AGENDA D-1(a, b, c)
FEBRUARY 2005

MEMORANDUM

TO: Council, AP, and SSC Members

FROM: Chris Oliver
Executive Director

DATE: February 1, 2005

SUBJECT: Groundfish Management

ESTIMATED TIME
8 HOURS
(All D-1 items)

ACTION REQUIRED

(a) Receive report from Non-Target Species Committee
(b) Receive report on rockfish management discussion paper
(c) Review discussion paper on BSAI/GOA "other species" plan amendments

BACKGROUND

Non-Target Species Committee

The Non-Target Species Committee was formed in October 2003 to develop improved measures to manage non-target species. A summary of committee recommendations to the Council are provided under Item D-1(a)(1)). In May 2004, the Committee convened jointly with the ad hoc working group, comprised of Scientific and Statistical Committee and Plan Team members, to review the draft problem statement, objectives, and suite of management alternatives recommended by the group for analysis (Item D-1(a)(2)). At its fourth meeting in September 2004, the committee adopted a draft problem statement for the larger initiative for Council consideration and requested additional guidance on its mission (Item D-1(a)(3)). The committee convened again in November 2004 to draft a problem statement for non-target rockfish and a suite of alternatives for analysis (Item D-1(a)(4)).

Rockfish Management

During deliberation for final action on the Programmatic Supplemental Environmental Impact Statement (PSEIS) in April 2004, the Council revised its policy and objectives for managing groundfish in the Gulf of Alaska and Bering Sea/Aleutian Islands. During its June 2004 review of the PSEIS work plan, the Council requested that staff prepare a discussion paper on appropriate elements related to rockfish management. The motion was to request that *"Staff draft a discussion paper addressing rockfish management alternatives. The end product after this first step will provide guidance in conjunction with the Programmatic EIS to address appropriate elements in future FMP actions: 1. No action; 2. Harvest rates and management measures; 3. Habitat consideration."*

As a first step, Council and ADF&G staff met with the Rockfish Working Group (RWG) in September 2004. The RWG, comprised of AFSC rockfish assessment scientists, will contribute to the preparation of the discussion paper. The RWG recommended that the paper address a Scientific and Statistical Committee request from December 2003 (Item D-1(b)(1)), specific management issues, and previous RWG reports provided to the Council in 2003 (Item D-1(b)(2)).

Staff drafted two outlines for the discussion paper and consulted with the Scientific and Statistical Committee at its October and December 2004 meetings. The revised outline is provided under Item D-1(b)(3). Neither the Council nor Advisory Panel reviewed or commented on the draft outlines due to other business. Therefore, preparation of the paper was rescheduled to allow for additional direction by the Council to staff on its desired contents in the context of other Council initiatives for revision of management of non-target rockfish species. While the Council motion was open-ended, staff have identified the following additional areas of investigation to be addressed in the discussion paper.

Is the level of protection of rockfish spawning biomass insufficient?

- If so, is it because of **age truncation** of the population (ie., are old fish no longer present in the poplulation?)?
- If so, is there evidence that are truncation has occurred or will occur at a level that would **jeopardize reproductive success** under current harvest policies?
- If so, is it because **there are many sub-populations** within most rockfish stocks?
- If so, what evidence is there of **sub-population structure**?

What alternatives would provide equal or greater protection of the spawning stock?

- What are the **costs and benefits** of pursuing other types of management measurs?

Previous presentations on management, research, and a response to the F_{40} Review comments on harvest strategy policies will be summarized during the meeting to determine what new information is being requested for this paper (Item D-1(b)(4)). The rockfish depletion study is the only study not presented to the Council at previous meetings.

"Other Species" Plan Amendments

In December 2004, the Council requested that staff develop a discussion paper of a proposal from the Groundfish Plan Teams and Science and Statistical Committee to amend the Gulf of Alaska and Bering Sea/Aleutian Islands Groundfish Fishery Management Plans. The amendments would provide additional precautionary management of five groups of non-target species that are managed in the "other species" category. The Plan Teams, SSC, ad hoc committee, and Non-Target Species Committee have been continuing development of recommendations for improving management of all non-target species.

The proposed plan amendments are the third step in a series of amendments under consideration by the Council at the February meeting, which were recommended by the teams, SSC, and two committees for improving management of non-target species. Step 1 would revise the GOA Groundfish FMP to set the GOA "other species" TAC $\leq$ 5 percent of the sum of all groundfish TACs in time for the 2006 specification cycle; this would allow for setting the category on bycatch status at the beginning of the year. Step 2 would set an overfishing level and allowable biological catch for the GOA "other species" category for the first time in the 2007 specification cycle (due to staff constraints), as is done in the BSAI. Due to analytical and stock assessment needs, BSAI/GOA "other species" plan amendments (Step 3) would not be ready for implementation until the 2007 specification cycle. At this meeting, the Council will review the paper (Item D-1(c)) and decide whether to initiate the plan amendments and set a timeline for action.

To date, the Non-Target Species Committee has recommended the following items to the Council:

1. General problem statement. The current management regime may not provide appropriate protection for all species in the ecosystem impacted by the groundfish fisheries, including species for which little biological information is available. The current management system also purports to manage species that are not targeted by groundfish fisheries and may be unaffected or minimally affected by groundfish fisheries. These non-target species are often managed as a complex, which carries the risk that individual species within the complex may be overfished while the complex catch as a whole is within allowable catch guidelines. Conversely, attempts to remove these species from complexes often result in single species quotas that constrain targeted groundfish operations. Since many of these non-target species are either not abundant, not well surveyed, or have life histories that are not well understood, the quotas may not be set appropriately. However, obtaining sufficient data to appropriately manage them under the current quota system may be prohibitively expensive or not possible with current sampling technology. In addition, there is no mandate to manage these species for optimum yield so it may be desirable for both management and conservation to move these species outside of the current quota system.

The problem is then one of deciding how to manage data-poor non-target species outside of the traditional yield-oriented framework used for groundfish species, while still maintaining appropriate protection for those species. If yield-based approaches are not used, then other guidelines for acceptable levels of catch must be determined. Also, if acceptable levels of take cannot be determined and catch is still of concern, protection measures outside of the current quota system may also be considered. Additionally, since markets and circumstances change, a process for transitioning in a timely manner between quota-based target and non-target species management should be established.

2. General goal and 3-step approach for revising management of non-target species:
   a. general approach and application to rockfish
   b. other flatfishes
   c. other species and non-specified species

3. Draft alternatives for analysis:

Alternative 1 No action.

Committee and GOA Plan Team recommendation (Nov. 2004); Council initiated analysis (Dec. 2004):

Alternative 2 Revise the TAC-setting formula for GOA "other species."

Option 1. Set TAC ≤ 5 percent, sufficient to allow for a directed fishery to occur during the fishing year.

Option 2. Set TAC at a level sufficient to meet anticipated catch levels in other directed fisheries during the fishing year

Suboption: Revise maximum retainable allowances for "other species" by fishery.

Bering Sea Plan Team and SSC recommendation (Nov. – Dec. 2004); Council review of discussion paper (Feb 2005):

Alternative 3 Eliminate "other species" assemblage and manage squids, skates, sculpins, sharks, and octopi as separate assemblages under specification process

Option: Add grenadiers and other non-specified species that are caught in the fishery.

Ad hoc group original recommendation (2003); Committee recommendation for analysis (Nov. 2004)

<u>Alternative 4</u> Revise the BSAI and GOA groundfish FMPs to:

Part 1 Identify a *policy* based on scientific *criteria* to determine when sufficient data are available to move species between the target and non-target species categories

Step 1 Separate species that are currently in the target category into:

- target species category, if there is an intent by the commercial fishery to catch and market it; OFL and ABC would be set for each species, but TAC could be set for assemblages)
- non-target species category for all remaining single species and all species complexes with no industry intent to catch/market it; ***OFL, ABC, and TAC would not be set***

Step 2. Characterize non-target species as:

(a) sensitive

(b) non-sensitive

Step 3. Manage:

(a) fisheries in the target species category under status quo management;

(b) non-target species category by protecting them from negative fishing effects of the fisheries:

(1) sensitive species: protection measures (maximum retainable allowances, closed areas, seasonal apportionments, etc.);

(2) non-sensitive species: monitor only (details to be decided)

Part 2 Identify a *policy* based on scientific *criteria* to determine when sufficient data are available to move species between the target and non-target species categories (*yet to be drafted*)

Ad hoc group revised recommendation to conform with proposed National Standard 1 Guidelines (on hold); Committee recommendation for analysis (Nov. 2004)

Alternative 5. Revise the BSAI and GOA groundfish FMPs to:

Part 1. Identify a *policy* to outline a *process* based on scientific *criteria* to determine core stock or assemblage management

Step 1. Separate species that are currently in the target and non-target category into:

(a) Core stocks, if there is an intent by the commercial fishery to catch and market it or if sufficient information exists to set species-specific status determination criteria and the stock is considered sensitive or important (see draft NS 1 guidelines); (OFL ,ABC , and TAC would be set for each species)

(b) Stock assemblages for all remaining single species and all species assemblages with no fishery intent to catch or market it but that are caught by the fishery; (***OFL, ABC, and TAC would be set for each assemblage***

(c) Non-specified species for all remaining species or assemblages that are not caught in the fishery and remove them from the FMP

Option. Revise the forage fish category to include species from the current target and revised non-specified species categories, as appropriate

Step 2. Characterize species in stock assemblage group as:

(a) sensitive

(b) non-sensitive

Step 3. Manage:

(a)Core stocks and stock assemblages under status quo management;

(b) Species within stock assemblages: protecting them from negative fishing effects of target fisheries:

(1) sensitive species: protection measures (maximum retainable allowances, closed areas, seasonal apportionments, etc.);

(2) non-sensitive species: monitor only (details to be decided)

(c) Non-specified species: monitor only

Part 2. Identify a *policy* to outline a *process* based on scientific *criteria* to determine when sufficient data are available to move species between the core stock and stock assemblage categories (*yet to be drafted subject of future ad hoc group meetings*)

4. GOA "other species" problem statement. In May 2004, a final rule was published which removed skates from the "other species" complex in the Gulf of Alaska. This rule established ABCs and TACs, based on survey biomass, for big, longnose, and other skates and thus provided a measure of protection against possible overfishing of skates in the Gulf of Alaska. Those species remaining in the other species complex include sharks, sculpins, and octopi. None of these species are currently the object of a target fishery, although the complex is open for directed fishing. While no ABC or OFL is set for this complex, TAC is defined as 5% of the combined TACs of all other groundfish species in the GOA.

