocols for the Trip Interview Program (TIP) for commercial length frequency (section 4.2.2) and the charter boat survey (section 4.2.3) use appropriate blocking factors and levels within blocking factors to produce reasonable estimates.

Report structure

Sections 4.2.2 to 4.2.6 provide a consolidation of the comments and recommendations of the Statistics Review Panel as they are presented in their written reports. For ease of reference they mirror the classification of data collection programs involved in management of the red snapper fishery listed above. Tables 4.2.1 to 4.2.3, at the end of Section 4.2, provide a convenient tabular summary of the main comments. Suggestions and recommendations made by the panel members are provided in the text. They are generally not included in the summary tables because their complexity merits detailed explanation which could not be properly expressed in a tabular format.

Section 4.2.7 presents comments and recommendations provided in the panel members reports regarding the estimation of bycatch of red snapper in the commercial shrimp fishery. All the panel members individually conclude that no other single subject under the statistics review has generated as much controversy or as much outside review activity as this. It was therefore deemed appropriate that a separate section be devoted to a consolidation of the panel members' comments and recommendations on this topic.

4.2.2 Commercial red snapper fisheries data collection programs

Total landings census (including LA and TX State supervised programs)

Several panel members individually conclude that the commercial landings data represent as complete a census count as possible and that there is little observable bias. Kaiser reports that the primary concern in this program is to ensure that data gathered from seafood dealers by port agents, some under federal supervision and some under state (LA and TX) supervision, are collected and recorded in a consistent manner. Mary Christman (Christman) suggests the following actions would make the program more consistent:

- ensure that the categories of dealers canvassed in each state (the state-level sampling frames) are consistent, e.g., if restaurant sales are a significant fraction of red snapper landings then all states should include direct restaurant buyers; and

- where possible, standardize the units in which the data are recorded, e.g., gear used is reported once a year in LA and TX although landings are recorded monthly in those same states.

Paul Fanning (Fanning) considers that the primary statistical concern with any census is the likely bias due to undercount, although Christman indicates that any biases which might result from census undercount, or mis-reporting, are un-controllable and non-quantifiable. She suggests, however, that there is a need to determine the portion of landings missed through direct sale to non dealers, i.e., restaurants and consumers. Hayes considers that all sources indicate that the amount of red snapper represented in such sales is negligible. Christman suggests dropping the gear and area reporting requirements from the dealer collected data, because the logbook program (see below) also records this information for each trip by a commercial vessel. However, all members individually mention the

merit in being able to cross reference data from different sources, e.g., between the landings census and the logbooks. In fact Christman specifically recommends that the comparison of landings census and logbook data should be done on a finer scale, for example at state-level, to ensure that there is no consistent pattern of under- or over-reporting within each state.

Logbook program for catch and effort data

Kaiser describes the logbook program, instituted in 1992, as a major step forward in data collection for the directed fishery, presenting an opportunity for a formal stratified sampling program targeted at the commercial fishery, with the potential to be developed into a major information source. Fanning reports that the possibility of deliberate under-reporting and non-reporting by the fishers exists as a potential bias, although the coverage of the fleet is good and should eliminate any census undercount *per se* (i.e., missed trips). Several panel members' reports highlight the problem that the logbook program does not cover non-permit holders, and that hence it is not clear whether it is in fact a census or sampling methodology. Comparison of the landings from logbooks and dealer records for three years showed generally good agreement.

Trip Interview Program (TIP)

The potential biases resulting from the opportunistic or convenience sampling in the Trip Interview Program (TIP) are of concern to all panel members, and most express the opinion that these are non-quantifiable. Hayes believes that there is in fact no evidence for a directional bias and without the legal authority to require fishermen to provide effort information or samples for determining the size composition of the catch, there is probably little that could be done to achieve a truly random sample. He therefore recommends that the current sampling methods be maintained. Christman suggests that, if it is not actually possible to estimate the variability of the TIP data resulting from the sampling design and measurement error, the best approach is to minimize it. She elaborates that it is necessary to ensure, through training programs, that the port agents are aware of the problems that can arise from selectively sampling a subset of the fishermen landing in their region. This would help to make sampling procedure in the TIP as random as possible. Kaiser suggests that sampling for length composition in the TIP could be improved by measuring all the fish in a selected bin or batch. There is also some concern expressed in the panel members' reports that the TIP only provides data on fish brought ashore, rather than on the fish actually caught.

Two approaches to quantifying sources of bias and uncertainty are suggested in the reports. Christman suggests a small pilot study should be undertaken, in which a concerted effort is made to obtain data from a representative sample of vessels to compare with the results of the present data collection protocol. Kaiser recommends a statistical model (multinomial-Dirichlet) for estimation of the distribution of size classes in the commercial catch, which could be used directly to incorporate uncertainty in estimation of this distribution in stock assessment.

Observer program for collection of data on discards

A strong recommendation made independently by all the panel members is that a permanent observer program onboard commercial vessels targeting red snapper be established to provide, *inter alia,* a systematic source of information on discard in the red snapper fishery. Fanning reports that these data are not collected by any routine means at this time. The discard data field was dropped from the logbook in 1996 (due to lack of use) and there is no regular observer program. Present direct estimates

of discard rate are based on data collected during a voluntary at-sea observer program in 1995, designed primarily to study the mortality of released fish. This program covered only about 20 or 30 trips and may not constitute a representative sample of discard rate in the fishery.

Hayes recommends a thorough examination and possible redesign of the at-sea observer program to ensure that sample sizes and sampling coverage are adequate to directly estimate discarding at sea. Besides the collection of discard data, Kaiser lists a number of other potential benefits of such an observer program:

- Sampling for estimation of the size distribution of the commercial catch, rather than the commercial landings could be obtained;
- periodic sampling for reevaluation of age-length and fecundity-length relations could be easily incorporated;
- independent assessment of catch per unit effort and other information could be obtained for assessment of the logbook program, since there would be available a natural pairing of observer and logbook information for trips on which an observer was present;
- by comparison of estimates from observer data and other currently existing programs (e.g., size distributions obtained from the TIP) an estimate of the reliability of cooperation-dependent sampling (i.e., observers) relative to those that are less dependent on cooperation could be obtained; and
- an observer program could allow actual random sampling of trips, at least among the proportion of vessels that cooperate in the program.

Hayes also stresses that continuing to collect information on discarding by the directed red snapper fishery with the at-sea observer program is also critical, given the possibility of changes in commercial fishermen's behavior in response to changes in minimum size or other management measures as identified in the amendments to the current fishery management plan.

4.2.3 Recreational red snapper fisheries data collection programs

Marine Recreational Fisheries Statistical Survey (MRFSS) and Texas Marine Sport Harvest Program

A number of difficulties are discussed in the panel members' reports in relation to the monitoring of recreational fisheries in the Gulf. These include the large number of boats and trips involved, the lack of a consistent Gulf wide permit system or landings reporting requirement and the division of effort amongst charter boats, headboats and individual recreational boats. The MRFSS and Texas Marine Sport Harvest Program are seen as having been developed partly in a response to these problems.

The panel members all individually consider that the MRFSS program is well conceived and well executed. Kaiser describes it as a quality effort to provide solid information about an exceptionally diverse and variable range of human activities that affect the red snapper resource in the Gulf. Similarly, the Texas Marine Sport Harvest program is considered to be well-developed, although designed around survey of access points to the water rather than the population at large. There is also satisfaction expressed in several reports that the program managers continue to consider possible improvements and modifications to their data collection plans.

4. Consolidation of the reviewers' reports

One of the main concerns with the MRFSS is that it is not well suited to collecting information on variable local fisheries, such as that for red snapper in the Gulf. In order to increase the ability of the MRFSS to characterize the recreational fisheries on a local scale, the sample size would need to be increased. If budgetary considerations preclude such action, then Christman suggests that at least there should be some additional cross-referencing between the results of the MRFSS and other data collection programs. Christman also suggests performing the MRFSS in Texas for a fixed period and comparing the results with the Texas survey.

The precision of MRFSS estimates of catch and effort for the charter and headboat components of the recreational fishery are thought to be poor due to the large proportion of non-coastal and out of state anglers participating in these sectors. Several panel members independently express concern that the use of a 5 year running mean for the ratio of coastal to non-coastal and out of state participants results in a bias in the number of headboat trips. Hayes suggests that the effect of shortening the period of the running mean should be investigated, to guard against possible bias in estimates of effort due to trends over time. With respect to the deletion of some large values in the MRFSS responses, Christman considers that a more appropriate approach would be to present the data and uncertainty both with and without the large values.

In common with the data from the commercial fishery, Kaiser points out that there has been no consideration of uncertainty in the estimates of size frequency obtained from the intercept interview program, and this should be rectified.

Several members of the panel express concern over the way in which the precision of the catch estimate for the Texas Marine Sport Harvest Program is expressed. Christman in particular elaborates on this. The quoted precision is based on summing the variances for average landings in each of the strata (bay system, season, day type and fishing area). This is correct as far as it goes, but what is not given is the estimate of the variance of the within stratum means. Christman explains that these means are products of several random quantities, including relative fishing pressure, percent of landings outside of a certain time window, etc., each with an associated variance. The variances of these adjustment factors have been ignored and certainly contribute to the true variance. She suggests that an effort should be made to incorporate these variances. Hayes proposes the methods of Guthrie *et al.* (1991) or Pollock *et al.* (1994) given the present design of the program.

NMFS charter boat and Headboat programs

NMFS has instituted two programs targeting the charter boat and headboat fleets to mitigate against the lower precision with which the MRFSS monitors these sectors. Several panel members independently conclude that the charter boat mandatory logbook program has been comprehensively undermined by the charter boat operators' refusal to cooperate, and has not provided a viable approach to monitoring the fleet. Hayes recommends that either a study be undertaken to evaluate whether the charter boat survey could be re-designed to provide synoptic estimates of catch, or alternatively resources be applied to improving the MRFSS in charter boat mode. The charter boat survey needs adequate commitment of resources, particularly personnel, including port agents, to make it work more effectively. Fanning considers that the rotating panel approach proposed by NMFS is sound and should provide the required catch rate and catch composition data.

The Southeast Region headboat survey is structured as a mandatory census, but as yet the coverage is incomplete. It is presently estimated that 75% to 90% of effort is reported, depending on the year. Adjustments are made to the data to fill in the gaps, including estimates made by port agents. Hayes reports that data on fishing effort are treated as a census, but there is no estimate of precision

calculated for the point estimates of total catch, derived from samples of catch per unit effort. He concludes that additional resources should be applied to make the census complete.

Kaiser makes a suggestion aimed at improving the provision of information from the charter and headboat fleets. The recreational fishery presents a difficult characterization problem, in part because of inherent differences between individual fishing trips and those taken aboard charter boats and headboats. To try to resolve this problem, the charter and headboat fleets could be considered as components of the commercial fishery, rather than the recreational fishery. Kaiser's view is that such a change in perspective would be more than a mere administrative shift in classification. Past assessment of the charter industry, in particular, has been approached from the viewpoint of gathering information from individual fishermen (i.e., charter boat clients) rather than from charter boats themselves. Charter trips are more similar to very small and heterogeneous commercial trips, and the collection of data and statistical estimation of effort, catch per unit effort, and release fraction could be approached from this perspective. His suggestion also includes the idea that an observer program could be established. In principle, an observer program aboard charter boats could provide much the same information about this segment of the overall fishery as an observer program aboard commercial vessels. In his view, the collection of reliable data from the charter boat fleet will be dependent on incorporation of charter operators in the data collection process, instead of relying on cooperation with a process to which they are external.

4.2.4 Fishery independent data collection programs

Fishery independent information is collected through two stratified trawl surveys, the Summer Southeast Area Monitoring Assessment (SEAMAP), and the NMFS Fall groundfish survey. Both provide information on relative pre-recruit abundance (year 1 in the SEAMAP survey and year 0 and 1 in the fall groundfish survey), distribution and species composition. These surveys also provide information which is used in the estimation of mortality due to shrimp bycatch, considered further in Section 4.2.7.

Since 1985 the two surveys have covered the same area. Hayes reports that the design of the surveys is good and is capable of producing sound, unbiased estimates of relative abundance. However, others express concerns that some biases, for instance in catch per tow, may result from the stratified design of the survey not being used in the calculation of estimates. Several panel members individually consider that the surveys are in fact over stratified. Having only one sample per stratum precludes the calculation of variance. Fanning's assessment is that the strata have been used as a means of ensuring a regular, rather than random, sampling of the Gulf of Mexico and not as a means of improving the precision of abundance estimates. Several suggestions are made in this regard:

- Increase the number of samples so that there is a minimum of two per stratum;
- investigate the design efficiency and examine the potential for collapsing of strata to produce more precise estimates without severely compromising the spatial coverage requirements (e.g., method of Gavaris and Smith, 1987); and
- apply methods presented in Cochran (1977) for stratified samples with a single observation per stratum be used to develop approximations for the variance of estimates of mean catch per tow.

Kaiser expresses a general concern that the sampling programs have not been well conceptualized with respect to the analysis of the data, and there has been little scrutiny of the statistical framework within which to consider the quantities being observed. He suggests that the development of such a

framework should be a priority, to examine *inter alia* whether or not spatial dependence structure exists across the sampling region.