While recognizing that no members of the complex are targeted, the Non-Target Species Committee also noted that the removal of skates from the complex resulted in the potential for increased harvest of the remaining "other species". This is because the harvest of skates no longer accrues to the "other species" category. In addition, when a member is removed, the sum of all the single species TACs increases, resulting in an increase of the "other species" TAC when the 5% default TAC is applied. Ideally, the TAC for the "other species" complex would be lowered when a member such as skates is removed. Unfortunately, biomass estimates for most of the species in this group cannot be determined reliably by trawl surveys, and the remaining species still exist in a group with TAC determined by the TACs of other groundfish species in the Gulf of Alaska. Lacking any means of determining a survey-based TAC for this group leads to the conclusion that when members are removed, the Council should consider reducing the percentage basis for the other species TAC to something less than 5% of the combined members.

5. Request for clarification from the Council on the committee's mission statement, regarding the potential for committee involvement with a separate but related management initiative on alternative management strategies for rockfish.

6. Direction from the SSC on management approaches for non-target species. Reconvene ad hoc working group when ready to begin analysis of Alternatives 4 and 5.

Ad Hoc Working Group Recommendations for Non-Target Species Management
May 2004

Proposed problem statement:

The current management regime may not provide appropriate protection for all species in the ecosystem impacted by the groundfish fisheries, including species for which little biological information is available. For example, data-poor species are often managed as part of a multi-species complex, which carries the risk that individual species within the complex may be overfished even though the complex catch is within harvest guidelines. Additionally, data-poor species are often stocks with low population sizes and low catch quotas that may severely tax the ability of our current regulatory system to manage these species without unduly limiting fisheries in which these are taken as bycatch. The catch quotas for data-poor species are typically derived from maximum sustained yield considerations, and alternative management goals such as protection of the stock may be more appropriate for low-valued stocks.

Proposed goal statement:

The goal for managing "non-target species" is to prevent overfishing, maintain healthy stocks, and rebuild depressed stocks, while providing for sustainable groundfish fisheries.

The most direct and effective way to prevent overfishing, maintain healthy stocks, and rebuild depressed stocks is to control the level of harvest by setting individual TACs for each species. However, monitoring the catch and assessing the status of hundreds of individual species is an unwieldy task requiring considerably more data collection, analysis, and monitoring resources than are presently available.

Applying TAC at a level higher than species (e.g., assemblages or species complexes) to improve efficiency with some sacrifices in effectiveness is currently the practice for some target and non-target species. However, a potential problem exists when a TAC is applied at a level above individual species. Species within the aggregate complex often have different levels of productivity and vulnerability to overfishing. If catch accounting is at the aggregate level, but the less productive species are harvested at disproportionately high levels, the species that exhibits lower productivity within the complex could be subject to overfishing even when the overall TAC for the complex is not exceeded.

Aggregate TACs are presently used to manage some North Pacific fisheries (e.g., Other Rockfish and Other Flatfish target species categories). The risk to less productive species can be monitored and prevented in practice, as long as the catch for each species within the complex is estimated. However, often information on species composition within non-target categories (e.g., "other species") is limited, making it difficult to monitor less productive components within the aggregate TAC. While setting aggregate TACs may be a necessary step initially due to data limitation, stock assessment and Plan Team scientists have recommended that the TACs should be set at the lowest practical level of aggregation and should attempt to include other measures to minimize potential overfishing of less productive stocks within the complex. Management by TACs is most effective at the species level or lower, and emphasis on this management tool implies that data collection efforts should be directed at eventually providing appropriate information to manage all species at that level.

Proposed objectives:

Increasing protection to non-target species places greater management emphasis on maintaining healthy fish stocks of non-target and forage fish, reducing bycatch and bycatch mortality, reducing discards, and using a precautionary approach when making decisions, while providing a future in which the American people are able to enjoy the wealth and benefits of diverse and self-sustaining living marine resources (NMFS 2001). The objectives used in shaping these policy decisions are listed below:

In the event of overfishing, maintain healthy stocks, and rebuild depressed stocks of non-target species
Maintain healthy stocks important to commercial, recreational, and subsistence fisheries
Prevent overfishing and rebuild depressed stocks important to commercial, recreational, and subsistence fisheries
Increase long-term economic and social benefits to the nation from living marine resources
Protect, conserve, and restore living marine resource habitat
Minimize discards by developing management measures that encourage the use of gear and fishing techniques that minimize discards
Use the precautionary approach when making decisions, and
Conform to the Magnuson-Stevens Act National Standards and the Council's Comprehensive Goals.

Proposed Alternatives for analysis

Alternative 1. No action.

Alternative 2. Eliminate "other species" complex and manage squids, skates, sculpins, sharks, and octopi as separate complexes under specification process
Option: Add grenadiers

Alternative 3. Revise the BSAI and GOA groundfish FMPs to:
- Part 1. Revise the target species category for fisheries[1] only
- Part 2. Identify a new non-target species category
  - Option. Revise the forage fish category to include additional species from the current target and non-specified species categories
- Part 3. List the species in each management category
  - Option 1. Do not list any species in each management category
  - Option 2. List species in each management category
- Part 4. Identify a *policy* based on scientific *criteria* to determine single species or assemblage management
  - Step 1. Separate species that are currently in the target category into:
    - (c) target species category, if there is an intent by the commercial fishery to catch and market it; OFL and ABC would be set for each species, but TAC could be set for assemblages)
    - (d) non-target species category for all remaining single species and all species complexes with no industry intent to catch/market it; ***OFL, ABC, and TAC would not be set***
  - Step 2. Characterize non-target species as:
    - (a) sensitive
    - (b) non-sensitive

  - Step 3. Manage:

    fisheries in the target species category under status quo management;
    non-target species category by protecting them from negative fishing effects of the fisheries:

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[1]The MSA defines "fishery" as "(A) one of more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics; and
(B) any fishing for such stocks."

(a) sensitive species: protection measures (maximum retainable allowances, closed areas, seasonal apportionments, etc.);

(b) non-sensitive species: monitor only (details to be decided)

Part 5. Identify a *policy* based on scientific *criteria* to determine when sufficient data are available to move species between the target and non-target species categories (*yet to be drafted subject of future ad hoc group meeting?*)

Alternative 4. Revise the BSAI and GOA groundfish FMPs to:

Part 1. Define the fisheries in the target species category as single species only; OFL and ABC would be set for each species, but TAC could be set for assemblages

Part 2. Remove non-target species (including non-specified species, but not prohibited species or forage fish) from the FMPs ***to avoid setting OFL, ABC, and TAC***

Part 3. Identify a *policy* based on scientific *criteria* to determine when sufficient data are available to add species to or remove species from the target species category (*yet to be drafted - subject of future ad hoc group meeting?*)

Staff Notes:

- The GOA Groundfish FMP is not in compliance with the MSA according to a draft NMFS report since it does not specify OFL for the "other species" complex, which is currently managed in the target category.
- It is necessary to balance conflicting goals, which may call for different approaches. That is, the Council will need to balance the goal of minimizing costs and maximizing benefits with the goal of protecting the marine ecosystem and preserving biodiversity. The former calls for a problem specific approach; however, its application becomes complex with multiple conflicting objectives as occurs in a complex fishery management regime. The management system may not be structured to detect certain types of problems in time to solve them effectively. On the other hand, protecting marine ecosystems and biodiversity appears to call for an approach that attempts to predict problems and designs management to prevent them. While this approach may save us from expensive mitigation of advanced problems (e.g., habitat loss) in the long run, it is impossible to predict all types of problems that might occur, and it is necessary to evaluate the likelihood of a given problem as well as the severity of its potential consequences in designing a management system. These decisions would be made objective under a formal policy that considers all aspects of the management system at once, rather than individual species piecemeal.