Fanning refers to a survey dataset including triplicate tows in sample squares, which could provide a means of estimating small scale variability compared to large scale variability, and making estimates of the magnitude of potential gains from improved design. He suggests two hypotheses that could be considered: whether there is a depletion effect within the sample square (i.e., $tow_1 > tow_2 > tow_3$) and whether variability increases with absolute distance within the small units.

Several of the reports note indications that red snapper juveniles may be expanding their range beyond the 50 fathom contour, based on presence of red snapper along the seaward edge of the survey in 1996, where they had not been previously observed. While this may be a sampling artifact, several reports independently recommend that it be carefully assessed and expansion of the survey area into the deeper waters be considered.

Hayes and Kaiser each note the importance of considering the possible effects of combining data from different research vessels, both federal and state. To date, the majority of trawl samples have been collected with the fishery research vessel Oregon II and all data have been pooled, without inter vessel calibration. Because of the relatively infrequent use of other vessels, and the lack of information on potential differences in fishing power between vessels, this has probably only contributed to a slightly higher between station variance, and does not appear to be a source of directional bias. As the Oregon II ages, however, and a replacement vessel begins service, Hayes believes the importance of inter-vessel calibration studies can not be overemphasized. Without such studies, the utility of the fishery-independent surveys as a 'tuning index' for the assessment and as an auxiliary variable for estimating discards in the shrimp fishery will be compromised, and any conclusions based on these surveys will be open to question.

4.2.5 Commercial shrimp fisheries data collection programs

The shrimp landings are collected by a census of seafood dealers each month, equivalent to the NMFS landings census for red snapper. In this instance, however, the entire program is supervised by NMFS (Texas and Louisiana have their own programs for red snapper) leading to a greater level of consistency over the region which is welcomed in each of the panel members' reports. The census is considered to be more or less complete with only a small potential for bias due to census undercount.

Interviews are conducted with available shrimp captains under the Trip Interview Program (TIP) to obtain catch and effort data. The effort data are available for a much smaller fraction of the total shrimp trips than are the catch data. Panel members' reports express concern about the non-random nature of the TIP samples arising from the opportunistic interviewing and deliberate targeting of larger and Coast Guard documented vessels. Christman recommends that the latter practice be stopped and that aspect of the sampling be made more random by randomly selecting among all boats in port at the time the agent arrives.

Also Christman reports that the number of trips sampled has fallen as fewer captains are willing to be interviewed. The current proportion of offshore trips sampled is estimated to be 15%. Christman believes that the data were far too sparse for the structure that the analysts wish to impose on the estimation effort, although others do not express this concern.

In August of 1992, a review of the estimation procedure was performed and the panel reports included several comments and recommendations for fine-tuning the GLM model, which were reiterated by the present review. These included:

- prior years are more similar than adjacent months but this has not been checked statistically
- gear is variable which can have an effect on the estimation effort if the proportion by gear types in the interviews doesn't match that in the population of trips. Review stated that the proportions "are fairly close" but this was not checked statistically
- recommended exploration of year*location interaction in GLM model
- recommended pooling of cells to get higher sample sizes per stratum
- recommended exploring nearest neighbor approaches for missing data
- recommended exploring spatial statistical methods for estimation
- recommended GLM model be developed to estimate effort for the entire Gulf by replacing observed with predicted values and exploring 3 different dependent variables:
    - done by Griffen, Shah, and Nance (no date)
    - Nance states that "no significant difference between the two estimates of effort" although the comparison is not a statistical one

The panel of the May 1994 review considered several alternative measures for estimating effort, but these were all rejected for the reasons listed below:

- number of vessels, rejected due to
    - undocumented vessels
    - vessels listed but no longer active
    - consolidated records for small vessels
- number of trips, rejected because
    - not always recorded
    - no lengths given sometimes
- time fished, rejected because
    - concerned about dependency on quality of interviews
    - fails to allow for 'fishing power' variability among boats
- standardized effort
    - standardize days fished by vessels with different fishing powers using correction factors
    - recommended additional research into a GLM for incorporating standardization
    - concerned about dependency on quality of interviews

In summary, the total effort is largely based on imprecise sample estimates or imputed values filled in by use of a model. Among other things, several panel members' reports reiterate the recommendation already made to the Council following previous reviews, that better data on the real shrimp effort could be obtained through the use of shrimp permits and trip tickets.

Other recommendations from the previous review reiterated in the panel the panel members' reports are:

- develop a more random selection procedure
- identification of individual vessels
- more descriptive analysis of the fishery (e.g., vessel types, etc)
- characterize uncertainty of effort estimates

4. Consolidation of the reviewers' reports

At-sea observer programs

Christman lists three early volunteer observer programs during the period 1972 to 1982: the Shrimp Bycatch Project 1972-78 (Pellegrin, 1982), the Turtle Incidental Catch Project 1980-81 (Stuntz and Henwood, 1987), and the Turtle Excluder Device Evaluations 1980-82, (Stuntz and Henwood, 1987). These were followed in 1992 by the Regional Bycatch Research Program, a volunteer observer program to study red snapper bycatch. Details of this program are provided in Appendix B of Christman's report. Christman notes that sample sizes and spatial/temporal coverages were much smaller than recommended in the research requirements (NMFS 1991). Observers are accepted voluntarily on board commercial shrimp boats and boats doing BRD bycatch reduction studies on sea trips of 1 to 56 days duration. The observers follow a well-designed, rigorous protocol for sampling the bycatch from every tow taken by the vessel. The data are used to characterize the species composition of the catch and the size frequency of red snapper in the bycatch, to estimate CPUE of red snapper for each stratum, and to estimate total bycatch of red snapper.

Funding for continuing the program is available for 1997 but it is not known at this time whether there are funds for future years. According to their reports, all the panel members are adamant that the only way to obtain direct measures of the bycatch is through at sea observations by trained observers on commercial vessels. Fanning believes that without a regular program of such at-sea observation, no model will be adequate to address the kinds of objections and challenges which such a contentious issue generates. In various ways, the panel members' reports all recommend very strongly that the program of at-sea observers in the shrimp fishery should be continued and expanded. Hayes points out that the program suffers from the fact that sampling is voluntary, resulting in a self-selected sampling pool. As with other programs where data reporting is voluntary, however, Hayes thinks there is very little that can be done to ensure that the trips sampled by at-sea observers are representative. Despite this drawback, Kaiser notes that the program provides common training for observers to be placed on distinct vessels (research vessels and commercial shrimp vessels), standardized recording procedures, and attention to minimizing adverse impacts of observation on the normal operating procedures of commercially active shrimp vessels.

Several of the reports recommend that the choice of sampled vessels should take much greater consideration of the temporal and spatial patterns of the fishery as a whole in order to gain adequate coverage. Hayes believes that a substantially larger number of trips needs to be sampled to gain better temporal and spatial coverage representative of the entire shrimp fishery. In conclusion, Kaiser expresses the opinion that if the observer program is administratively curtailed or eliminated, there will be little legitimate basis in the future to require a scientifically verifiable estimate of bycatch on which to base management decisions.

4.2.6 Collection of biological data on red snapper

Data on the biological characteristics of red snapper such as growth and mortality rates, size relationships, and post release mortality, have been provided through a number of special studies, rather than a single comprehensive program. Appendix B of Christman's report lists five main studies of biological characteristics:

- Morphometric study 1989 to 1993 (Wilson, Render and Neiland 1994)
- Age-length study by NMFS Panama City Lab 1993 to 1996 (Allyn Johnson 1996)
- Release mortality (cage studies)
- Release mortality (headboat studies)
- Release mortality (Commercial hook and line studies of discard fish)

Additionally Kaiser's report mentions a one time study by the NMFS Panama City laboratory to collect data on reproductive characteristics between February 1991 and November 1993.

Discussion of biological data in the panel member's reports focuses primarily on two issues: age and growth, and discard mortality.

Age and growth

Fanning's report notes that the Trip Interview Program (TIP) is the established program available for sampling for aging material, however, the only data reported to the panel (by C. Grimes) were obtained independently from Panama City Fl and Louisiana. Fanning has several concerns about the quality of the data, relating to poor characterization of the size composition of older ages and longevity, which he attributes to small sample sizes. His main recommendation is that some form of ageing quality control be introduced, including reference collections and cross referencing between multiple readers. He further suggests statistical age validation based on nuclear fallout isotope ratios in otoliths from fish alive in the 1950's and 1960's may have potential application for red snapper.

Hayes also regards age and growth as an important issue. He considers that the opportunistic sampling of otoliths and scales for ageing is not amenable to the construction of time-specific age-length keys. He explains that this has lead to the adoption of a 'non-traditional' approach in which all the available information on length at age is used to construct a monthly growth model, used in the estimation of catch at age. The procedure was not presented for review by the statistics panel, but Hayes expresses concern that the present method of age determination assumes that the growth rate of red snapper remains constant from year to year. There was no evidence to suggest otherwise, but he notes that it is not uncommon for growth rates to change with environmental changes (e.g., the extent of the hypoxic region near the mouth of the Mississippi) or with fish density as management measures are implemented. Hayes recommends that a sampling program be designed to collect age structures from a representative sample of the commercial and recreational landings to provide the basis for evaluating potential changes in growth.

Both Christman and Kaiser also express concern about size selection or selective sampling of the fish from which information on growth is obtained. Kaiser's greater concern is the source of the samples themselves, rather then the way in which individual fish are taken. True random sampling is impossible as the fish are all taken in shore-based or dockside sampling programs. Despite admitting to being unsure of the importance of the issue in the assessment, he would prefer to see growth data collected from samples of fish taken directly at sea, rather than from the landings at dockside. He would also like to see more evidence of incorporation into the assessment of measures of uncertainty in the life history parameters used for procedures such as in the estimation of spawning potential ratio, or generation time. Finally, on this topic, he expresses a general concern about the lack of evidence of the use of statistical procedures or model diagnostics in the development of various relations among biological and morphological characteristics of red snapper. According to his assessment, the development of these relations seems to have been conducted with unflagging faith in linear regression and properties of ordinary least squares estimation.

As potential solutions to these problems, Kaiser makes three recommendations:

- Data on growth, age, and possibly fecundity could be obtained directly from the catch as part of an at-sea observer program. This would not result in random sampling, which would only be

possible with a mandatory observer program, but it would eliminate potential bias in the source of fish from which the samples are taken (see also similar recommendation under section 4.2.4).

- Estimated standard errors and covariance in parameter estimates of growth curves and age-length or fecundity-length relations could be incorporated into a simulation-based procedure for investigation of uncertainty in estimation of spawning potential ratio from stock assessment models. A suggested procedure involving Monte Carlo simulation is provided in the Appendix to Kaiser's report (Annex 1).

- Statistical models used to estimate relations among life history characteristics should be subjected to a routine diagnostic procedure to examine specification of the systematic model component (i.e., regression equation), distributional assumptions (e.g., normality and homogeneous variance), and independence of residuals. The use of such diagnostics should be routine in the development of statistical models used in the management of red snapper.

Discard mortality

Two approaches to the estimation of discard mortality were presented to the panel: surface release and cage studies. Both Hayes and Fanning independently conclude that the cage studies are likely to give better estimates of the mortality associated with capture and release. Post release effects appear to be related to depth of capture. Fanning confirms that the 33% mortality assumed by Goodyear (1995) for discards in the commercial fishery is supported by the experimental results. He recommends that further studies be undertaken to improve the estimates of mortality, particularly with respect to the effect of depth of capture. He favors the use of cage methods and suggests that experimental design focuses on the ability of fish to control their buoyancy and return to depth.

Natural mortality

Kaiser believes that uncertainty in the level of natural mortality in the stock assessment procedure has been handled as well as possible. He comments, however, that uncertainty about this quantity, for which virtually no information is available to gauge the level of uncertainty that exists, seems to have been handled in a more satisfactory manner than has uncertainty about quantities for which it may actually be possible to assess the level of uncertainty.

4.2.7 Comments and recommendations regarding the estimation of bycatch of red snapper in the commercial shrimp fishery

All the panel members individually conclude that no other single subject under the statistics review has generated as much controversy or as much outside review activity as the bycatch of red snapper in the commercial shrimp fishery. This section is therefore devoted to a consolidation of the panelists' comments and recommendations on this topic. Before discussing their considerations in detail, however, several general issues raised in the reports are mentioned briefly here. These relate to the importance of understanding the role that estimation of bycatch plays in the overall process of making management decisions concerning the red snapper resource.

An important use of bycatch estimation is to provide mortality rate estimates for use in the stock assessment procedure and, in particular, the estimation and prediction of spawning potential ratio (SPR). However, Kaiser suggests that it is not clear whether the crucial aspect of stock assessment

for management decisions relative to the use of bycatch reduction devices (BRDs) is prediction of SPR under various alternative management strategies, or estimation of current SPR. The fact that bycatch mortality involves primarily pre-recruitment aged fish (ages 0 and 1) would appear to accentuate the effect of bycatch mortality rate in the estimation of SPR. That is, it seems that an increase in the rate of mortality for younger fish has a greater impact on estimation of SPR than an equivalent increase in the rate of mortality for older fish. Under current stock assessment procedures, it is not only estimation of the current level of bycatch and current data collection programs that are of concern, but also the estimation of bycatch mortalities in the past and therefore the use of past data. Kaiser notes that herein lies one of the major problems for the assessment, because it is impossible to improve the quality of the past data.

Proper estimation of bycatch is therefore important for providing a scientific basis for management decisions about red snapper in the Gulf of Mexico. Kaiser expresses the opinion that the need to make use of both current and past sources of data in assessing the need for immediate regulations relative to the use of Bycatch Reduction Devices (BRDs) makes it unlikely that those assessments can be based on a statistical estimation of bycatch that can withstand careful scrutiny. He notes that programs designed to provide data that allow a concrete probabilistic formulation of the problem of bycatch estimation have not been instituted until recently, if at all. He considers, therefore, that the issue of statistical estimation of bycatch is one that deserves substantial attention, but that further review of current methods constitutes only a recipe for inaction.

- Data collection and estimation protocol

Total shrimp fishing effort, derived from the shrimp TIP and the landings census, is used in the assessment to expand the estimated bycatch rates of red snapper in the commercial shrimp fishery. The bycatch rate itself is estimated from the fishery independent survey data using a multiplicative model (using GLM) based on the times when both these data and the shrimp effort data are available. The GLM model uses several datasets: the fishery independent data from the groundfish surveys, the bycatch per unit shrimp effort data obtained from the regional bycatch research program, and data from three volunteer observer surveys conducted during 1972-1982. Predictions of bycatch rate are made for all statistical data cells and then the effort associated with the given cell (estimated or imputed) is used to convert the bycatch per unit effort (BPUE) into an estimate of the total amount of red snapper in the shrimp catch. Fanning, and the other panelists, note that no attempt has been made to carry the estimates of precision or bias through the calculation.

- Previous reviews / other models

There have been a large number of previous reviews of the NMFS assessment work carried out on red snapper, which are mentioned in the reports of the panel members. Previous statistical reviews have occurred in 1991 and January 1997. Christman notes that the reports of the members of the January 1997 statistical panel, tasked to review bycatch estimation techniques, provide updates and recommendations for the more recent efforts of modeling the bycatch. Models that have been studied include: using raw means in each of the cells, using the Delta distribution to account for the excessive number of zeros; using various forms of the GLM model with ln(CPUE+c) as the response variable; using various pooling strategies for the strata and using those data in a GLM model; using fish to shrimp ratios as the response variable in a GLM; and, using different datasets in the GLM models for CPUE. She concludes that some form of the GLM model appears to be the currently accepted method for estimating bycatch, but argues that various efforts to pool data in different ways and then use the

results in the GLM model will provide neither any indication of whether the model is correct nor more accurate results. The data base itself is insufficient and pooling will not make it more sufficient.

Hayes also notes that past reviews have considered or suggested the use of the Delta distribution to estimate discard rates and he cautions against the use of this procedure. In his experience, while this method is useful when sample sizes are large, it is not a robust technique when small sample sizes occur in many cells, as is the case here.

- Problems

The problems described in the review panel's reports focus primarily on two issues - data collection programs and estimation protocols.

The key information required to monitor the bycatch is considered by each of the panel members to be at-sea observations of the amount, size and species composition of the both the target catch and bycatch. Observer data are only available for the periods 1972 to 1982 and 1992 to 1996. All the reports indicate that the lack of direct observations during the mid to late 1980's is the most serious hindrance to the estimation of discards. Problems with the observer data themselves are also noted, arising, for example, from the spatial and temporal coverage of the voluntary program. These problems are discussed in Section 4.2.6. Problems inherent in the other data collection programs which contribute to the estimation of bycatch, that is the fishery independent survey data and shrimp commercial catch and effort data, are also discussed in previous sections (see Sections 4.2.4 and 4.2.5).

The panel members' reports highlight a number of problems with the estimation procedures presented at the meeting. For example, Kaiser notes that none of the models proposed offer a means of producing variance estimates of bycatch. He further notes that neither NMFS nor LGL were able to provide, at the New Orleans meeting, error estimates for BPUE produced from their models, let alone for bycatch estimates produced by multiplying BPUE by estimated shrimp effort.

Another primary concern, expressed by Fanning, is that the present models used in the estimation procedure do not adequately account for the severe constraints imposed by the data. Christman lists the standard assumptions about the data made by the model: observations are independent, constant variance, functional relationship between dependent and independent variables is correct, and the independent variables provide the relevant information to explain the dependent variable. These assumptions do appear to be reasonable for the fishery independent data since those data were collected according to a standard sampling strategy. However, she considers that the observer data observations are unlikely to be independent because, at a minimum, they are clustered in time, space, boat, observer, and gear. Also the voluntary nature of the observer programs violates the assumption that the observations are randomly selected. Christman believes the assumption of constant variance is very unlikely to be met for several reasons: 1) differences in natural abundance levels by region and the way in which data are collected imply that the mean and variance are proportional; 2) the distinct differences between sampling designs (observer vs. SEAMAP) lead to different variance levels; and 3) since data are often pooled over varying numbers of observations the variances associated with each are also different. There is some variation in the level of importance attached to these various violations of assumptions in the panel members' reports. However in various ways they all independently express concern about the lack of adequate diagnostics in the presentations to assess their significance.

Several of the reports focus on the problems caused by the large numbers of zero valued data cells, which arise due to either no fishing (structural) or, more often, no data from the fishery (observational). Fanning notes that there is no distinction made in the analysis between these two reasons for having zero valued data cells. Kaiser notes that both the linear model used by NMFS and the similar model proposed by LGL at the New Orleans meeting make use of a design matrix (i.e., the matrix of covariate values, X) of less than full rank. This means that a generalized inverse of the $X'X$ matrix is used in solving the normal equations and, hence, that estimates of linear coefficients are not unique. For the prediction of values that do not correspond to columns of the design matrix X this can be serious problem, unless those values all correspond to estimable functions of the fitted model. There was no indication at the New Orleans meeting by either NMFS or LGL that the capability to estimate values for missing cells in BPUE models had been considered by any of these parties. Kaiser believes that this criticism alone is sufficient to render all of the various linear models presented to the panel potentially inappropriate for prediction of BPUE in the overall procedure for estimating bycatch.

All the reports consider the various efforts at reworking the estimation of shrimp effort, which have relied mainly on the GLM model and the same data, with various forms of pooling, which gave essentially similar results. Effectively summarizing the comments of several panel members, Fanning notes that both the current procedures and the recommended alternatives proposed during the meeting rely on indirect means of estimating bycatch and the existence of a relationship between the red snapper catches in research vessel surveys and in the commercial shrimp fishery. All the panel members individually conclude that one of the main problems with any of the potential estimation procedures is the poor quality of the dataset. Consequently, each member expresses the belief that it is unlikely that a reasonable statistical solution can be found for estimation of bycatch using present methodologies and the historic data. Having said that, Kaiser stresses that there are statistical considerations that should and can be addressed to improve the treatment of bycatch issues in the future.

- Recommendations of the review panel

In essence, the panel members all individually consider that the poor quality of the dataset undermines the results of the indirect approaches to estimating shrimp bycatch presented at the meeting by both NMFS and LGL. The present GLM-based methodology of estimating the red snapper bycatch from the shrimp fishery is deemed to be inappropriate. In various ways, the reports all indicate that provision of measures of uncertainty for bycatch estimates is vastly complicated by the use of methods which multiply estimates of bycatch per unit effort (BPUE) and estimates of total shrimp effort. Each panel member makes recommendations for alternatives, which strongly favor the testing and possible use of a variety of more direct methods of estimating or predicting the bycatch, without relying on this composition of estimates. The recommendations range from alternative estimation procedures, incorporating explicit measures of uncertainty, to suggestions for future data collection through the further development of the at-sea observer program.

The fish:shrimp catch ratio

Fanning and Kaiser independently recommend the use of the fish:shrimp catch ratio raised by the total shrimp catch as a promising alternative to the present method. At-sea observations, which provide the red snapper BPUE, also provide observations on the fish (red snapper) to shrimp ratio in the catch. If this ratio could be reliably predicted, it would provide an immediate means by which to estimate total bycatch. In essence, the Gulf wide mean red snapper:shrimp ratio could be calculated and expanded by the total shrimp landings to provide an estimate of the total red snapper bycatch. Expanding the

ratio by the total shrimp landings is likely to be a less controversial approach than using the total estimated shrimp effort, because it uses the direct landings records, which are based on a census. This also avoids the problem of imputing effort where no observations are available from the TIP. Kaiser notes that this does not presuppose that the covariates to be used in estimation or prediction of red snapper catch per shrimp catch are those used in the models of NMFS or LGL. In fact, there is no statistical reason that the so-called main effects of year and area should be employed in the estimation of this fish-to-shrimp ratio or even of the bycatch. He believes it is irrelevant whether the ratio of red snapper to shrimp caught displays any constancy across tows or geographically defined strata, or whether it has a 'nice' or 'ugly' distribution. According to Kaiser, it is simply the case that, if this ratio could be reliably predicted, the problem would be solved.

Fanning suggests two methods of estimating the red snapper:shrimp ratio: a design based ratio estimator and a calibration model. The calibration model would allow estimation for years when no commercial fishery observation data are available, by calibrating the research vessel observations with observer observations, where both exist. In this regard, he recommends the recent work by Prairie *et al.* (1995). The ratio estimator would provide a means of making efficient design-based estimates for years when both survey and commercial data exist. Having the two methods would provide some degree of cross-validation of the estimate properties. He also suggests a further alternative, which combines to some extent the design-based and model-based estimators, as presented in Smith (1990).

Small Area Estimation Methods

An alternative estimation model is suggested by Hayes, which directly relates the total number of discards to the abundance of red snapper and the amount of fishing effort applied to a time*area block:

$$\text{Discard}_{\text{area, time}} = f(\text{SEAMAP Index}_{\text{area, time}}, \text{Shrimp Effort}_{\text{area, time}}, \text{Area}, \text{Time})$$

Where,

$\text{Discard}_{\text{area, time}}$ is estimated from the at-sea observer program. Note that this is intended to represent the total amount of discards in an area*time block, and would likely be estimated from the at-sea observations of discard per unit shrimp effort times the total shrimp effort in the block.

$\text{SEAMAP Index}_{\text{area, time}}$ is the SEAMAP red snapper abundance index for the comparable area and time

$\text{Shrimp Effort}_{\text{area, time}}$ is the shrimp effort in the comparable area and time block

Area is a geographic region (potentially split into separate depth zones)

Time is a categorical variable indicating a particular year*month (or any other time resolution such as year*quarter) combination.

As an example, Hayes suggests a simple formulation of the functional relationship in which discard catches are related directly to the product of abundance and fishing effort. Area fished, season, and year are used as blocking factors rather than as explanatory factors. He also mentions more complex formulations of the model, including the use of other covariates such the fish:shrimp ratio and the amount of shrimp landed, or a non-linear approach, using the catch equation to predict discard (catch of red snapper) from effort measures. He proposes that the simpler approach be tested before trying more complex models.

Estimates of total discards based on at-sea observations would be available for some area*time combinations. The total discards for areas without at-sea observations would be predicted from observations of red snapper relative abundance and shrimp fishing effort. For areas with at-sea observations, the point estimates based solely on the observed samples could be combined with the model prediction to develop an improved estimate for those areas. A method to appropriately combine the observed data with model predictions is the small area estimation method (see Ghosh and Rao 1994). This method is recommended independently by both Hayes and Kaiser.

Kaiser explains that a small area estimation problem results from a situation in which a large geographic region of interest (in this case the relevant portion of the Gulf of Mexico) is subdivided into a partition of smaller areas or regions. These small areas need not be regular in dimension or of equal size. An estimator of the quantity of interest is available for each of the small areas, but these estimators may be based on very few observed data values. Thus, individual estimators for the small areas are unacceptably imprecise. Kaiser explains that the essential feature of small area estimation is the incorporation of variability at the level of the small areas, but variability that follows a definable pattern across the small areas comprised by the larger area of interest. Details of a suggested approach using small area estimation is also provided in the Kaiser's report. The crucial message, articulated in that report, is that the method provides for the capability to judge its performance through measures of uncertainty. Kaiser stresses that a procedure based on small area methodology may or may not perform well, but in contrast to all current methods, for which no variance estimators are available, its performance can be judged.

Data collection

Christman expresses the opinion that any alternative data analyses will not provide better results unless the data base on which the estimates are based is upgraded. Several of the panelists' reports recommend, in various contexts, that better data be obtained through some form of sampling design which allows for more data and better coverage spatially, temporally, over all gear types, tow types, and vessel types.

Fanning points out that most of the data used in the current procedure for estimating bycatch in the shrimp fishery are generated for other purposes, primarily for shrimp fishery management. The bycatch assessment procedure therefore uses an indirect means of getting to an answer. In particular, there is no specific requirement to estimate red snapper bycatch directly in the shrimp fishery. All the reports individually stress the importance of obtaining data on the bycatch directly from the fishery and suggest that this can be done through the at-sea observer program (see section 4.2.2)

- Evaluation of the performance of bycatch reduction devices (BRDs)

Kaiser raises concerns with respect to the evaluation of the effectiveness of bycatch reduction devices, and specifically the lack of consistency between sampling design and statistical analysis of the resulting data. He considers that evaluation of BRDs through comparison of red snapper bycatch for nets with and without such devices is a clear statistical problem. Despite this, it seems not to have been treated as such. Kaiser's primary concern is the lack of a coherent probabilistic framework attached to the experimental design. Either the statistical analysis did not make use of important structure incorporated in the sampling design (i.e., blocking to improve the validity of comparisons among treatments) or the sampling procedure was designed without consideration of appropriate statistical analysis. He recommends that if further evaluation of BRD effectiveness is important, NMFS

should seek statistical advice not merely for the analysis of data, but in formulation of an appropriate statistical framework for consideration of the problem.