NON-TARGET SPECIES COMMITTEE MEETING
SEPTEMBER 15, 2004

Members in attendance: Chair Dave Benson, Julie Bonney, Karl Haflinger, Michelle Ridgway, Whit Sheard, Lori Swanson, Paul Spencer, and Lisa Butzner for Thorn Smith. Eric Olsen was absent. Staff support was provided by Sarah Gaichas and Jane DiCosimo. Others in attendance included Sue Hills, Rebecca Reuter, Phil Rigby, Dave Clausen, Mike Sigler, Dean Courtney, Andy Smoker, Tom Pearson, Melanie Brown, John Lepore, and Diana Stram.

The purpose of the meeting was to adopt a problem statement for the management of non-target groundfish species as a framework objective. The committee reviewed draft problem statements from Lori Swanson, Karl Haflinger, and the ad hoc working group. It adopted the following draft problem statement for the framework of separating all groundfish species into target and non-target categories.

> *The current management regime may not provide appropriate protection for all species in the ecosystem impacted by the groundfish fisheries, including species for which little biological information is available. The current management system also purports to manage species that are not targeted by groundfish fisheries and may be unaffected or minimally affected by groundfish fisheries. These non-target species are often managed as a complex, which carries the risk that individual species within the complex may be overfished while the complex catch as a whole is within allowable catch guidelines. Conversely, attempts to remove these species from complexes often result in single species quotas that constrain targeted groundfish operations. Since many of these non-target species are either not abundant, not well surveyed, or have life histories that are not well understood, the quotas may not be set appropriately. However, obtaining sufficient data to appropriately manage them under the current quota system may be prohibitively expensive or not possible with current sampling technology. In addition, there is no mandate to manage these species for optimum yield so it may be desirable for both management and conservation to move these species outside of the current quota system.*
>
> *The problem is then one of deciding how to manage data-poor non-target species outside of the traditional yield-oriented framework used for groundfish species, while still maintaining appropriate protection for those species. If yield-based approaches are not used, then other guidelines for acceptable levels of catch must be determined. Also, if acceptable levels of take cannot be determined and catch is still of concern, protection measures outside of the current quota system may also be considered. Additionally, since markets and circumstances change, a process for transitioning in a timely manner between quota-based target and non-target species management should be established.*

The committee agreed that the management issue for rockfish, flatfish, and other species was too broad for a uniform problem statement, therefore the committee agreed to develop two problem statements (for the framework (above) and rockfish) and recommended splitting the non-target initiative into three separate analyses. The committee recommended analyzing the framework approach (see ad hoc group recommendations) and alternative management for non-target rockfish simultaneously. The framework would be refined by applying the rockfish example to it. The committee recognized that management problems for non-target rockfishes have been identified separately and have crossover implications, e.g., in the annual specification process, proposals from stock assessment authors to separate species from within complexes, GOA groundfish rationalization, IRIU in the BSAI, PSEIS recommendations.

The **committee requested clarification from the Council on the committee's mission statement**, regarding the potential for committee involvement with a separate but related management initiative on alternative management strategies for rockfish. The committee noted that a staff discussion paper that is scheduled for review at the December 2004 Council meeting would address both target and non-target rockfish management. However, the same rockfish species may be a target in the GOA, but not a target in the BSAI.

The committee tentatively identified its next meeting for November 15, 9 am - noon at the AFSC- Seattle (the morning prior to the Groundfish Plan Team meeting). It will review guidance from the Council on whether it should also address target management of rockfish, develop a problem statement for rockfish, and adopt a suite of alternative for the framework for separating all groundfish into target and non-target categories.

The committee requested that AFSC staff provide a briefing on the status of the draft revisions to the National Standard Guidelines and how they may affect proposed management of non-target groundfish species. The committee had reviewed an earlier recommendation of the ad hoc group that would have placed the non-target groundfish species outside of the OFL and OY concepts. This does not appear likely under proposed revisions. An alternate solution would be to remove the non-target species from the groundfish FMPs. This is not the preferred approach because it is believed that the FMPs offer additional protection. The committee also requested that AFSC staff clarify the definition of a "fishery."

Non-target Species Committee Meeting
Seattle, WA
November 15, 2004

Committee members: Dave Benson (chair), Lori Swanson, Julie Bonney, Karl Haflinger, Paul Spencer, Whit Sheard, Janet Smoker, Eric Olson, Dave Wood. Michelle Ridgway was absent (jury duty). Staff: Jane DiCosimo and Sarah Gaichas. Ten agency staff also attended.

At its previous meeting, the committee discussed whether to define non-target species as a separate fishery management unit with unique management objective(s). John Lepore reviewed the MSFMA definition of "fishery," at the request of the committee. The Act defines a "fishery" as "(a) one or more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographical, scientific, technical, recreational, and economic characteristics; and (b) any fishing for such stocks." Therefore, the Act allows a definition based on either a single species or multiple species caught together or on those that fish on those single or multi-species stocks, or both. The Act requires that FMPs define fisheries, although the BSAI and GOA Groundfish FMPs do not do so. Defining fisheries would achieve consistency with the Act if the OFL and OY acts at the same level of aggregation. Future FMP amendments under the non-target species initiative may include options to define the fisheries.

The Council did not take the September 2004 committee report at its October 2004 meeting; *the committee reiterated its request for Council clarification regarding its draft problem statement for revisions to management of non-target species and its recommendation for a 3-step approach which prioritizes the development of a FMP amendments to revise management of non-target rockfishes, and subsequent analyses for non-target flatfishes and "other species." The committee also had requested that the Council provide additional direction to the committee as to whether it should also develop recommendations for target rockfish management, as some species that are targeted in the GOA are caught incidentally in the BSAI.*

The committee reviewed revised draft alternatives recommended by the ad hoc working group in November 2004 (attached). It discussed that it may not be prudent to proceed with initiation of an analysis until proposed revisions to the National Standard Guidelines are published as a final rule. In the interim, *the committee recommended initiating a GOA FMP amendment to revise how the GOA "other species" TAC is set as a near term conservation act with final action in June 2005*, as follows. The Problem Statement for the proposed analysis will be provided at the Council meeting.

Alternative 1.	No action (TAC = 5 percent of sum of all GOA TACs).
Alternative 2.	Revise the TAC-setting formula for GOA "other species."
Option 1.	Set TAC $\leq$ 5 percent, sufficient to allow for a directed fishery to occur during the fishing year.
Option 2.	Set TAC at a level sufficient to meet anticipated catch levels in other directed fisheries during the fishing year
Suboption:	Revise maximum retainable allowances for "other species" by fishery.

Problem Statement: In May 2004, a final rule was published which removed skates from the "other species" complex in the Gulf of Alaska. This rule established ABCs and TACs, based on survey biomass, for big, longnose, and other skates and thus provided a measure of protection against possible overfishing of skates in the Gulf of Alaska. Those species remaining in the other species complex include sharks, sculpins, and octopi. None of these species are currently the object of a target fishery, although the complex is open for directed fishing. While no ABC or OFL is set for this complex, TAC is defined as 5% of the combined TACs of all other groundfish species in the GOA.

While recognizing that no members of the complex are targeted, the Non-Target Species Committee also noted that the removal of skates from the complex resulted in the potential for increased harvest of the remaining "other species". This is because the harvest of skates no longer accrues to the "other species" category. In addition, when a member is removed, the sum of all the single species TACs increases, resulting in an increase of the "other species" TAC when the 5% default TAC is applied. Ideally, the TAC for the "other species" complex would be lowered when a member such as skates is removed. Unfortunately, biomass estimates for most of the species in this group cannot be determined reliably by trawl surveys, and the remaining species still exist in a group with TAC determined by the TACs of other groundfish species in the Gulf of Alaska. Lacking any means of determining a survey-based TAC for this group leads to the conclusion that when members are removed, the Council should consider reducing the percentage basis for the other species TAC to something less than 5% of the combined members.

The committee intends to meet again immediately prior to or coincident with the February 2005 Council meeting in Seattle. Availability of the draft rockfish discussion paper will inform the choice of meeting date.

Excerpt from SSC December 2003 minutes

ROCKFISH - General Considerations

1. $F_{40\%}$ Report Recommendations

The SSC received a report in 2002 from Goodman et al., known as the "F40 report," that recommended consideration of more conservative harvest rates for rockfish species in the GOA and the BSAI. In response, the SSC requested that stock analysts evaluate the harvest strategy for rockfishes during the 2003 TAC setting process. Stock analysts completed two types of analyses. The first analysis, reported in the BSAI SAFE for POP and northern rockfish, was an incorporation of process and measurement error in estimating $F_{35\%}$. The result was a finding that the added uncertainty did not produce a lower F_{ABC} than the status quo harvest policy. The second analysis was reported in a draft manuscript by Drs. Paul Spencer and Martin Dorn, in which they evaluated BSAI POP management parameters using Bayesian stock-recruit analysis. Dr. Spencer summarized that report for the SSC at the December 2003 meeting with a conclusion that the $F_{35\%}$ and $F_{40\%}$ policies are not overly aggressive for the BSAI POP stock. The SSC appreciates the efforts by Drs. Spencer and Dorn, and offers the following considerations for further analysis.

The SSC notes that the Bayesian stock-recruitment analysis used methods adapted from Dorn (2002) applied to the BSAI POP stock. The SSC notes that use of the early 1980's data that exhibit extremely high year class success is very influential in determining the results. Different data sets with weak recruitment could yield different results. Further, caution is warranted in extrapolating these results to other species. Nevertheless, the SSC supports further analyses and encourages authors to explore alternative spawner-recruit analyses based on subsets of the data and contrast those with an analysis using all of the data.