Kaiser suggests a possible approach using a type of blocking structure defined through groups of vessels or boats rather than individual vessels. In this approach, a basic sampling unit would consist of tows conducted by three boats within a given area and time span. One of these boats would be designated as the 'control' or 'baseline', and would use only nets without BRDs. The other two boats could consist of one that uses only nets with BRDs and one that, similar to the control boat, uses only nets without BRDs. The random variables of concern would then be defined as differences between the baseline tows and tows from the two 'treatment' boats. Such an overall structure would allow differences between tows conducted with and without the use of BRDs to be compared to differences between tows conducted only without BRDs, which is different than the simple comparison of tows with BRDs to those without BRDs.

Table 4.1 Commercial Red Snapper Fisheries Data Collection Programs

	NMFS Landings census (including LA and TX State supervised programs)	Mandatory Logbook Program for catch and effort data	Trip Interview Program (TIP) for size frequency data
1. Appropriate design?	• Port agents collect landings data from seafood dealers; • Incentive to under report; • No discard information; • Misses catch sold to any non-dealer (e.g., restaurants, consumers); • Some inconsistencies between national and state schemes should be rectified; • Gear used and area fished provided by port agents based on their knowledge of the fishery, no information on these items from reports provided directly by dealers.	• 100% coverage of vessels with a federal vessel permit since 1992, but does not cover all the commercial red snapper harvest; • Opportunity for comparisons with landings census data - shows good agreement to within 6%; • Discard field dropped in 1996 due to lack of use; Provides information not available from other programs.	• Since 1992 focused on size frequency data only; • Opportunistic or convenience sampling is non-random and may introduce bias; • Some groups of fishers may be systematically missed due to working hours and landing practices; • Provides no information on discards; • At least 50% of the data are aggregated landings collected from the dealer rather than from individual vessels; • Provides data on the size distribution of the landings rather than the catch.
2. Estimation protocol appropriate?	• Complete census results; • Data are apparently used correctly .	• Tabulation of census results, but does not cover non-permit holders, hence it is not clear whether it is a census or sampling methodology; • Logbook presents an opportunity for a formal stratified sampling program targeted at the commercial fishery .	• Data used to characterize (i) the size distribution of commercial red snapper and (ii) the spatial distribution of red snapper by size; • Conversion of lengths to age (Goodyear 1995) appears to be appropriate; • Estimation procedures assume samples are randomly selected; they are not and the resulting length distributions are therefore likely to be non-representative; • Spatial distribution of samples is very uneven; • Location of catch probably poorly defined in aggregate samples; • Uneven probability aspect of sampling difficult to quantify. • Appropriate blocking factors used
3. Sampling level and coverage adequate?	• Sampling adequate for main dealers; • Should determine the portion of landings missed through direct sale to restaurants and consumers.	• Good coverage, but does not cover non-permit holders; • Permits denied if vessels fail to report	• No, it is not adequate - there is little opportunity to take random samples ; • Provides samples of fish brought ashore, not of the actual catch ; • Sampling coverage is adequate .
4. Identifiable biases?	• Potential for census undercount and incentive for under-reporting; • Biases not controllable and not quantifiable ; • relies on port agent experience for information on gear and area fished.	• Incentive for under-reporting by fishers, but reasonable agreement with landings census.	• Non-random 'opportunistic' sampling may introduce bias, but it is not quantifiable; • Uneven spatial coverage of samples, possibly leading to exclusion of large subsets of the population; • Haphazard selection of fish by port agents for length measurement may introduce bias.
5. Precision properly expressed?	• Census with no error assumed, uncertainty not relevant.	• Census with no error assumed, but uncertainty may be an issue since not all effort is recorded.	• No; • Variability results from the sampling design and also measurement error.; • Precision should not be estimated due to non-random sample selection ; • but a measure of uncertainty would be relevant .

Table 4.2 Recreational Red Snapper Fisheries Data Collection Programs

	MRFSS private/rental, charter/head boat and shore	Texas Marine Sport Harvest Program	NMFS charter boat program	NMFS Southeast region headboat survey (Beaufort Lab)
1. Appropriate design?	• Telephone survey for effort data and trip intercept interviews for discards and cpue; • Well designed survey for national coverage (excluding Texas) and estimation of effort by individual anglers; • Random dialing strategy not well suited to local area estimation of variable fisheries, such as red snapper, due to small local sample size; • Particularly poorly suited to collecting information on more rare modes of fishing such as charter boat and headboat effort; • On-going studies to improve the sampling frame for party and charter modes;	• Analogous to the MRFSS; • Well designed and well implemented; • On site rather than telephone interviews; • Shore based fishing not sampled; • Charter boat component also poorly estimated	• Mandatory logbook program effectively refused by charter boat operators; • Voluntary program operated from Panama City Lab	• Mandatory logbook program; • Structured as a census but coverage is variable between years. Presently about 80 to 90% of fishing effort is directly reported.
2. Estimation protocol appropriate?	• Estimators are constructed correctly; • Concern with deletion of large values for number of charter trips in telephone survey; • Concern with use of 5 year running mean for charter boat data may introduce bias; • Insufficient attention given to the comparison of estimates made across programs.	• Estimators appear to be constructed correctly; • Estimation of effort done differently to MRFSS, which may change the variance.		• Sampling bias due to incomplete census and possible non-random sampling not accounted for; • Attempts made to fill in data for missing trip reports, due to poor spatial and temporal coverage.
3. Sampling level and coverage adequate?	• Not best suited to local single species studies; • Sample size and coverage insufficient to characterize the recreational fishing pressure to the desired level of precision; • Private access fishing and night fishing not sampled by the intercept survey; • missing observations are imputed - needs to be considered when calculating precision, otherwise sample sizes may be inflated; • Sample sizes for private and shore modes .	• Sample size and area covered is reasonable; • Lack of sampling shore based fishing, but red snapper apparently not caught in that mode.	• Geographical scope too small to be useful in the overall Gulf of Mexico	• Needs additional resources to intensify coverage to complete census.
4. Identifiable biases?	• Survey personnel have accounted for all obvious sources of bias and continue to improve their procedures; • Adjustments made to account for unsampled populations or for high variance observations may introduce biases.	• Small potential for introducing bias due to assumptions and adjustment for missing data and post stratification required to construct MRFSS-compatible estimates.	• Use of volunteers in the survey introduces unknown bias. • Not applicable at this time	• Incomplete census introduces unknown bias; • Concern over Imputation of values for vessels for which no data exist, other than they made some trips
5. Precision properly expressed?	• design aspects are incorporated in the variance estimation procedures; • considerable attention paid to the estimation of variance, but no indication of how the information is used; • No consideration of uncertainty in size frequencies from intercept interviews .	• Variance only estimated for total landings; • No estimation of variance of within stratum means.	• Not applicable at this time	• Considered but unresolved; • Claim that precision does not need to be estimated because the ratio of recorded trips to unrecorded trips is high is invalid .

Table 4.3 Fishery Independent Data Collection Programs

	SEAMAP	NMFS Fall groundfish survey
1. Appropriate design?	• Stratified survey design to provide fishery independent information on, distribution, abundance and stock structure for red snapper and other groundfish resources in the survey area; • Over-stratified.	• Stratified survey design to provide fishery independent information on, distribution, abundance and stock structure for red snapper and other groundfish resources in the survey area; • Over-stratified.
2. Estimation protocol appropriate?	• Estimation protocol ignores stratification; • estimation procedure for mean catch/tow was a mean of all tows because of problems with strata with missing observations.	• Estimation protocol ignores stratification; • estimation procedure for mean catch/tow was a mean of all tows because of problems with strata with missing observations.
3. Sampling level and coverage adequate?	• Sample allocation of 1 per stratum precludes design based estimates of variance; • Suggestions of possible expansion of juvenile red snapper distribution may require increase in the survey area.	• Sample allocation of 1 per stratum precludes design based estimates of variance • Suggestions of possible expansion of juvenile red snapper distribution may require increase in the survey area.
4. Identifiable biases?	• concern over the effects of combining data from different research vessels.	• concern over the effects of combining data from different research vessels.
5. Precision properly expressed?	• Sample allocation of 1 per stratum precludes design based estimates of variance.	• Sample allocation of 1 per stratum precludes design based estimates of variance

Table 4.4 Commercial Shrimp Fisheries Data Collection Programs

	NMFS Landings census	Trip Interview Program (TIP) for catch and effort	Voluntary at-sea Observer Programs
1. Appropriate design?	• Port agents collect landings data from seafood dealers; • All under NMFS supervision, hence no problems of inconsistency; • Port agents assign grid zones to the reported landings based on their knowledge of the shrimp fishery.	• opportunistic sample interviews to obtain catch and effort data; • Non-random sampling; • Suggest shrimp permits and trip tickets would be a better source of information on shrimp effort ; • Deliberate effort to target larger shrimp vessels (Coast Guard documented); • Data collection program inadequate	• Three volunteer observer programs associated with turtle catch reduction research and SEAMAP data; • Regional bycatch research program - a voluntary observer program started in 1992; • Voluntary program insufficient to obtain representative samples.
2. Estimation protocol appropriate?	• complete census of landings.	• Effort data available for a much smaller fraction of the total shrimp trips than are the catch data; • Data used to estimate CPUE of the shrimping fleet in each of 221 cells each month; • Missing data imputed using GLM model; • Used to estimate total shrimping effort; • Excessive number of strata ; • Available data are inadequate for estimating the CPUE for the entire industry, as assumed in the GLM .	• Many tows show zero catch of red snapper, but it is unclear if this indicates that red snapper are not being caught (exclusion from the nets) or there are no red snapper to be caught in the area (low or no abundance); • Areas where no red snapper can reasonable expect to be found should be excluded from the estimation procedure; • See text for discussion of bycatch estimation procedures.
3. Sampling level and coverage adequate?	• data collected as fully as possible.	• Missing vessels which fish very close to the shoreline; • Fewer and fewer captains willing to be interviewed; • Approximately 15% of all offshore trips sampled; • Sample size adequate • Data too sparse for the structure the analysts wish to impose on the estimation effort .	• Observer coverage between 1992 and 1996 insufficient; • 30% of strata used in estimation had no data; • Data clustered spatially in terms of gear, boats and observers .
4. Identifiable biases?	• Small potential for census undercount.	• 1994 review identified several potential sources of bias which are still relevant; • Random sampling of vessels not possible in this fishery; • Deliberate targeting of larger and Coast Guard documented vessels should cease.	• several potential sources of bias, including clustering of sampling and volunteer status.
5. Precision properly expressed?	• Complete census, assumed no variance.	• Estimation of variance not possible without making strong assumptions about the unsampled subsets of the population.	• No precision expressed.

4.3 The Economics Review

4.3.1 Outline

As with the Statistics Review Panel, the Economics Review Panel was presented with a detailed package of information, in the form of written reports and verbal presentations, on which to base their appraisal of the data and analyses which contribute to the economic ramifications of alternate management strategies for red snapper. In this case there were four specific objectives of the review, to be achieved through the consideration of three specific questions (see section 3.2)

In responding to the task set for them, the four panel members have each produced a separate report presenting their personal professional review of the economic analyses underpinning management of the red snapper fishery and the control of bycatch in the shrimp fishery in the Gulf of Mexico. As with the Statistics review, the four panel members each use a different report structure to present their findings. Whilst each of the reports provide comments on the major economic issues, the depth of coverage of each issue varies between reports, depending on what the individual reviewers have chosen to focus on. In cases where a reviewer has not responded on a particular point or question, this should not be construed as tacit agreement or disagreement with the findings of the other panel members, rather it is simply that on these particular issues, the panelist made no comment.

In order to produce a consolidated report, the details of the reviews are presented in three main sections; the commercial red snapper fishery, the recreational red snapper fishery and an economic analysis of the reduction of bycatch in the commercial shrimp fishery. The first of these is subdivided into subsections focusing on the various alternative management strategies which have been under consideration for the commercial sector at one stage or another, and are discussed in the panel members' reports. These are open access with and overall quota, limited entry, season closures, effort control, 2-tier license, trip limits, split season, first 15 days each month and, Individual Transferable Quotas (ITQs).

Frederick Bell (Bell) considers that an understanding of proposed management regimes must consider the three components (commercial and recreational fisheries targeting red snapper, and bycatch in the shrimp fishery) in a simultaneous model showing how efficient economic outcomes can accrue when they are properly integrated. Thus, he suggests, proposed management measures such as ITQs or a fixed number of licenses, for example, must be imposed on all three economic sectors to evaluate the economic outcome. He believes that a piece meal approach can be useful, but only by integrating the three sectors in terms of economic behavior can an acceptable economic analysis be accomplished.

Ralph Townsend (Townsend) provides readers of his report with a brief explanation of his view of the role of economic analysis in fisheries management, and specifically regulation. He concludes that economic analysis should not be tightly constrained by the immediate or short-run political and legal context. In evaluating the economic analysis conducted on the management of the red snapper fishery, the standard he applies is whether the analysis is both relevant to the immediate regulatory context and still sufficiently independent and broad to educate participants in the regulatory process about fundamental economic forces.

In opening his report, Gardner Brown (Brown) outlines some of the problems associated with economic analysis of fisheries. In particular he believes that harvest cost *functions* for fisheries don't exist, or are so primitive that it is not possible to know with credible reliability how costs would vary with one or more policy changes. He notes that the red snapper fishery is no exception and considers that the problem is further exacerbated by a sport fishery for which *no economic* values are available. In general he considers that the management body considered a reasonable set of alternative policies and made a very good appraisal in light of the data limitations and budget constraint.

4. Consolidation of the reviewers' reports

The report prepared by James Wilson (Wilson) was considerably longer than those of the other three panel members. In it, he provides detailed comments on the economic analyses undertaken, and on the specific texts of Amendments 8, 9 and 15 to the Reef Fishery Management Plan. This consolidated report aims to summarize these comments and extract the most important recommendations. However, in the interests of producing a balanced consolidated report, some of the more detailed comments on the text of the Amendments are not reproduced here. The reader is therefore directed to Wilson's original report, included in Annex 1, for additional detail.

4.3.2 Background to the economic analysis

This section reflects the information in several reports providing a brief review of the recent history of management of red snapper in the Gulf.

According to Bell, it is recognized that the fundamental problem in the red snapper fishery is overcapitalization(i.e., too many vessels) and that this problem has led to a depletion of the stock and a fleet operating in an economically inefficient manner. Overall quotas were implemented in the fishery in 1991 by the Gulf of Mexico Fishery Management Council (the Council). In the following year a derby fishery started and got progressively worse in succeeding years. Ancillary restrictions on commercial fishing began with a requirement for 50% income from fishing and later included "endorsements" for trips limits of either 2000 pounds or 200 pounds. Minimum fish sizes were introduced and gradually increased from 14" to 16".

According to Townsend, the Council recognized the potential problems of quota management relatively early and analysis of limited entry options began in 1992. Over the period 1992-1995, the Council took a variety of actions that increasingly focused upon ITQs as the most desirable management option. In 1994, the Council approved Amendment 9, which collected the data necessary for making allocations under an ITQ program. Amendment 8 considered three alternative management regimes; open access with an overall quota, a license limitation scheme and ITQs. These management systems had the objective of rebuilding the red snapper stock to the management target of 20%SPR by the year 2019, but their economic efficiency was also considered by the Council. It arrived at the conclusion that an ITQ system is projected to be economically more efficient and is thus "preferable alternative".

The Council approved ITQs in May 1995 and NMFS approval was secured in November 1995. In a budget resolution in 1996 (HR 3019), Congress set a retroactive moratorium on implementation of new ITQ programs. In Townsend's opinion, the legislative history indicates that this action was motivated specifically by interest in the red snapper fishery. In the Magnuson-Stevens bill, Congress extended that moratorium until October 1, 2000. He further explains that because the existing license moratorium and endorsements expire December 31, 1997, the Council must either enact a replacement for Amendment 8 by the end of 1997 or let the existing limitations expire.

Through Amendment 15, the Council moved to adopt the second-best alternative identified in Amendment 8, which was license limitation. Townsend notes that given the time constraints for preparation and implementation of Amendment 15, the Council did not carefully consider options beyond those in Amendment 8 nor did staff prepare additional analysis. Wilson describes Amendment 15 as essentially Amendment 8 without the ITQ option. He suggests that it could be revised with a view to describing how limited licensing could be melded with a future ITQ program, which includes not only red snapper, but other important reef fishes exploited by commercial and recreational fishermen. Also, given that limited licensing appears to be the only politically feasible option to date, he suggests that it may be worthwhile to study the performance of license limitation policies elsewhere. He explains that whilst limited entry in certain regions of the world has failed to

produce the desired effects, it is important to consider this option seriously, and to make suggestions on its application that could pave the way for a more rational introduction of ITQs in the future.

4.3.3 Summary of findings and recommendations of the panel members

The four reports from the members of the Economics Panel present a considerable amount of detail on the economics of management of the red snapper fishery. For ease of reference, this section of the consolidated report aims to provide a brief, at-a-glance summary of the main findings of the panel with respect to the principal issues discussed in the individual reports. Additional detail is provided in the following three sections, focusing respectively on the commercial fishery (4.3.4), the recreational fishery (4.3.5) and the bycatch of young fish in the shrimp fishery (4.3.6).

At the outset, Wilson emphasizes that what is being confronted is essentially an integrated management problem, having at least three well-identified groups who are major stakeholders: the commercial red snapper fishermen, the recreational sector (headboats/charter boats and private fishermen), and the commercial shrimp fishery. He notes that the peer review is ostensibly for the commercial snapper fishery management actions, but suggests that more important issues, having arguably more important economic impacts, involve the other two sectors.

The reports of the members of the Economics Panel are generally complimentary of the attempts made by NMFS to resolve these complex issues. According to Wilson, while there are points of disagreement on detail, analytical vision and possible management options, the basic themes and arguments in support of the analyses are convincing. He considers there is a high level of sophistication and diverse information derived from the economic analyses in Amendments 8, 9 and 15. He specifically elaborates that analyses in support of Amendment 8 are largely anecdotal, but with a number of direct references to notions in welfare economics, while the analyses in support of Amendment 9 are highly organized, largely empirical, though well-grounded in economic theory, and yield some unexpected results which could not have been divined, *a priori*, by intuition. Bell concludes that The Gulf of Mexico Fishery Management Council and National Marine Fisheries Service did an overall excellent job in describing the economic effects of an ITQ system for the Gulf of Mexico Red Snapper and Brown believes the management body considered a reasonable set of alternative policies for the commercial fishery. As with the other panel members, he considers the principal limitation to the analyses was the incomplete integration of the three sectors: (l) commercial; (2) recreational and (3) the bycatch of red snapper by the shrimp fleet.

- The commercial fishery

Several different potential management regimes have been considered in the context of the commercial fishery for red snapper, including ITQs and license limitation. With respect to ITQs, Townsend concludes that the economic analyses in Amendment 8 were sufficient to support the conclusion that ITQs would be the best way to end the derby fishery and, hence, to support the conclusion that ITQs are the preferred management alternative. He further notes that had the data been available to estimate the cost savings under ITQs, the conclusion that ITQs are preferred would have been strengthened. Bell also considers that the economic analysis of ITQ options in Amendment 8 was adequate, although somewhat limited. He cites three fundamental economic benefits of the ITQ system over the *status quo* (i.e., open access and overall quotas) and license limitation systems:

- reduction in fishing effort;
- reduction in fishing cost; and
- improved quality of the catch.

He concludes that despite concerns about the interaction of the recreational fishery with the commercial fishers (see section 4.3.4), it is highly recommended that the proposed ITQ system be implemented as soon as possible. The reason he gives is that it has proved effective almost everywhere in the world in terms of stock rebuilding; reduction in overcapitalization and making the fishery economically more efficient.

Brown also believes that policies other than ITQs are second-best and cause losses in economic benefits for the nation. However, he goes on to summarize a concern, expressed independently by other panel members, that an important qualification to the support of ITQs, on the grounds of economics, is that if the costs of monitoring and enforcement for ITQs exceeds those of monitoring and enforcement for an alternative management policy, they must not exceed the otherwise economic superiority of ITQs. A further concern, mentioned by Brown, is the need to avoid concentration of ownership, through limitation of the number of rights any single entity can own.

According to both Bell and Townsend, the economic analysis of license limitation in Amendment 15 was appropriate, given the regulatory context and time constraints created by the suspension of Amendment 8. However, a common opinion expressed independently by several panel members is that if license limitation is to become the core of red snapper management, then additional economic analysis of limited entry and effort controls is necessary. Townsend also suggest that the relationship between costs of fishing in the commercial red snapper fleet and alternative regulatory approaches (including both ITQs and effort controls) needs to be investigated using the recently completed cost survey (Waters 1996). Notwithstanding these additional analyses, Bell concurred with the findings of the Council that license limitation is wanting in its effectiveness in both rebuilding of the stock and promoting the economic efficiency in the red snapper commercial fishery.

In terms of other management options, Townsend believes the data are clearly adequate to document the negative consequences of reinstating open access or maintaining the *status quo* of license limitation at a level of excess effort. He notes that effort restrictions other than simple license limitation were not considered in Amendments 8 and 15. This is understandable, given that Council had good reason to believe that effort restrictions would be less satisfactory than ITQs. However, he points out that if ITQs are no longer a management option, the Council needs to explore further the alternative approaches to effort control. He suggests that these would include fractional licenses and individual transferable input systems (see section 4.3.4 for details), although implementation of such effort controls needs a clear understanding of the relationship between inputs and outputs and how harvesters will respond to restrictions. In his opinion this evidence is not presently available. The recently completed NMFS economic survey (Waters 1996) should provide some of the necessary data, but an understanding of how industry will respond to these controls will require extensive industry input.

- The recreational fishery

Several panel members express concern about the poor data and lack of economic analysis of the recreational sector. According to Bell, the recreational fishery data are of questionable validity and Townsend believes that the economic analysis of the commercial/recreational allocation and of the regulation of the recreational fleet is not sufficient to adequately inform regulatory decisions. The efforts made by NMFS to correct some significant data deficiencies are noted, and Bell specifically recommends that more research should be undertaken in this area, but he believes that substantial problems are likely to persist. As part of this process, Townsend suggests that the economic value of the recreational fishery needs to be assessed to determine the appropriate allocation between

recreational and commercial fisheries. The planned supplemental survey for the MRFSS should provide data to better address this task. He also proposes that the differences between the headboat/charter boat and the private/rental recreational sectors need to be explored, to investigate whether uniform treatment of these sectors is appropriate.

All the panel members express concern in various ways at the quota overages by the recreational sector. Townsend points out that under the Magnuson-Stevens Act, the Council will be forced to take action to deal with quota overages. Several suggestions are made in the reports regarding the approach to regulation of the recreational fishery and these are described in section 4.3.5.

- Bycatch reduction

Bell considers that the approach to the economic analysis of bycatch reduction requirements under the Shrimp Fishery Management Plan is generally appropriate. However, as do other panel members, he notes that analysis of impacts on the shrimp fishery is more thoroughly developed than the effects on the red snapper fishery and this deficiency should be corrected. Townsend suggests that a comprehensive model of shrimp, commercial and recreational red snapper fisheries, and other impacted fisheries needs to be completed to assess the appropriate bycatch strategy in the shrimp fishery.

The main criticism leveled by several of the panel members is that alternatives to the use of bycatch reduction devices (BRDs) were not fully explored (e.g., Wilson and Townsend). Additional detail on this issue and suggestions for alternative approaches are provided in section 4.3.6.

- Conclusions

Brown concludes his report by speculating that if it were possible to:

- estimate the sport and commercial net economic value of harvest (as a function of harvest level) for each year for many years;
- estimate the population dynamics of the red snapper; and
- estimate the opportunity cost of reducing bycatch to the shrimp fishery,

then the economically optimal recovery rate of the red snapper population could be estimated. He believes, however, that this scale of optimization cannot be undertaken until at least further research is directed at the recreational fishery since there are currently no useful recreational values. He suggests the goal of the optimization exercise would be to equalize the marginal value of the fish across the three sectors (commercial, private/rental and headboat/charter boat) and allocate a fraction of the harvest each year to each. He explains how various uncertainties and practical realities (e.g., the short term prohibition on ITQs in the Magnuson-Stevens Act) could be incorporated in the analysis, but acknowledges that political feasibility is not included. Townsend also believes that the economic value of the recreational fishery needs to be assessed to determine the appropriate allocation between recreational and commercial fisheries. He considers that the planned supplemental survey for the MRFSS should provide data to better address this task. Echoing Brown's division of the red snapper fishery into three sectors, he also believes that the differences between the head boat/charter boat and the private/rental recreational sectors need to be investigated to determine if uniform treatment of these sectors is appropriate. Following on from this, Townsend suggests that the relative impact of minimum sizes, bag limits, and other types of recreational restrictions (such as minimum hook sizes) should be evaluated, with the goal of devising regulations that maximize the value of the fishery to participants.

4.3.4 Economic analysis of alternative management regimes for the commercial fishery

This section consolidates the parts of the panel members' reports which provide specific responses to the question which they were posed:

> *When the Gulf of Mexico Fishery Management Council was considering implementing effort controls for the red snapper commercial fishery, were all reasonable effort management alternatives considered? In addition to ITQ management for red snapper, to what degree did the Council consider license limitation, multi-species effort management, management involving specific geographical areas or other relevant alternatives designed to limit overall commercial effort?*

According to Brown, the most relevant management regimes were considered and the quantitative analysis was suitable, assuming that only existing data were used. Wilson, questions whether "all feasible management regimes and approaches" are being considered in the management process and takes this to mean those options currently discussed in the management literature, which should be readily accessible to the Council and NMFS staff. He notes several factors which may have limited the analytical and management options open to the Council and NMFS, including their selective investment in certain types of information, and the public management structure, legal framework and the economics of the industry. He further suggests that the authors and interpreters of the Magnuson Act have historically been wary of limited entry and ITQs, even though these management approaches organize the industry in ways which are closer to the spirit of free enterprise and individual initiative than management by regulation or community-based commons management. What remains is open access management of effort by regulation and global quota restrictions.