It is unknown if the loss of older age classes have measurable consequences to stock productivity. The implications depend on whether older/larger individuals contribute to stock productivity disproportionate to their biomass. Relevant questions include: (1) do older individuals have higher reproductive success?, (2) do they spawn in more favorable habitats?, (3) do they spawn at more favorable times of the year?, (4) do the progeny have a higher survival rate?, and (5) do fisheries cause genetic selection such that heritable growth and mortality traits are lost when old fish no longer survive to contribute to reproduction? The answers to these questions are unknown for rockfishes in Alaska, but there are some hints from other species. Older herring consistently spawn days to weeks earlier than younger herring. Genetic selection has resulted from size-selective harvests of populations of short-lived fishes in laboratory studies within just a few generations. Studies on Atlantic cod suggest that migration pathways to spawning grounds may be a learned attribute from older cod. Closer to home, one study in California suggests differential spawning time and increased viability of young from old versus young adult black rockfish. Owing to lack of studies, it is difficult to quantify and incorporate such considerations into harvest specifications. The SSC is concerned that undesired outcomes could occur if exploitation rates are too high for the most productive individuals in the population. This is an area of needed research.

2. Local Depletion

The SSC requests that additional analysis be provided for rockfish regarding:

- A listing of species of rockfish which are most likely to be subject to local depletions either due to specific life history characteristics or fishing practices;
- The availability of data for those species which could be used to evaluate the occurrence of local depletion; and
- The quality of data that would be needed to detect local depletion with reasonable certainty.

3. Disaggregation of ABCs

The general direction of rockfish management is towards increased splitting out of ABCs stock segments. More often than not, there are insufficient or unreliable data to fully support these splits. This characteristic of the data requires that care be taken in determining the splits to ensure that they achieve the Council's conservation objectives, while not inflicting undue economic hardship on members of the fishing community. Where data are found lacking or inadequate, a recommendation should be made on how to improve data availability.

Rockfish Working Group
Meeting Summary
September 14, 2004

The RWG proposed to examine a number of issues in the discussion paper:

- Using the tier system as a method for identifying management measures
- Shortraker and rougheye rockfish species identification in the catch – observer program special project – GOA trawl survey reports more rougheye rockfish, while the GOA catch shows more shortraker rockfish
- Requiring retention of rockfish – address biological and legal issues (full retention of DSR not implemented yet)
- Age and growth task – unable to disaggregate species by area in the survey compared with the catch due to small sample sizes – partially due to not collecting what samplers don't think will get read
- Dedicated (slope) rockfish survey that emphasizes habitat type would also improve assessments for "other species" – under Stock Assessment Improvement Plan; trawl survey only adequate for thornyhead rockfish, particularly poor in the EGOA, but slope survey would not assess northern rockfish
- Spatial management – closed areas, refugia. (questionable for rockfishes because so little is known about their spatial movements over various life-history stages); could be successfully identified by bottom mapping (habitat); useful to evaluate geographic distribution of a population
  1. identify appropriate species
  2. identify survey vs. fishery (by area)
  3. local depletion/spatial distribution – can have little mixing although the population is broadly distributed (e.g., northern, POP, SR/RE)
  4. Observer Program – does not cover rockfish well; shore plants, small boats
  5. IPHC survey data – has rockfish catch info
  6. 2 species of dusky rockfish – FMP amendments
  7. 2 species of rougheye rockfish – action?
  8. yelloweye rockfish under ADF&G management
  9. NMFS hot spot authority
- Compare the EGOA to the rest of the GOA to determine the effect of the EGOA trawl closure, although this analysis would be complicated due to differences in the age composition of rockfishes inside and outside the EGOA before closure
- Sport harvests – Treating sport harvest as part of the ABC may be important for some rockfish in some areas.
- How to manage species at end of its range (more vs. less). One of the unique features of the BSAI management area is that the EBS slope extends so far north that it represents the edge of the range for some rockfish stocks. A management issue is the degree of conservation required for stocks at the edge of the range. One viewpoint is that because the bulk of the population resides elsewhere, conservation efforts should be focused on those locations where the bulk of the population exists. Alternatively, one could view populations at the edge of their range as unique situations requiring additional precaution.
- State "pocket" fisheries – e.g., black rockfish jig fishery in Dutch Harbor
- Create a "formal" relationship between the fleet and managers
- Management inconsistencies among areas – e.g. black rockfish in the Aleutians are in the FMP while black rockfish in the GOA are under State management
- How to incorporate genetic stock structure information into stock assessments

The RWG emphasized the following:

- Genetic research to define stock structure is further along in the GOA than in the BSAI
  Fine structure: Pacific ocean perch
  Broad structure: shortraker rockfish
- No directed fishing for any rockfish species in the BS, some targeting in the AI for POP (July). Target fisheries may develop in the AI, as some species that are not currently targeted in the AI are currently targeted in the GOA
- High discards
- OFL tier 6 may be less conservative (based on average catch)

Participants included Dave Clausen, Dean Courtney, Jane DiCosimo, Jeff Fujioka, Sara Gaichas, Dana Hanselman, Jon Heifetz, Chris Lunsford, Tory O'Connell, Phil Rigby, Paul Spencer, Rebecca Reuter, Kalei Shotwell, Mark Wilkins.

Revised annotated outline of proposed rockfish management paper (12/04)

1) Description of current management practices and associated practical difficulties
   a) Bycatch and discards (e.g., northern rockfish)
   b) Management of species at the end of their range (BS slope)
   c) Management of small quotas

2) Management actions taken to improve rockfish management, and management initiatives under development

   a) Change in rockfish MRA ratios (white paper from Sue Salveson and Andy Smoker)
   b) Movement to break species assemblages into component species for conservation and management purposes (however, can lead to practical difficulties with small quotas)
   c) Ongoing management initiatives (GOA rockfish pilot project and GOA groundfish rationalization, HAPC management, full retention of shortraker and rougheye rockfishes, Plan Team recommendations to remove dark, black, and blue rockfishes from the BSAI FMP and dark rockfish from the GOA FMP).

3) Criticisms of rockfish management
   a) Based upon west coast experience, F40 policies may not be sufficiently conservative (Goodman report)
   b) The very principle of quota management is not sufficiently conservative because it does not recognize demographic, spatial, and temporal differences in spawner productivity (Berkeley's 2004 papers). What is required, Berkeley says, is protected areas.

4) Responses to criticisms of current management
   a) Analyses assessing stock productivity for Alaska rockfish (papers by Dorn, Ianelli; Thompson's response to the Goodman report, Spencer's analysis of BSAI POP stock productivity presented to the SSC and plan team)
   b) The points Berkeley makes are valid, but refugia management would require more information than we currently have available to do it right.

5) Local depletion studies

6) Summary of current data on rockfish population biology
   a) genetics/stock structure/species ID (could update information on Tony Gharrett's work)
   b) early life history (Give and update of where Art Kendall is in his studies)
   c) habitat issues/associations (Heifetz)
   d) problems of surveying patchily distributed populations (Fujioka/Spencer/Hanselman)

7) Data needs for improved science and management.

Background papers on rockfish management	Preparer	Date	Tab
Discussion Paper on 2003 Management of BSAI Rockfish Species	Region	11/02	Attachment 1
Discussion Paper on Rockfish Research and Management	AFSC	1/03	Attachment 2
Powerpoint of Discussion Paper on Rockfish Research and Management	AFSC	1/03	Attachment 3
Powerpoint of Rockfish Research Plan 2003/2004	AFSC	4/03	Attachment 4
Excerpt of Harvest Strategy Report (F_{40} Report)	Independent Panel	12/02	Attachment 5
Comments on the 2002 Independent Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish FMPs	AFSC	9/03	Attachment 6
Powerpoint of Comments on the 2002 Independent Scientific Review . . .	AFSC	9/03	Attachment 7
Local Depletion Study	AFSC	1/05	Attachment 8

AGENDA D-1(b)(4)
FEBRUARY 2005

BACKGROUND ON PROPOSED ROCKFISH DISCUSSION PAPER

JANUARY 2005

Prepared by
NPFMC and AFSC staff

Purpose

During deliberation for final action on the Programmatic Supplemental Environmental Impact Statement (PSEIS) in April 2004, the Council revised its policy and objectives for managing groundfish in the Gulf of Alaska and Bering Sea/Aleutian Islands.

The Council identified 45 objectives to meet the goals of this overall management approach. In June 2004, Council staff matched each of the 45 objectives with its related bookend range to assist the Council in assessing whether current groundfish management meets the policy and the status of each bookend action. The Council identified a work plan to address management policy actions in April 2004. It noted that many objectives directly or indirectly address rockfish management and requested that:

"Staff draft a discussion paper addressing rockfish management alternatives. The end product after this first step will provide guidance in conjunction with the Programmatic EIS to address appropriate elements in future FMP actions: 1. No action; 2. Harvest rates and management measures; 3. Habitat consideration."