Townsend notes that aggregated species quotas and geographical fishing areas were not seriously considered in the management process, but since these types of management are not common, and review panel was not presented with any evidence that specific proposals were presented in the regulatory process, there is no reason to expect such proposals to have been analyzed.

- Open access with an overall quota

Brown notes that a quota is merely a change from open access to a population, to open access to the quota based fraction of the population. All the economic disadvantages of open access remain. Bell reports his agreement with the findings of Raulerson (1997) that the derby fishery under the overall quota has led to:

- excess capacity;
- safety problems;
- lower ex vessel prices; and
- a dissipation of rents from the red snapper fishery resource.

In addition to these, Brown lists the following more specific effects:

- increase in the unit cost of harvesting and consequent decrease in profit;
- changes in the pattern of landings;
- changes in regulatory policy causing increased uncertainty in the planning horizon;
- increased imports.

Summarizing, Brown quotes the following information provided during the panel meeting:

- fleet size doubled from 1975-1985;
- fleet size tripled from 1975 -1990;
- an annual quota established;
- the length of the season dropped from 235 days to 51 days;
- dramatic price decrease induced by the pulse fishing activity (when industry quota is a constraint, the quota causes a loss of real ex-vessel price of $0.85 per pound).

Bell considers that the overall quota system has sent a false economic signal to the fishermen, embodied in the rising catch or TAC, which has induced optimism, yet the industry is characterized by gross inefficiency. In Bell's opinion, the overall quota system has been demonstrated to be grossly inefficient from the yellowfin tuna fishery on the West Coast to the yellowtail flounder fishery on the East Coast of the U.S. Elaborating on the safety problems caused by the derby fishery, in which harvesters are more likely to venture out in bad weather, Brown notes that the owners of small vessels are actually discriminated against, because small vessels are more vulnerable to bad weather than are large vessels.

Referring to depreciation in value resulting from market glut, Bell notes that derby fishing within the context of an overall quota actually decreases industry revenue during the short quota periods. He concludes that the nature of red snapper demand is critical in evaluating the economic impact on the fleet. The price may also be affected by increasing imports (from about 0.5 million pounds in 1990 to 2 million pounds in 1996).

- Limited entry

In Brown's opinion, limited entry merely concentrates what he refers to as the rushing (i.e., derby fishing), the capital stuffing, the increased danger, the decreased price and the increased harvest cost to those fortunate enough to own the privilege of remaining in the fishery. Each of the insiders has an incentive to capture as much of the quota as he/she can. The owner of an entry right buys as much of every possible element in the vector of fishing power as long as he/she thinks its cost will be covered by expected additional harvest revenues. Bell also notes that license limitation almost universally results in gradual increase in fishing effort as technology improves and fishermen find new ways to outwit the regulatory authority.

Wilson cites examples of both success and failure of limited licensing management strategies. He explains that limited licensing is relatively successful in Alaska is because:

- Gear types are defined;
- Species (salmon and herring) are defined;
- Areas are defined, and;
- Fishermen had to be involved, through contributions to hatchery investments and other activities, in the enhancement and development of salmon stocks in their regions.

He considers that failures in limited licensing have more to do with problems in the application of the tool rather than the tool itself. For example, the British Columbia salmon program had a government-administered buy back program to reduce effort, but since it was not self-funded, it ran out of money early in its existence.

- Season closures

Brown explains that season closures, combined with limited entry, partition in time the open access phenomenon and its consequences. Prices, therefore, continue to fall each time the fishery is opened. He poses the question that if splitting the season is good, why not divide the season up into many intervals? Although he acknowledges that this would imply that a federal agency knows best when to allow and when to prohibit harvesting, and that there is some evidence to support a policy which dictates when all harvesters should concentrate their harvesting activity. Brown has not seen evidence to show that efficiency or equity is enhanced by such a uniform policy. He suggests it would have to be based on some form of asymmetric information which one or more government agencies have, and is too costly to distribute to the harvesters. Without such evidence, he considers there is no reason not to design a policy which gives harvesters the choice of when to fish, as long as the biological goals are met, and that it would be difficult to allow this freedom except under an ITQ system.

- Effort controls

Townsend attributes the successful reduction of effort and fishing costs in some fisheries to the application of effort limitations, such as limits on the number of traps, or allocations of fishing days. He notes, however, that there are disadvantages in that harvesters have incentives to undermine the restrictions by increasing the use of unregulated inputs (such as crew size or gear design). He believes that the success of effort control strategies depends upon the specific characteristics of the fishery. For example, he suggests that the multispecies nature of the Gulf of Mexico reef fishery might raise particular problems. He suggests that an examination of the feasibility of effort limitations will require not only greater economic analysis but also extended discussions with the industry. The disadvantages of effort limitations must then be weighed against the clear costs of a derby fishery. In any event, he notes that the options of the Council for effort control are restricted by Section 407 (b) of the Magnuson-Stevens Act. That section has a moratorium on red snapper plans that authorize "the consolidation of licenses, permits or endorsements that result in different trip limits for vessels in the same class". When the moratorium expires, a referendum of the industry is required to implement such regulations.

Townsend is concerned by the scope of the cursory economic analysis in Amendment 8 of how license limitation might work in the red snapper fishery. He cites the core economic problems of license limitation identified on pages 13-14 of the final Amendment: For license limitation to end the derby, either:

(a) the number of licenses would have to reduced by as much as 75%, which would face immense political opposition, or

(b) effort would have to restricted by increasingly cumbersome and onerous restrictions on trip limits and fishing time.

But, he points out that the discussion did not examine options such as transferable fishing-days or other forms of individual transferable inputs ("ITIs") and explains that in some fisheries, ITIs (such as trap limits in lobster fisheries) have been effective. The New England Fishery Management Council has adopted non-transferable days-at-sea programs in both its scallop and groundfish industries. He suggests that greater depth in the analysis of license limitation and effort control was warranted.

According to Brown, with rare exceptions, effort control is inferior to an ITQ type policy. He believes that effort control cannot be supported analytically except under exceptionally restrictive assumptions and it has been rarely tolerably economically efficient. His argument is that, in comparison to ITQs, effort controls are an indirect approach to defining the property right (the right to harvest fish). ITQs fix the harvests taken by all the agents in the fishery, and the target harvest is automatically achieved, *assuming no cheating*. By contrast, in order for the target harvest to be achieved under effort control, the regulators have to fix *every* element of the operation (the 'production function') which are necessary for the harvest taken by each agent. The more uniform the production function across harvesters, the easier the task of effort control becomes. However, the harvesters are not uniform in gear skill or days fished in the red snapper fishery. Similarly, the smaller the number of element of the operation which are necessary for the harvest the easier it is to establish effort control. But there is not excellent information about this. Brown also point out that each time technology or the price of any input changes, if the regulators don't respond appropriately, fishermen will lose money using the old technology and will have an incentive to circumvent the rules legally and illegally.

Brown concludes that to establish sound effort controls, it would be necessary to obtain time series data on the inputs that determine fishing power and prices for these inputs. Since none of those data exist at present, the time series would have to be long enough to provide the desired statistical accuracy, which he suggests is more than a decade. Such data are not necessary to implement ITQs.

Amendment 15

Several panel members make specific comments about the effort and other controls in Amendment 15. Amendment 15 proposes a two tier license system (one type for "full time" fishermen and another for part time fishermen based on the catch over the period 1990-1992), to limit catch per trip, to split the season into spring and fall, and to limit harvest to the first 15 days in each month. Brown believes these policies can reduce, but not eliminate, the rushing associated with the derby fishery, and therefore cannot eliminate the attendant costs of rushing which this policy regime causes.

Echoing the concerns of other panel members, Townsend warns that the cursory economic analysis of license limitation in Amendment 8 becomes a more serious liability in Amendment 15. He believes that the proposed controls on fishing effort will create annoying problems for all concerned: the harvesters, the buyers, and enforcement. With respect to the potential for reducing effort, he notes that under Amendment 15 the Council does not have the option of using attrition as a license reduction strategy because the licenses are transferable. License buy-backs, he thinks, are an attractive option, but as noted in Amendment 8 they are unavailable under the Magnuson Act. He suggests two scenarios which might be ways around this: firstly an independent association of harvesters that finances the purchase and voluntary surrender of licenses, and secondly, a state program using license fees to finance the purchase of excess licenses.

In mitigation of the effort reduction problem, Townsend suggests that once Amendment 15 is in place, a careful examination of either (a) license reduction or (b) effort-per-license reduction (with or without transferability) is required. As an example, he proposes that license reduction could be accomplished by fractional licenses (Townsend 1992; Townsend and Pooley 1995).

4. Consolidation of the reviewers' reports

In summary, Brown makes the following specific comments about the controls proposed in Amendment 15:

- The policy regime increases uncertainty, but there are no data on the specific effects on efficiency, equity and safety. NMFS or the Council should undertake some indicative planning using historical landings data with reasonable assumptions.

- The extent to which limiting the harvest to the first 15 days of each month limits price fluctuations will depend on the responsiveness of harvesters to 'beat the clock'.

- Safety may be reduced for the following reasons:

    - Trip limits redistribute catch from larger, relatively high volume to smaller, relatively low volume boats, the latter being relatively less safe.
    - Trip limits increase the days fished and because the boats in each tier must compete against the others in a derby each month, the increased total volume of days increases the danger in the fishery.
    - There is no evidence that the first part of the month is safer than the last part.
    - If the more productive skippers take better care of their boats, and therefore they are marginally safer, then the trip limits are a further source of enhanced danger

- Trip limits and time closures increase uncertainty because the skippers have to plan their harvesting strategy each month not knowing when the closure will occur. They further don't know when the trip limit will occur.

- The uniform policy for each tier discriminates against some gear types because they are not all equally suited to the constraints. For example, historically, bottom longline gears are disproportionately preferred in March, April and May so those harvesters are discriminated against by a fall season

Bell questions whether the transferability of licenses should be limited to the commercial fishery. This conflicts with a basic economic principal and that is that the market should determine who holds property or quasi-property rights to a resource. He explains that the limitation would preclude, for example, a conservation society or an organization of recreational fishermen, who wished to "buy" a right to preserve or use the red snapper resource, out-biding all commercial fishermen at an auction. Thus, Bell believes an economic link between the commercial fishery licenses and their respective value on the real open market is severed. He believes the Council has not dealt with this issue on even a research basis because of its political sensitivity. He concludes that history, empirical research and economic theory must categorically reject the license system as a means to solving the tragedy of the commons and notes that it is to the Council's credit, that they have recognized these profound limitations and have rejected its adoption as a viable alternative.

- ITQs

Summarizing the independently expressed views of other panel members, Townsend states that both economic theory and empirical evidence from a variety of fisheries strongly support the central premise of Amendment 8: that ITQs are generally very superior to license limitation, and that license limitation is almost always very superior to open access (see also Townsend 1990 on limited entry and Grafton 1996 on ITQs). Bell describes as "brilliant" Water's 1997 analysis, which enabled the identification of

the impact of the overall quota system on the demand curve for red snapper. This leads to the estimation of possible rents in the fishery if the overall quota were replaced with an ITQ system. He further considers that an ITQ system comes to grips with the basic problem in the fishery, which is the lack of well defined property rights. Under the system there would be transfer of property rights from the US Government to the fishers. According to Townsend, the Council received very appropriate economic analysis on these points throughout the development process (e.g. Waters 1991), and notes that the Council arranged for meetings with the industry to examine these issues (Orbach 1993). He further notes that by the time Amendment 8 was adopted, there was considerable industry support for ITQs , as well as significant remaining opposition (Thomas *et al.* 1993).

Summary of advantages cited by the panel members

The following economic advantages of an ITQ system over other approaches to managing the red snapper fishery were cited independently by the members of the economics review panel:

- By individualizing the fishery quota it greatly or completely reduces rushing (ends the derby);
- it reduces the cost of fishing per unit effort;
- it increases the landed value due to the end of the derby;
- it increases participants' earnings;
- it may reduce overcapacity and fishing effort significantly, as shown by other fisheries, although no quantitative estimates were made for the red snapper fishery
- By removing competition between skippers on the fishing grounds, safety is increased compared to other quota systems (assuming the overall quota is the same in each case);
- According to a survey, among red snapper harvesters there was a modal preference for an ITQ policy as the harvesters look forward in time;
- Harvest control on each vessel should be more economically efficient than effort control on each vessel, depending on the relative costs of enforcement - see below;
- the more efficient harvesters would pay the less efficient more than they could earn for their rights to fish

Townsend concludes that the analysis of the price effects in Amendment 8 alone was sufficiently compelling to warrant the conclusion that ITQs were the preferred alternative. He believes that a detailed analysis of cost savings, which was not included, would simply have made the case for ITQs stronger.

Bell presents a 'quick and dirty' spreadsheet based re-analysis of the economic benefits derived from the ITQ system, which corrects the economic benefits presented in Amendment 8. The main change is the conversion of the benefit evaluation from 1982-84 dollars to 1996 dollars (to conform to the values used for the evaluation of cost). He acknowledges that the estimates derived are very crude, but notes that they demonstrate that the ITQ system, if not impacted by negative variables (e.g., the recreational fishery), will generate considerable economic rents to those participants that are granted

the initial allocation. He notes that this will take place in the 1997-2019 time period while the stock is being rebuilt. After 2019, rents may increase as the TAC is increased. The implementation cost is estimated at $.428 million and the annual cost of enforcement, etc. is estimated at $0.659. Without discounting, the net economic benefits on an annual basis will be $4.231 million ($4.89 less $0.659 million). Thus the benefit/cost ratio will be about 6 to 7 for this undertaking and ITQs are clearly cost effective.