In response, staff drafted and revised an outline for this paper after consulting with the Scientific and Statistical Committee at its October and December 2004 meetings *(Attachment 1)*. Neither the Council nor Advisory Panel reviewed or commented on the draft outlines due to other business. Therefore, this brief background paper should be reviewed as a preliminary attempt to address the Council's general directive to "think outside the box." Once the Council refines its intent for the outcome of the proposed discussion paper as it relates to other already initiated management approaches for rockfish management, it will be revised to reflect Council intent. The intended goal is to identify potential plan or regulatory amendments to revise rockfish management in Federal waters off Alaska.

While the Council motion was open-ended, staff identifies the following areas of investigation that could be addressed in subsequent analyses:

Is the level of protection of rockfish spawning biomass insufficient?
- If so, is it because of **age truncation** of the population?
  - If so, is there evidence that this has occurred or will occur at a level that would **jeopardize reproductive success** under current harvest policies?
    - If so, is it because **there are many sub-populations** within most rockfish stocks?
      - If so, what evidence is there of **sub-population structure**?

What alternatives would provide equal of greater protection of the spawning stock?
- What are the **costs and benefits** of pursuing this type of management?

Draft outline of rockfish management paper

1) Description of current management practices and associated practical difficulties (Jane DiCosimo)
    a) Discarding (northern rockfish)
    b) Management of species at the end of their range (BS slope)
    c) Management of small quotas (Region paper from 12/04)

2) Management actions taken to improve rockfish management, and management initiatives under development (JDC)
    a) Change in rockfish MRA ratios (white paper from Sue Salveson and Andy Smoker)
    b) Movement to single-species management in the BSAI (however, can lead to practical difficulties with small quotas)
    c) Ongoing management initiatives (GOA rockfish pilot project and GOA groundfish rationalization, HAPC management, full retention of shortraker and rougheye rockfishes, Plan Team recommendations to remove dark, black, and blue rockfishes from the BSAI FMP and dark rockfish from the GOA FMP).

3) Criticisms of rockfish management (Paul Spencer)
    a) Based upon west coast experience, F_{40} policies may not be sufficiently conservative (Goodman report)
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4) Responses to criticisms of current management (Paul Spencer)
    a) Analyses assessing stock productivity for Alaska rockfish (papers by Dorn, Ianelli; Thompson's response to the Goodman report, Spencer's analysis of BSAI POP stock productivity presented to the SSC and Plan Team)
    b) The points Berkeley makes are valid, but refugia management would require more information than we currently have available to do it right.

5) Local depletion studies (Paul Spencer)

6) Summary of current data on rockfish population biology (Paul Spencer)
    a) genetics/stock structure/species ID (could update information on Tony Gharrett's work)
    b) early life history (Give and update of where Art Kendall is in his studies)
    c) habitat issues/associations (Heifetz)
    d) problems of surveying patchily distributed populations (Fujioka/Spencer/Hanselman)

7) Data needs for improved science and management (Paul Spencer)
    (more of everything)

Previously presented Powerpoint presentations on management, research, and response to the F_{40} Review comments on harvest strategy policies are attached for advance review and will be summarized during staff presentations at the February Council meeting to determine what new information is being requested for this paper:

1. Discussion Paper on 2003 Management of BSAI Rockfish Species	Region	11/02
2. Discussion Paper on Rockfish Research and Management	AFSC	1/03
3. Powerpoint of Discussion Paper on Rockfish Research and Management	AFSC	1/03
4. Powerpoint of Rockfish Research Plan 2003/2004	AFSC	4/03
5. Excerpt from Harvest Strategy Report (F_{40} Report)	Independent Panel	12/02
6. Comments on the 2002 Independent Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish FMPs	AFSC	9/03
7. Powerpoint of Comments on the 2002 Independent Scientific Review . . .	AFSC	9/03
8. Maternal Age as a Determinant of Larval Growth and Survival in a Marine Fish, *Sebastes Melanops*	Berkeley et al.	2004
9. Fisheries Sustainability via Protection of Age Structure and Spatial Distribution of Fish Populations	Berkeley et al.	8/04
10. Why Mothers Matter	Palumbi	8/04
11. Powerpoint of Rockfish Management: Are We Circling the Wagons Around the Wrong Paradigm?	Berekely	11/04
12. Rockfish local depletion study	AFSC	1/05

AGENDA D-1(b)(4)
FEBRUARY 2005

AGENDA D-1(b)
DECEMBER 2002

Discussion Paper on 2003 Management of BSAI Rockfish Species

NMFS Alaska Region
November 15, 2002

In October 2002, the North Pacific Fishery Management Council requested the National Marine Fishery Service to review rockfish management for 2003, including discussions of reliable species identification within the shortraker/rougheye rockfish species group and apportioning the TAC for shortraker/rougheye rockfish among the Bering Sea subarea and 3 Aleutian Islands subarea districts. The Council also requested a discussion of long term management of the red rockfish complex that addresses: the scientific information necessary to support separate species or stock management by area; management implications of separate species OFLs/ABCs/TACs by management area; adequacy of existing survey methodology for these species and potential enhancements to existing protocol to address shortcomings; and potential management response to ongoing and perhaps unavoidable bycatch.

This discussion paper reviews the implications of creating 3 separate TACs in the Aleutian Islands subarea for shortraker/rougheye species group. Table 1 compares the catch of shortraker/rougheye through October 26, 2002, to the TAC distributions by districts in the Aleutian Islands subarea and the Bering Sea subarea. The TAC distributions were provided by the Alaska Fisheries Science Center and are based on survey biomass distributions from 1991 through 2002. The discussion paper reviews 2003 management issues for CDQ rockfish species and presents NMFS's 2003 strategy for assessing the use of observer data for purposes of species-specific catch monitoring of shortraker and rougheye rockfish in 2004 and beyond. Last, this paper provides an overview of information on long range planning for rockfish research and management that will be presented to the Council in February 2003.

Management of Bering Sea and Aleutian Islands Subarea Shortraker/Rougheye TACs in 2003

The shortraker/rougheye complex has been managed as such in the Aleutians Islands subarea since 1992 and in the Bering Sea subarea since 2001. The overfishing level and ABC for shortraker/rougheye is established for the BSAI and TACs are applied to the two constituent subareas. Prior to 2001, the complex was managed in the Bering Sea subarea as part of the 'other red rockfish' species group (which included shortraker, rougheye, sharpchin and northern rockfish), and OFL and ABC were established by subarea rather than across the BSAI. Whether managed as a distinct complex or as part of the 'other red rockfish' category, the species group has not been open to directed fishing, that is, it has only been allowed to be taken in proportion to other species that are open to directed fishing.

In 1997, the ABC for shortraker/rougheye in the Aleutian Islands (938 mt) was caught. To prevent overfishing of the complex, special reporting requirements were implemented, many fisheries were closed, and other groundfish catch forgone to prevent overfishing of the complex. The estimated catch for 1997 was 1,043 mt, or 207 mt less than the overfishing level of 1,250 mt. In 1998 the Council recommended and NMFS implemented a revision of the maximum retainable bycatch of shortraker/rougheye. Retention was reduced from 15% as part of aggregated rockfish that are closed to directed fishing. Shortraker/rougheye was separated as a species category and retention was limited to 7% of deep water species and to 2% of shallow water species. During that same year, under Amendment 53, the TAC of shortraker/rougheye in the Aleutians was allocated 30% to vessels using hook-and-line gear and 70% to vessels using trawl gear.

In October 2002, the Council heard public testimony that expressed an interest in apportioning the shortraker/rougheye TAC in the Aleutian Islands subarea among districts. Table 1 compares the 2002 catch by district with the potential 2003 distribution of TAC among the same areas. Under the current management structure and potential Aleutian Islands TAC distributions, a disproportionate catch of shortraker/rougheye in the Aleutian Islands subarea is not detected. This may be because the primary targets for trawl gear (Atka mackerel and Pacific ocean perch) which take the greatest amount of groundfish in the Aleutian Islands (65% of the groundfish harvest), are apportioned by district. Retention of shortraker/rougheye rockfish in the Atka mackerel target is limited to 2% and in the Pacific ocean perch target, 7%. The estimated retention of shortraker/rougheye relative to retained Pacific ocean perch in that target in 2002 has averaged about 4%.

Table 1. Catch in metric tons of the 2002 shortraker/rougheye species complex (through October 26) by Bering Sea subarea and Aleutian Islands Districts relative to submitted 2003 TACs. Catch data are through 10/26/02.

	BSAI (ABC)	Bering Sea Subarea	Eastern Aleutian	Central Aleutian	Western Aleutian
Submitted 2003 TAC	967	137	216	335	279
2002 Catch	570	99	175	122	173

In 2002 three quarters of the Aleutian Islands catch of shortraker/rougheye occurred in trawl targets and the remainder in hook-and-line. Within the trawl fishery, the Pacific ocean perch target accounted for 69% of the total catch and Atka mackerel 7%. Within the hook-and-line fishery, the sablefish target accounts for 15% and Pacific cod 8% of the total catch (Appendix 1). The two hook-and-line fisheries retained about 25% of the shortraker/rougheye they caught. Trawl Atka mackerel retained 65% and Pacific ocean perch 86% of their catch.

The breakout of shortraker/rougheye rockfish into the three separate TACs in the Aleutian Islands districts from one TAC for the subarea may have several ramifications for management.