Concerns expressed by the panel members

Quoting the figure reported by Raulerson (1997), Bell expresses a concern shared independently by several panel members, that the implementation cost of an ITQ system is 20 to 25 percent higher than either the status quo or the license limitation system, and the annual running costs, assuming the high enforcement scenario, may be nearly three times as expensive. He also notes, however, that it is not entirely clear from the analyses just how these figures were derived. Brown considers that if the costs of monitoring and enforcement for ITQs exceed those of monitoring and enforcement for an alternative management policy, they must not exceed the otherwise economic superiority of ITQs. He notes that there are no data on this issue, but he considers that the nature of the red snapper fishery gives no persuasive reasons to believe that monitoring and enforcement costs are disproportionately high for ITQs.

Townsend notes that NMFS has moved appropriately to address the data limitations on costs in the red snapper fishery. They have recently conducted an economic survey of the commercial red snapper fleet (Waters 1996), but this new data set, including both fixed cost data and trip-level data has yet to be applied to econometric analysis of costs in the industry. The data set includes information on trips that target species other than red snapper or reef fish. Townsend believes the fleet coverage is quite good and notes that the data collection protocol made extraordinary efforts to avoid sampling biases. He further notes that while the data have great potential for estimating switching behavior in response to regulation, they cannot be used to construct total annual costs for any vessel that is engaged in more than two different target fisheries. This is because to avoid extremely long interviews, data were collected only for the two most important target fisheries.

Bell endorses the denomination of ITQs in percentages, in recognition of the potential variation in the TAC between years in response to exogenous biological factors, but he expresses concern over the four year duration chosen by the Council, after which the program may be extended. Bell prefers a longer duration for issuing ITQs and believes that the four year caveat is likely to undermine the perceived value of the asset being transferred to the fishery. He sees no basis in reviews of existing ITQ programs for an introductory period. It may cause banking institutions to regard ITQs as risky collateral for loans to fishermen, who may be seeking to upgrade their vessels, a development that would help to improve the efficiency of the fishery. Bell notes that in focus groups 21% favored ITQs , leaving nearly 80% who may be opposed to the new system. He believes the introductory four year period will further undermine a fragile proposal as it now stands. He also notes that because of the little long term control of fishing effort by the recreational sector, the effectiveness of ITQs in the commercial sector may be threatened (see also section 4.3.5). If the rents in this latter sector are reduced, then fishers will have less incentive to stay within their individual quota.

Three issues regarding the allocation and transferability of assets were of concern to Bell. Firstly, regarding the initial allocation, he notes that while the ITQ proposal recognizes the importance of the historical captains of vessels, it fails to consider labor as a participant in the potential transfer of wealth. He questions what economic benefits, if any, will accrue to deckhands as a result of the ITQ system, and stresses the importance of gaining the confidence of all fishermen when introducing it.

Secondly, Bell suggests there are serious problems in the provision for persons eligible to transfer ITQ shares. He believes that the Council's preferable choice of the conditions for transferability may deprive the shareholder of considerable asset value, which would undermine the system. In his opinion, Alternative 5 is most easily justified on economic grounds, allowing persons who are not fishermen to buy up shares. There may be those outside of the commercial sector who would be interested to buy shares, ranging from conservation groups wanting to preserve the red snapper, to recreational fishermen wishing to increase their catches by leaving part of the TAC un-taken. He notes that commercial fishers can only be removed by outside forces if they are willing to sell their share derived from the initial allocation.

The third transfer issue addressed by Bell is concentration of ownership, or the tendency toward monopolization. He notes that elsewhere in the world there has been great concern over this issue, but cites two important conditions which argue against such a result for red snapper in the Gulf of Mexico. First, the demand curve is highly price-elastic. High prices may reduce whatever share of the reef fish market red snapper still retains. Second and more importantly, he believes an attempt to raise prices by market power would induce a flood of imports, thereby defeating such an attempt. He concludes that the best interest of all is served by low ex vessel prices in the red snapper fishery, and agrees with the Council that their should be no limit on the ITQ shares.

Other issues

One final point raised by Bell regarding ITQs is that there is apparently no discussion of the basis for transferring a valuable property right to the commercial fishermen other than to cite the provisions of the Magnuson-Stevens Act. He cites a number of examples from around the world where fees are collected for catch quotas, not as a resource rent, but as a use charge, for example to cover the cost of management and surveillance. He urges the Council to consider the application of a user charge as an issue of current interest and future research and recommends that the Magnuson-Steven Act be amended to include the provision for such a fee. He also suggests that the Council might consider allocating a share to itself, sell it at the appropriate time and manage the red snapper fishery on the proceeds from the invested endowment.

As indicated in section 4.3.1, Wilson provides a number of detailed comments on the text of the Amendments, which will not be repeated here. Many of these relate to the proposed implementation of ITQs and other issues in Amendment 8. They relate *inter alia* to issues such as the minimum quota needed to enter the fishery, and how one can obtain this, the mechanics of reporting of data, and cost estimates for the tracking system.

4.3.5 The recreational fishery for red snapper

As Wilson explains, the main focus of the peer review was on the economic analysis of the commercial fishery for red snapper. He notes, however, that there is obviously substantial interaction between the management of commercial sector and the large recreational component of the red snapper fishery in the Gulf of Mexico. At present, 49% of the overall TAC for red snapper is allocated to the recreational sector (the headboat/charter boat sector and the private recreational sector as a single unit), based on historical participation. However, this quota has been exceeded every year since 1991.

4. Consolidation of the reviewers' reports

Assessment of recreational fishing demand

In view of the size of the recreational allocation, several panel members express concern about the apparent marginal treatment of the issue of recreational fishing demand. Wilson, for example, thinks this is one of the most disturbing aspects of the management initiatives to date. Townsend notes that a low priority has been placed on developing economic analyses of the recreational sector. He warns, though that changes in recreational demand will eventually render the present allocation inappropriate and urges the undertaking of an economic analysis to evaluate the importance of these changes. The key issue for such an analysis would be the relative value of red snapper as commercial landings versus its value as a recreational target. Townsend considers that economic analysis to date has been severely limited by large gaps in the information, but there are suggestions that the recreational value of reef fish is quite high. This accords with the report of Bell, which notes that the recreational fishery generates immense economic value as measured by user value (i.e., consumer surplus) or economic impact on local communities and states. Brown acknowledges that valuing recreational catch properly is not easy, but he expresses surprise that no attempt has been made, and that no data have ever been made available that informs policymakers about order of magnitude estimates for a substitute recreational fish in the region which might provide some sense for possible values. He questions this situation, particularly given that about one half of the TAC has been allocated to the recreational sector for a number of years. In conclusion, Wilson recommends that the Council and NMFS commit to the development of an integrated policy on recreational fisheries of reef fishes, and red snapper in particular, which will at least make the sector respect the existing apportionment.

Comments on the MRFSS add-on economic survey

Townsend notes that NMFS has initiated action to substantially increase the available economic data to assess recreational demand for red snapper in the form of a supplemental economic survey for the Southeast MRFSS. Wilson suggests ways in which it could be altered to improve the response rate and data quality. He considers that some of these questions are far too complex to respond to over the telephone. He proposes that the quality of responses would be greatly improved if the intercept questionnaire was folded into the main questionnaire, and the contact time was spent getting the respondent interested in actively participating in the study. The main add-on questionnaire could then be physically given to willing participants, and a telephone rendezvous could be set for two weeks later, at which time the information could be recorded. That way, Wilson believes, complex questions requiring mileage calculations, budgets, costs, and multiple trips could be worked out before the interview begins.

Brown also points out some problems with the survey. He suggests that, ideally, the stages of research proceed by:

- developing a theoretically consistent model;
- deriving a set of estimable equations;
- designing a survey [in the present instance] to collect the data called for by the model; and
- specifying the error structure; etc.

But in this instance the procedure has been that a number of researchers were assembled to discuss approaches and to review a survey. He expresses three specific reasons for concern:

- how can we be assured that there is a good match between the data set and the needs and capabilities of the chosen researcher?
- how do we know that the estimable models are state of the art? and most important, in his view,

- how do we know that the data collected are appropriate?

With respect to question 3, Brown notes that any reputable contingent valuation study is preceded by a series of one or more procedures for ground testing the adequacy of the surveys. This was not done. He also considers that the open ended contingent valuation question is wrongly worded. Finally, the order of the valuation questions and their nature suspiciously resembles that of the design for the double bounded dichotomous choice models ["Would you pay X_i?" X_i varies across the sample. Conditional on the response, "would you pay $\{Y_i, Y_j\}$?" (Y_i is a value if the first response is no. Y_j is a value if the first response was yes)]. The published and unpublished results of this question format, that Brown is aware of, are a disaster. Theoretically, the distribution of responses to the first and second questions should be equal, but they are not. Brown reports that it has been hypothesized by some of the leading experts that the design of the questionnaire induces irrationality. He also notes that many of the important advances in contingent valuation analysis are unpublished and recommends that agency economists seek substantial guidance from specialists in the conduct of *applied* recreation valuation analysis.

Wilson also suggests that the add-on survey should be reviewed by researchers interested in these types of issues and field tested at least two times, one with a focus group made up of recreational fishermen, and another with a small group of fishermen which are intercepted and asked for their help in reviewing the instrument by filling it out. It is important for NMFS and their contracted interviewers to realize that they are, in the eyes of at least some recreational fishermen, nuisances. In dealing with nuisance calls, two approaches (which are fatal to a survey) are to tell the interviewer anything if it gets too difficult to answer, or to refuse to answer. User-friendliness, both in human form and in the survey, may help reduce this tendency. In his extensive report, Wilson also makes some additional recommendations about specific questions in the survey, particularly the contingent valuation component, which will not be reproduced here. The reader is referred to his full report in Annex 1 for details. In conclusion, however, he strongly encourages the organizers of this enquiry to rethink their instruments and the survey protocol to make it easier for respondents to give accurate answers. He suggests that NMFS might also think about obtaining support for their survey from sport fishing associations in order to reduce the "nuisance" factor and also to provide some advance publicity for their efforts, as long as it remains an independent survey.

Future management of the recreational sector

Bell considers that if the trend of exceeded quotas continues, it will seriously undermine not only the rebuilding of the stock, but the introduction of the ITQ system for the commercial fishery. He goes further and suggests that the failure of Amendment 8 to address what he believes to be the most obvious expansion in recreational fishing effort in the future is almost grounds for rejecting the ITQ system. He is concerned that so much research has been aimed at controlling fishing effort in the commercial fishery sector, but almost no research has been directed toward controlling recreational effort in a meaningful way. He thinks that overall quotas would be almost impossible to enforce with so many anglers. The bag and size limits used by the Council, he regards as 'temporary Band-Aids'. He notes that if the catch rate elasticity displayed by single day trips for reef fish is the same for red snapper, it is quite likely that a declining catch rate or reduction in bag limit will have a moderating influence on the expansion in fishing effort by red snapper anglers, because for example, as Townsend points out, the reduced bag limit detracts from the fishing experience. However, Bell believes that the inescapable conclusion based on the literature is that angling fishing effort for red snapper will increase greatly over the period in which the stock is projected to recover and the ITQ system for the commercial sector is introduced. Bell concludes that the success of management efforts is severely threatened by this trend. As alternative strategies, he suggests reduced length of fishing season could

have limited success along with some form of stock augmentation via hatchery operations. Townsend points out that the possible changes in fishing effort described above are inconsistent with the assumptions of fixed recreational effort in Holiman (1995).

Bell cites data from the MRFSS, which show a slight downward trend in number of fishing trips over the period 1991 to 1996 and explains that he believes these data are very suspect. With rapid growth in population and affluence in the Gulf States he would expect that the actual trend would be the reverse. Townsend explains that, while there is a national trend toward lower fishing participation generally, there may also be a trend towards increasing fishing activity during away-from-home vacations (as opposed to local trips on weekends, etc.) These forces may be fundamentally different in Florida, which has a very large vacation industry, as compared to the rest of the Gulf.

Townsend notes that the MRFSS data also show that charter boat catches of red snapper increased steadily over the period 1990-96, while private/rental red snapper catches decline significantly in the period 1993-96. This suggests very different responses to stock conditions and regulations by the different recreational sectors. He suggests that economic analysis should be presenting this kind of background information to the regulatory process.

The recommendation made in several reports is that research should be undertaken on ways of controlling fishing effort in recreational fisheries including bag and size limits and other measures such as minimum hook sizes. The relative impact of different approaches should also be evaluated with the goal of devising regulations that maximize the value of the fishery to its participants. Bell suggests that the feasibility of a regulation to make the release of sport fish mandatory should be considered. Townsend recommends that the analysis of minimum size regulations should be approached from a Beverton-Holt framework, in which effort, size-selective regulations, and yield are interdependent. Information on natural mortality and on mortality from release can be built into the model to predict the impact on future catch and size distributions of changes in the minimum size. Townsend points out that Beverton-Holt analyses of other hook fisheries indicate that minimum hook sizes may be able to accomplish very similar (or superior) results as minimum fish sizes. He suggests two possible advantages to such an approach: avoiding the mortality associated with catch-and-release and better acceptance by recreational harvesters. He concludes that while some of the biological data necessary to conduct this analysis may be unavailable, economic analysis should at least identify the potential importance of this line of analysis.