While examination of the 2002 data doesn't indicate catches in excess of the TACs, if the distribution of the target species (Pacific ocean perch, Atka mackerel or sablefish) or shortraker/rougheye change significantly in the surveys the relative catch may change as well. For example if the distribution of Pacific ocean perch were to change (though survey data indicates the relative distribution of POP has remained fairly consistent over the last 10 years), the bycatch of shortraker/rougheye rockfish could increase or decrease by district perhaps increasing the incidental catch in one district to the point of exceeding a TAC. Likewise if the absolute amount of a target species increased greatly and the shortraker/rougheye TACs remained consistent, the district specific TACs could be approached or exceeded. If a shortraker/rougheye TAC were exceeded it would have to be placed on prohibited species status and any future catch of shortraker/rougheye would be required to be discarded.

It is difficult to determine whether changing the status of shortraker/rougheye so that retention is prohibited as the target fishery continues will significantly reduce or terminate the mortality of shortraker/rougheye. Previous studies of shortraker/rougheye bycatch in the Pacific ocean perch target (the target group that took the greatest amount of shortraker/rougheye as bycatch, has the highest MRB, and greatest potential for 'topping off') indicate bycatch rates from survey data of about 2%. Observer data from the Pacific ocean perch fisheries in the Aleutians during July of 2002 show bycatch rates per vessel ranging from 2% to 7% with an overall rate of 3% for 5 trawl c/ps that participated in the fishery. Fishery data might be higher because catcher/processor vessels are targeting rockfish in general and do have an economic incentive to retain shortraker/rougheye which may result in 'topping off' activity. If shortraker/rougheye are prohibited to retention, bycatch rates of at least 2% for the remainder of the fishery could be expected, resulting in that amount of discard. Appendix 1 and 2 to this discussion paper provides a summary of 2002 and 2001 catch data of shortraker, rougheye, and northern rockfish by fishery. Monthly catch amounts and catch rates are provided.

Aleutian Islands district-specific TACs create three much smaller catch limits to manage. Dividing an ABC into small groups increases the management complexity. As TACs become smaller, inseason management becomes less flexible and closures become pre-emptive rather than based on current inseason data. This condition is especially true for species or species groups that are incidentally caught in relatively small target fisheries like the three Pacific ocean perch fisheries in the Aleutian Islands. In order to prevent exceeding the suggested shortraker/rougheye TACs, inseason management may have to prohibit retention earlier than necessary to ensure they're not exceeded, which could have the effect of increasing discards.

Other approaches can be developed to conserve shortraker/rougheye. For example in the Pacific ocean perch fishery the maximum retainable bycatch rate for shortraker/rougheye could be further reduced to minimize 'topping off' potential if it is indeed occurring. This potential was the motivation for the MRB reduction in 1998. Another option is to examine restrictions on the type of trawl gear that can be used to target Pacific ocean perch and the amount of shortraker/rougheye that can be retained. The Aleutian Islands Pacific ocean perch fishery currently is conducted with non-pelagic trawl gear. In the Gulf of Alaska rockfish fisheries, some catcher/processors and catcher vessels use pelagic trawl gear to target Pacific ocean perch. Observer data from this year's fishery indicate no bycatch of shortraker/rougheye in the pelagic trawl gear fishery and catch rates of about 95% Pacific ocean perch.

While current data indicate disproportionate harvest is not occurring, changes in the population structure could change the relationship between the target fisheries and the shortraker/rougheye complex. Splitting the Aleutian Islands TAC into three TACs will decrease the flexibility and increase the complexity of inseason management. Creating three TACs may increase the potential for discards. If the intention is to restrict the catch of shortraker/rougheye in the target fisheries that take them, other approaches may be more appropriate without increasing the complexity for management and risking additional discards.

Management of Bering Sea Shortraker, Rougheye, and Northern Rockfish in the 2003 CDQ Fisheries

The CDQ Program allocates a portion of all BSAI TACs, except squid, to CDQ reserves. The allocations are 10% of the pollock TAC, 20% of the fixed gear sablefish TAC, and 7.5% of all other groundfish TACs and prohibited species catch limits. Regulations at 50 CFR 679 further allocate these CDQ reserves among the six CDQ groups based on percentage allocations recommended by the State of Alaska and approved by NMFS. The most recent percentage allocation recommendations apply for the three year period of 2003 through 2005.

NMFS regulations prohibit the CDQ groups from exceeding any of the quotas allocated to them. Quota overages are violations of NMFS regulations and result in enforcement actions against the CDQ group. Although NMFS does not require the CDQ groups to stop fishing when any one of its quotas has been reached, the prohibition against exceeding a quota and the resulting enforcement actions have the effect of limiting further CDQ fisheries once any quota has been reached. Almost all groundfish species and halibut prohibited species quotas are caught in each of the CDQ groups' target fisheries. Continuing to fish, therefore, while avoiding most of the species with CDQ allocations is very difficult..

The Bering Sea "other red rockfish" species group was split into BS sharpchin/northern and BS shortraker/rougheye in 2001, and into BS northern and BS shortraker/rougheye in 2002. Similar groups for these rockfish species are expected to be recommended for 2003. These species groups result in relatively small TACs, CDQ reserves, and allocations to the individual CDQ groups. A complicating problem is that the State's CDQ allocation recommendations for 2003-2005 provides allocation recommendations for BS "other red rockfish," rather than the two species categories that will exist in 2003.

Tables 2 and 3 show the amount of BS northern and BS shortraker/rougheye that would be allocated to the six CDQ groups in 2003, based on recommended ABCs for 2003 and the State's allocation recommendations for BS Other Red Rockfish.

Table 2. Estimated 2003 CDQ Reserve for BS Northern Rockfish and BS Shortraker/Rougheye Rockfish (in metric tons).

Species Category	ABC	TAC	CDQ Reserve (7.5%)
BS Northern	18	18	1.35
BS Shortraker/Rougheye	137	137	10.275

Table 3. Allocation of the Estimated 2003 CDQ Reserve for BS Northern Rockfish and BS Shortraker/Rougheye (SR/RE) Rockfish among the CDQ groups (in percentage and metric tons).

CDQ Group	% Allocation	BS Northern	BS SR/RE
APICDA	21%	.284	2.158
BBEDC	19%	.257	1.952
CBSFA	7%	.095	0.719
CVRF	17%	.230	1.747
NSEDC	17%	.230	1.747
YDFDA	19%	.257	1.952
Total Reserve	100%	1.35	10.275

Assumes State of Alaska recommended percentage allocations for BS other red rockfish for 2003-2005.

These allocations would result in all CDQ groups having quota balances of less than a ton for BS Northern rockfish. For example, CBSFA would have a quota of 95 kg of BS northern rockfish to support all of its BSAI CDQ fisheries.

One of the goals of the multispecies CDQ allocations was to provide the CDQ groups with quotas for all groundfish species and prohibited species, but require the CDQ groups to be more accountable than other sectors for catch of target, non-target, and prohibited species. However, another equally important goal of the multispecies CDQ allocations was to provide additional allocations to support economic development goals for Western Alaska. Regulations developed in 1997 and 1998 for the multispecies CDQ allocations would not likely have included strict quota accountability for species categories with TACs as small as some of the rockfish TACs are now getting. The creation of these very small CDQ allocations are an unintended consequence of the Council's recommendations to improve conservation and management of BSAI rockfish.

The Council has requested analysis of alternatives to revise CDQ regulations to address problems related to splitting of the rockfish and "other species" quota categories. However, the appropriate regulatory amendments to address problems in the CDQ fisheries will depend on what the Council recommends for the management of rockfish and "other species" in the BSAI for all fisheries. Permanent revisions to the CDQ Program regulations should be made as part of one of these more general fisheries management actions. Therefore, NMFS proposes the following interim management measures for BS northern rockfish and BS shortraker/rougheye rockfish CDQ in 2003 to provide more time to develop alternatives for regulatory amendments that could address the problems being created by splitting species groups.

1. Continue to allocate 7.5% of the TAC as a CDQ reserve for BS northern rockfish and BS shortraker/rougheye rockfish. This allocation is required by the MSA and NMFS regulations.

2. Do not allocate BS northern rockfish or BS shortraker/rougheye rockfish among the six CDQ groups. NMFS will consider whether the decision to not allocate these species among the groups can be made through the 2003-2005 CDQ allocation process, which must be complete before the 2003 CDQ fisheries start. If this approach is not possible, NMFS will consider an enforcement policy.

3. Continue to require each CDQ group to report its catch of these species through the standard CDQ catch reporting procedures and to follow all other CDQ catch accounting regulations, including observer coverage and equipment requirements. Monitor the catch of these rockfish species by each CDQ group, and monitor the overall catch in the CDQ Program.

4. If CDQ allocations of BS northern rockfish and BS shortraker/rougheye rockfish are not made to individual CDQ groups, the groups would not violate NMFS regulations related to quota overages for their catch of these species.

5. Manage the CDQ allocations of BS northern rockfish and BS shortraker/rougheye rockfish at the CDQ sector level. Use regulations at 50 CFR 679.20(d), which already apply to the CDQ allocations, to manage the catch of these species in the CDQ fisheries. These regulations allow NMFS to establish retention standards and to close directed CDQ fisheries, if these measures become necessary to maintain total catch within allocations, ABCs, and OFLs. These measures have not been necessary to date in the multispecies CDQ fisheries, because of the allocations to each group and strict quota accountability. However, they would be necessary to manage species allocated to the CDQ sector, but not to individual groups.

6. Under §679.20(d), if the catch of BS northern rockfish or BS shortraker/rougheye rockfish approaches the overfishing limit, NMFS would have to take management action to prevent overfishing of these species. The CDQ fisheries would be among those fisheries that NMFS would consider for closure to prevent overfishing. NMFS could issue a closure notice that would prohibit any vessel fishing for a CDQ group from participating in a specified directed fishery. As with the non-CDQ fisheries, these closures could be focused on target species, gear type, or area.

NMFS's 2003 Strategy for Assessing the Use of Observer Data for Species Specific Catch Monitoring of Shortraker and Rougheye Rockfish

Shortraker and rougheye rockfish are currently managed as a group. The Plan Team and Council have expressed interest in separating the species, so that ABCs, TACs and overfishing levels could be established by species. Separating shortraker and rougheye rockfish is problematic because the two species are caught together in a broad range of trawl and fixed gear fisheries and they can be very difficult to reliably distinguish. So long as the species are managed as a group, the accuracy of species identification does not pose a significant quota monitoring issue. However, if the species are separated for management, accuracy of species identification becomes critical.

In order to separate shortraker and rougheye for management purposes, a system for accounting catch of the two separate species must be developed that is unbiased. Two key catch accounting issues have been identified:

1. Observer data collection practices on longline vessels must be modified to ensure an unbiased sample of shortraker and rougheye rockfish are taken for species identification. The current sampling practices result in adequate estimates for the shortraker-rougheye group, but can bias individual species estimation.

2. Identification of the two species in commercial catch data is probably biased. Commercial catch is generally sorted by color. Shortraker rockfish and the rougheye rockfish that are completely red in color form one market and are more valuable than darker colored rougheye rockfish. This market-category sorting results in some rougheye rockfish reported in the commercial catch as shortraker rockfish.

As a result of these catch accounting issues, shortraker and rougheye rockfish should continue to be accounted for and managed as a group, until acceptable methods can be developed to adequately account for them separately. The following actions will be taken in 2003:

1. Shortraker-rougheye will be managed as a group.

2. The observer program will conduct a special project to evaluate changes in observer sampling procedures to collect unbiased species composition data on the proportion of shortraker and rougheye rockfish in longline sets.

3. NMFS will assess whether the changes in procedures result in significant improvements in the available data from the longline fishery.

4. NMFS will assess the feasibility of utilizing unbiased species composition data from observed vessels to estimate the composition of the commercially-reported catch (including catch by unobserved vessels), because species identification by the industry is unlikely to be improved significantly or made verifiable.

5. NMFS will notify the Plan Teams prior to the fall 2003 meetings whether a suitable methodology for separating the species can be implemented for 2004.

Long-range Planning for Rockfish Research

Several important factors affect the assessment and management of rockfish in the north Pacific, including variability in survey biomass estimates, genetic stock structure, and rockfish habitat associations at various life history stages. The Rockfish Working Group (RWG), a collection of rockfish assessment and survey scientists within the Alaska Fisheries Science Center, has a history of conducting and supporting research addressing each of these topics. Work conducted by the RWG on reducing variability in survey biomass estimates originated with studies evaluating different net designs and has progressed to examination of various survey designs such as adaptive sampling and double sampling with sonar.

Evaluating survey designs that incorporate sonar and trawl technologies is an active area of research, and analyzing echosign data collected in the 2002 Aleutian Islands and eastern Bering Sea trawl surveys will be the focus of future research. Rockfish density estimates can also be obtained from submersible vessels. Submersible research on shortraker and rougheye rockfish has been conducted in the eastern Gulf of Alaska in the early 1990s and, more recently, in the Aleutian Islands in 2002. Additional information from submersible research includes habitat associations of rockfish, and fine-scale observations on the patchiness of some rockfish species. Recently, additional information on earlier life-history stages is obtained from examination of rockfish collected opportunistically in pollock larval surveys and juveniles collected from tows of the Ocean Carrying Capacity research. Additionally, research on habitat association, growth, and diet composition of juvenile rockfish in near-shore waters (using ROV, beach seines, and SCUBA) has been supported by the RWG.

Finally, the issue of rockfish stock structure has particular relevance in the Bering Sea/Aleutian Islands given the definition of management areas. The RWG has supported Dr. Tony Gharrett of the University of Alaska in his genetic research of stock structure, which to date has largely focused on samples collected in the Gulf of Alaska. However, the development of the EBS slope survey allows for the possibility that more samples will be collected in this area in the future. Pacific Ocean perch tissue samples were collected in 2002. The RWG has also supported and funded the development of a genetic species identification database of larval rockfish using DNA. This is an invaluable tool for determining larval distribution where identification previously could not be made with morphometric measures.

For the February Council meeting, the RWG plans on drafting a paper describing past research and future plans on each of these research topics in more detail.

APPENDIX 1 SPREADSHEETS

Ai 1

2002 ALEUTIAN ISLANDS NORTHERN CATCH

GEAR	HAL	HAL	HAL	POT	TRW	TRW	TRW
TARGET	C	O	S	S	A	C	K
01	2.15	-	-	-	475.51	-	-
02	0.17	-	-	-	769.06	29.11	-
03	7.04	-	0.08	-	22.09	75.66	-
04	0.42	-	-	0.00	50.84	0.10	-
05	-	0.01	-	-	-	-	-
06	0.01	-	-	-	106.16	-	-
07	-	-	0.04	-	-	-	117.22
08	1.41	-	0.20	0.00	91.92	0.01	4.05
09	16.65	-	0.01	0.00	2,100.39	10.54	0.01
10	0.31	-	0.00	-	22.86	-	-
3,904	28.16	0.01	0.33	0.01	3,638.81	115.43	121.28

GEAR	HAL	HAL	HAL	POT	TRW	TRW	TRW
TARGET	C	O	S	S	A	C	K
01	0%	0%	0%	0%	12%	0%	0%
02	0%	0%	0%	0%	20%	1%	0%
03	0%	0%	0%	0%	1%	2%	0%
04	0%	0%	0%	0%	1%	0%	0%
05	0%	0%	0%	0%	0%	0%	0%
06	0%	0%	0%	0%	3%	0%	0%
07	0%	0%	0%	0%	0%	0%	3%
08	0%	0%	0%	0%	2%	0%	0%
09	0%	0%	0%	0%	54%	0%	0%
10	0%	0%	0%	0%	1%	0%	0%
1	1%	0%	0%	0%	93%	3%	3%

BERING SEA NORTHERN CATCH

GEAR	HAL	HAL	POT	POT	TRW	TRW	TRW	TRW	TRW	TRW	TRW	TRW	TRW
TARGET	C	S	C	S	B	C	F	K	L	P	R	W	Y
01	0.02	-	-	-	-	0.09	-	-	-	-	-	-	-
02	0.17	-	-	-	-	0.82	-	-	-	0.01	-	-	-
03	0.28	-	0.03	-	-	19.14	-	-	-	0.05	0.75	-	0.18
04	0.11	-	-	-	-	0.53	-	-	0.77	-	-	-	0.42
05	-	-	-	-	-	0.19	-	-	-	-	-	-	-
06	-	-	-	-	0.01	4.39	-	-	-	1.59	-	-	-
07	-	0.06	-	-	0.01	-	0.21	14.59	-	4.23	-	-	-
08	0.80	0.22	-	0.02	-	14.06	-	-	-	31.42	-	0.80	-
09	4.92	0.01	0.15	-	0.01	0.14	-	-	-	6.49	-	0.09	-
10	1.65	-	0.13	0.00	-	0.31	-	-	-	0.25	-	-	-
110	7.94	0.28	0.31	0.03	0.03	39.68	0.21	14.59	0.77	44.04	0.75	0.89	0.60

GEAR	HAL	HAL	POT	POT	TRW	TRW	TRW	TRW	TRW	TRW	TRW	TRW	TRW
TARGET	C	S	C	S	B	C	F	K	L	P	R	W	Y
01	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
02	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
03	0%	0%	0%	0%	0%	17%	0%	0%	0%	0%	1%	0%	0%
04	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
05	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
06	0%	0%	0%	0%	0%	4%	0%	0%	0%	1%	0%	0%	0%
07	0%	0%	0%	0%	0%	0%	0%	13%	0%	4%	0%	0%	0%
08	1%	0%	0%	0%	0%	13%	0%	0%	0%	29%	0%	1%	0%
09	4%	0%	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	0%
10	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
100%	7%	0%	0%	0%	0%	36%	0%	13%	1%	40%	1%	1%	1%

Discussion Paper on Rockfish Research and Management

Rockfish Working Group
Alaska Fisheries Science Center
January 27, 2003

Executive Summary

The North Pacific Fishery Management Council recently requested a description of the scientific information necessary to manage rockfish on a single-species basis on finer spatial scales, in particular focusing on the issues of stock structure, the adequacy of existing surveys, and the availability of life-history information. The purpose of this discussion paper is to describe our information on these topics, and past and current research on problems relevant to rockfish management. First, we address the question of what information is necessary to scientifically assess the stock structure of rockfish, including genetic and life-history information. Second, we address the question of what information is necessary to adequately assess the population status of north Pacific rockfish stocks, and consider the information available for various rockfish species. Both types of information are viewed as relevant to questions regarding the overall effectiveness of our current management system, as such inquiries can only be considered in the context of the scientific information available on stock structure, life-history, and population status. Current fisheries management practices are designed to provide effective conservation of rockfish stocks given our current understanding of rockfish stock structure and available data. Therefore, biological studies on stock structure are essential in defining the appropriate spatial scales of fisheries management (i.e., establishing harvest quotas by management area), and as new information on stock structure becomes available the question of effective management strategies will need to be revisited. A similar updating of management strategies would also be expected to occur as new information on life-history and population status becomes available for data-poor portions of rockfish populations. A summary of our overall findings and recommendations is presented below.