All the panel members express concern in various ways at the quota overages by the recreational sector. Townsend points out that under the Magnuson-Stevens Act, the Council will be forced to take action to deal with quota overages. According to Wilson, the panel was assured during the hearings that the enforcement of the quota would occur during 1997 through quota closure. However, it was never clear exactly how one could determine when the quota was attained. Wilson regarded this as a major weakness of Amendment 8. Townsend suggests that the answers to the problem may differ between the private recreational and the headboat/charter boat sectors, which raises the possibility of separate regulatory structures for these two recreational sectors. In this regard, Wilson suggests that the implementation of a positive in-season management program designed to close the recreational fishery upon quota fulfillment, should be a high priority. One possibility he proposes is to develop, along with the LL or ITQ plan, a "snapper tag" program, similar to the salmon tags used to control catch and possession limits in Quebec.

4.3.6 Economic analysis of the reduction in bycatch by the shrimp fishery

As explained in the Statistics review section, reduction of the bycatch of juvenile red snapper by the Gulf of Mexico shrimp fleet is considered to be an integral part of the rebuilding of the red snapper stock. Bell explains that it has long been recognised that the shrimp fleet discards many different kinds of young fish, which later in life are the target species of other fisheries. Brown notes that bycatch of red snapper by the shrimp fishery is the third major non-natural source of mortality. The current goal is to reduce bycatch of 0-1 red snapper by 50% in 1997, which, according to the NMFS assessment, will achieve the target SPR of 20% by 2019.

Bell considers two main questions with regard to bycatch reduction:

(i) what impact, if any, will a bycatch reduction of 50% have on the shrimp fleet? and
(ii) do we have the technology to achieve this objective?

Responding to the first question, he suggests that the main impacts of adding a technological device to a shrimp vessel are the potential increase in cost and reduction in productivity. This is discussed in more detail below.

In answering the second question, he believes the technology is available, citing the results presented by NOAA (1997), which indicate that the Fisheye bycatch reduction device (BRD) (12 times 5) reduces the bycatch of snapper by a mean value of 51%. Wilson notes assurances from the NMFS Pensacola laboratory staff that the BRDs which are designed to meet this target will be adopted by the shrimp fleet. However, he also notes what he describes as the voluminous, voluble, angry, and, on some points, well reasoned testimony of the industry which points to the contrary.

In commenting on the specific text of Amendment 9, Wilson points out some apparent confusion. In the proposed alternative C.1, it is understood that any adopted BRD has to demonstrate that it reduces the average bycatch **mortality** of snapper by 44% (because there has been a 10% decline in mortality due to exiting firms). On the other hand, the Gulf of Mexico Fishery Management Council's goal is also stated as a **50% bycatch reduction** (as indicated above). Other parts of the text talk about a 44% **bycatch reduction**. He concludes that unless the Council and NMFS are willing, for every single BRD ground proof, to make a comparative determination of the **mortality reduction** implied by reduced bycatch, then they may just want to settle on a **bycatch reduction figure** (44% or 50%), which seems easier to measure. He also suggests that the language of the BRD certification criterion should be changed to say that ground-proofing **will** (not should) report measures of:

- comparative (between gear) fin-fish bycatch by species;
- shrimp loss;
- handling times for each gear and sorting times for their respective catches; and
- special operating tactics necessary to make the technology work.

He goes on to suggest that once it is established that a BRD meets the bycatch requirements, the BRD certification **will** (not should) include language that requires proofing on an actual working vessel under commercial situations, and that the same measurements be taken as well as the estimated costs of use and handling of the gear and the resulting catch. This should include fuel consumption and sorting times. In addition, both performances will be reported for a certified BRD in the *Federal Register*. Wilson explains that the objective of this proposal is to encourage the collection and transmission of as much information as practicable on the likely **costs and benefits** of using a certain BRD technology on an actual fishing firm, and that this information is made public. This way, he believes, all of the debates over the costs of using the equipment will be enriched with real data.

4. Consolidation of the reviewers' reports

Townsend explains that in principle, the economic objective of bycatch reduction is to maximize the economic return from the resources produced by an ecosystem. This logic leads to the solution that bycatch in the shrimp fishery should be reduced until the marginal cost of bycatch reduction equals the marginal benefit of bycatch reduction. This requires information on the costs and benefits of bycatch reduction. Townsend reports that in general, the information about the costs of bycatch reduction in the shrimp fishery is much better than the information about the benefits of bycatch reduction in red snapper, while other impacted fisheries are largely ignored in analysis to date.

According to Townsend, the absence of integrated analysis seems to reflect:

(i) data limitations in the red snapper fishery;
(ii) the apparent treatment of 50% shrimp bycatch reduction as an exogenously-determined target; and
(iii) an apparent decision not to include economic analysis of impacts on red snapper in Amendment 9 to the Shrimp FMP.

Reviewing the work of Ward (1994), Townsend suggests that, while it is informative, it is not entirely appropriate for the shrimp/red snapper case. He is particularly concerned with the use of the Schaefer production model, which is not age structured and assumes that the pounds not taken as bycatch are caught by the red snapper fleet. Townsend notes that this does not accurately represent the size selectivity of the two fleets. The shrimp fleet take juveniles and the red snapper fleet take recruited adults, so the effects on the biomass are in fact not identical. He also recommends that the analysis should be extended to analyze how ITQs or effort limitation in the shrimp and/or red snapper fisheries might affect economic rents and how alternative regulatory approaches in the recreational red snapper fishery interact with bycatch reduction.

Regarding the quantitative analysis of the impact of various BRDs upon the shrimp industry provided in Amendment 9, he believes the analytical approach is reasonable, but that the presentation does not adequately explain the results. His concerns were somewhat allayed by John Ward's subsequent updating of the estimates in Table R-17 on page 101 of Amendment 9 (also referred to by Wilson), but he maintains that if this model is to be the primary tool for analyzing shrimp regulatory changes, it should receive further review (as does Brown - see below). Townsend also points out that the presentation fails to make clear that the results are entirely driven by changes in infra-marginal rents for producers. The major effect of BRDs for producers is to increase costs. In principle, cost increases can either increase or decrease infra-marginal rents. He is doubtful that the necessary data is available to truly estimate the distribution of cost effects among producers, and has great skepticism about estimates of changes in infra-marginal rents. He concludes that the analysis should indicate the potential limitations in this area.

By apparent contrast, Bell regards the model from which Ward derived his conclusions regarding the impact of requiring the shrimp fleet to use the Fisheye technology as one of the most sophisticated economic models he has encountered in the literature. Given the apparent negligible effect of adopting a BRD (no significant change in the equilibrium fleet size or shrimp catchability, small increase in operating cost offset by the increase in shrimp price) he considers that the burden really falls upon the shrimp industry to demonstrate just why these conclusions are not correct. Bell notes that they sent no representatives to the peer review meeting in New Orleans so the committee could better understand their concerns.

Likewise, Brown finds it a little difficult to understand why the shrimpers should be upset with a bycatch reduction program that causes no change in abundance, increases total producers' surplus by about 300 million dollars over open access (result in Ward's analysis) and causes a mere reduction of

about 9 vessels from more than 2,900 (note, there is a minor inconsistency here with Bell's report, which reports Wards model as predicting a change from an initial equilibrium fleet size of 3,148 vessels to a new equilibrium of 3,149 vessels after the adoption of the BRD). In fact this is sufficiently perplexing for Brown to include the caveat that he reports Ward's results, but he has not vetted them.

Brown frames his review of the economics of bycatch reduction in a different way to Bell. He regards the questions of economic interest as:

(i) rank the least cost alternatives (to the shrimp fishery) for reaching the stated goal of bycatch reduction; and
(ii) what is the economic gain to the red snapper fishery from reducing catch?

In considering (i), he cites the results presented in Table R-17 in Amendment 9 for three different types of BRDs. However, at least in part, the results tabulated in his report (Table 2), appear to be different to those in Bell's report. Bell reports that the Fisheye (12 times 5) reduces bycatch of red snapper by a mean value of 51% (see above), but in Table 2 in Brown' report, the value for the 'Fisheye 30' (reduced abundance ?) is 31 to 34%. This may be because the latter refers to all finfish. Brown concludes that if the shrimp fishery was modeled accurately, the commercial shrimpers should prefer the BRD that creates the most producers' surplus. According to his Table 2, this is option (1) - the extended funnel BRD.

As with Townsend, Brown reports that no estimate has been made of the economic gains to the red snapper sport and commercial fisheries as a result of requiring BRDs in the shrimp fishery. Moreover, he believes that the effect a BRD policy has on the shrimp fishery is really unknown, since Ward's baseline is open access, not some policy which includes restricted access.

In summary, Wilson concludes that the analyses supporting Amendment 9 were well reasoned and complete. He had no difficulties with the main results of the analyses in their revised forms (i.e., as revised by Ward subsequent to the panel meeting). His main criticism, however, is that he believes there are alternatives to the use of BRDs which were not fully explored. Regarding the use of season closures, Townsend, Brown and Wilson all mention the analysis of Hendrickson and Griffin (1993). Townsend and Brown believe this work supports the conclusion that BRDs are economically superior to closed seasons. However, Brown considers their economic models to be inferior to Ward's, and Wilson notes that the analyses were done with large area closures in mind, such as the Cooperative Texas Closure. He further notes that in the written testimony, some shrimp fishermen make reference to the Texas Closure as a desirable thing, deserving to be emulated throughout the Gulf.

Wilson examines the history of how policy making came to revolve around the technological fix of BRDs. He cites the success of turtle excluder devices, in particular, as having heightening the interest in the use of BRDs. He concludes that few fundamental alternatives were explored in the analytical component of Amendment 9, with the exception of limited effort regimes (which he views as being presented as straw men) and closed seasons (see above). He expresses the concern that the investment in BRD technology has oriented discussion and behavior in the Gulf fisheries in such a way that reducing bycatch means using BRDs, even for those who really do not want to use them. He believes that even though the industry and public managers are poised to adopt Amendment 9, they should be aware that the benefit cost analyses are valid only in this context. He stresses that presently it is not known whether this solution is the best one, or the only one, that could have been devised.

Wilson discusses the possible refuge value of man-made and natural obstructions or hangs, which render ground "un-trawlable". He notes that there is some debate over the importance of assumed no-

trawl zones around hangs and reefs in the estimation of bycatch. Some industry members, for example, believe that bycatch calculations made by government scientists rely on assumed no-trawl zones which are smaller than those actually left by practicing fishermen. Fishermen argue that these unreasonable assumptions have increased bycatch estimates, making the problem seem more dire than it is in reality. Wilson believes that in reality it is not clear how much is really known about the behavior of fish or fishermen at a high spatial resolution. He suggests that the lack of environmental knowledge may be explained by insufficient economic incentives to surmount the barriers (and the costs) associated with acquiring high resolution or high definition data sets. He views this as having lead to the extensive use of inference and consequently analyses continue to be open to debate.

One of Wilson's suggestions for an alternative approach to the bycatch problem is the development of a bycatch minimization program based upon, for example, Global Positioning (GP) and Geographical Information Systems (GIS). This is envisaged as entailing within season mapping of bycatch "hot spots" to be avoided by the shrimp fleet and that it would be industry-organized and industry-run in response to their own economic interests. Such a system, he believes, would have knock-on advantages in terms of data collection and availability.

Wilson summarizes the written testimony on Amendment 9, most of which he notes was against it, but was mainly anecdotal in nature. Among others, he cites Swetman (1996), who argues that instead of a technological solution, marine sanctuaries and enhancement programs would be more cost effective. In conclusion, he encourages managers to think in terms of technologies which reduce transactions costs; and which can provide geographic information in real time, in order to take advantage, where possible, of the desire by most reasonable fishermen to avoid bycatch of non-target species.

In accordance with Wilson's report, Townsend describes the approach to bycatch reduction in the shrimp fishery as "command-and-control" or "technology-forcing", that is, government has developed technology in net design and has then mandated its adoption. As an alternative, he would prefer to see the placement of economic incentives on the shrimp industry to develop and utilize bycatch technology and believes this could be accomplished by a tax on bycatch that is set at the marginal damage done by bycatch. He also notes that if the cost of handling discarded fish is non-trivial, then there may already be some economic incentive for the industry to cooperate in bycatch reduction. He acknowledges that taxes may face serious enforcement problems, but considers that a theoretical analysis of their application is still important because it emphasizes the relation between incentives and technology and is in accordance with the current trend towards the adoption of incentive-based environmental regulation.

Bell suggests that an acceleration in imports prompted by aquaculture in South America and other parts of the world could reduce the bycatch of red snapper through the attrition of shrimp vessels from the industry. Bell says there is no evidence that this scenario was examined by the NMFS economists, but he believes it is worthy of consideration.

5. References

Citations to the following papers in the panelists reports were copied forward to the Consolidated Report. Full lists of citations are provided at the end of each of the panelists reports in Annex I.

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