Genetic studies and spatial units for fisheries management

Identification of stock structure is an essential part of examining whether a particular management scheme is providing conservation of rockfish resources. Genetic research indicates that little stock structure is seen for northern rockfish across wide areas, although a more comprehensive study could be pursued. For shortraker rockfish, weak structure is seen across relatively broad spatial scales and rougheye rockfish are likely two different species that cannot easily be identified in the field. Canadian researchers have found that Pacific ocean perch (POP) off British Columbia show strong stock structure on very fine spatial scales, and some preliminary research from Alaska POP stocks is consistent with this view. The Rockfish Working Group (RWG) supports the continued work by A.J. Gharrett and his colleagues at the Juneau Center for Fisheries and Ocean Sciences (JCFOS) to further refine our understanding of rockfish stock structure.

It is unlikely that the spatial boundaries of stock structure for a particular species will correspond to our current management boundaries or to other related rockfish species. The

establishment of spatial management systems for individual species is dependant, in part, on information such as the identification of areas where reproduction occurs and the duration and mortality of the pelagic life stages. This information is currently unknown for rockfish, and research conducted by Dr. Art Kendall suggests that identification of rockfish larvae is difficult without genetic analyses. In the absence of biological information, spatial management can be influenced by the spatial structure of fishery harvests. For example, recent stock assessments of other red rockfish have identified areas where much of the bycatch of northern rockfish has occurred and fishing closures in these areas could reduce harvests. The eastern Bering Sea (EBS) pollock fishery is currently voluntarily using this approach in order to reduce northern rockfish bycatch.

The management of two stocks (or species) that are intermixed in the same area poses unique problems for management. If distinct reproduction areas can be identified for particular stocks, then fisheries may be able to harvest on these stocks in these areas; however, reproductive isolation may occur by depth as well. Mixed stock analysis (Utter and Ryman 1993) may be useful in these situations.

Survey design

Potential improvements in survey design vary by species. Shortraker and rougheye rockfish are not thought to be highly clustered, but do live in fairly rough habitat relative to other rockfish species. Thus, these species may be best sampled by improving the footrope of survey trawl gear. These species are also obtained in current longline surveys, and the biomass indices from these surveys should be assessed with respect to whether additional sampling would substantially improve rockfish estimates.

For species that are thought to be aggregated, such as POP and northern rockfish, survey designs that explicitly consider "patchiness" such as adaptive cluster sampling (ACS) or trawl and acoustic presence/absence survey (TAPAS) (Iverson et al. 1996) may be useful. POP are generally thought to occur over relatively smooth bottom, but northern rockfish may occur over rough bottom and gear design considerations may need to be pursued here as well.

Implementation of research on survey gear and design are complicated by at least two factors. First, trawl surveys in Alaska federal waters are designed as multispecies surveys, and changes in gear design that would increase the precision of rockfish biomass estimates may decrease the precision for other species. Second, most of our trawl surveys have used a standardized methodology for several years and changes to this methodology without gear standardization field experiments would complicate interpretation of these time series. The increase in frequency of the Aleutian Islands and Gulf of Alaska trawl surveys from triennial to biennial, and the addition of the EBS slope survey, reduces the personnel and equipment available to conduct specialized field work. Specialized surveys focused on rockfish may need to be considered, although this would not be inexpensive.

Biological data collection

Despite recent changes in fishery observer sampling procedures designed to sample more otoliths and increase length measurements of bycatch species, these data remain low for non-POP rockfish species. For example, the number of otoliths collected in the Bering Sea-Aleutian Islands (BSAI) area for northern, rougheye, and shortraker rockfish has not exceeded 200 per species in any year, and the number of lengths taken has not exceeded 1000 for any species since

1996. Steps taken in 2003 to improve species identification of shortraker and rougheye on longline vessels should help with collection of biological data for these species, although further steps may be necessary to improve biological sampling from the fishery.

Otolith collections and length measurements on research surveys has generally been adequate across broad areas, but if smaller spatial areas are to be considered for management then the sample sizes per area may need to increase as well. Much of the genetic sampling of rockfish has focused on the AI and GOA regions because data from the EBS area were not available. POP tissue samples for genetic analyses were collected in the 2000 and 2002 EBS slope surveys, and other species will likely need to be collected in future years in order to address questions of EBS rockfish stock structure.

Maturity studies are required on all rockfish species in the BSAI area. A study on POP maturity (estimated from field classification of maturity state) from the 2000 AI trawl survey produced an estimated length at 50% maturity substantially different from published estimates. Future studies may require histological studies from samples collected near the time of parturition. Because our research surveys may not coincide with the time of parturition, specialized research cruises may be useful here as well.

Age reading of some rockfish species, such as shortspine thornyhead and shortraker rockfish, is limited because of a lack of standardized methodology. Another species, rougheye rockfish, is difficult to age and requires a significant training period. In recent years, rockfish age readers have often taken other positions prior to becoming sufficiently trained to read rougheye rockfish, thus this species has a low number of otoliths read. In the past, only specific personnel were trained as rockfish age readers, thus leaving the group particularly sensitive to personnel losses. A new policy of training all groundfish age readers to read rockfish should stabilize interannual variability in the number of otoliths that can be read.

Stock assessment modeling

Several steps can be taken to improve the stock assessment models currently used for BSAI rockfish. In recent years, northern rockfish have been viewed as the most likely candidate for a separate age-structured model, given the size of the stock in the AI area and the availability of otoliths from the survey. Although no fishery otoliths have been aged, a sufficient time series of age composition now exists from the survey data. Thus, the development of an age-structured model should be investigated for the 2003 assessment; this model will likely require using maturity data from the GOA northern rockfish assessment. For other species of BSAI red rockfish, investigation of state-space modeling should be pursued. A model of this type was investigated by Ianelli and Gachais (1999) for other species in the GOA, and has the advantage of providing probability distributions upon quantities of interest, such exploitation rates, given uncertainty in both our observation of biomass and in the year-to year stock dynamics of the species. The biomass estimates of shortraker and rougheye rockfish from longline surveys should also be obtained and possibly used in stock assessments.

Introduction

In the October, 2002, meeting of the North Pacific Fisheries Management Council, the Council requested that NMFS staff present a discussion paper in December 2002 on short and long term approaches to managing BSAI rockfish. A discussion paper describing management strategies for 2003 was presented at the December 2002 Council meeting, with agreement that a discussion paper addressing long term (2004 and beyond) rockfish management issues would be presented to the Council at the January, 2003, meeting. The Council has requested that the long term discussion paper specifically address "*the scientific information/research necessary to support separate species management by area; management implications of separate species OFLs/ABCs/TACs; adequacy of existing survey methodology for these species and potential enhancements to existing protocol to address shortcomings; and potential management response to ongoing and perhaps unavoidable bycatch*".

In the December meeting of the Council's Statistical and Scientific Committee (SSC), the following additional requests for information regarding rockfish were made:

1. *Are current management approaches appropriate; do they effectively provide for conservation of rockfish resources?*
2. *Are surveys effectively estimating stock abundance and providing requisite demographic data?*
3. *What are the strengths and weaknesses of survey data and how might surveys be improved?*
4. *Is knowledge of individual species life history adequate? Do we have reliable estimates of natural mortality, maturity, and growth?*
5. *Do we know the stock structure for managed species?*

Where data deficiencies are noted, the white paper should identify the specific steps to be taken to acquire the needed data.

The purpose of this document is to describe past and ongoing scientific research that addresses the scientific information/research necessary to support separate species management by area. The management implications of managing species separately, as opposed to species complexes, are expected to be provided in a companion discussion paper that uses rockfish as a special example. Much of the research discussed has been conducted by the Alaska Fisheries Science Center's Rockfish Working Group (RWG), a collection of assessment and survey scientists that conducts or supports research on survey methods, genetic larval identification and stock structure, and rockfish habitat associations at various life-history stages.

This discussion paper is organized into two sections. First, we address the question of what information is necessary to scientifically assess the stock structure of rockfish. The available genetic and life-history information for assessing stock structure of north Pacific rockfish is presented, thus addressing questions 4 and 5 from the December Council meeting. In addition, we consider the relation of stock structure to spatial management. Second, we address the question of what information is necessary to adequately assess the population status of north

Pacific rockfish stocks, and consider the information available for various rockfish stocks, thus also addressing question 4 above. This section also considers our current surveys in detail, thus addressing questions 2 and 3 from the December Council meeting.

Information necessary to scientifically assess the stock structure of BSAI rockfish

Effective management would manage each stock (defined here as a reproductively isolated or semi-isolated population unit of a species) according to its level of productivity in order to optimize harvest and reduce the likelihood of overfishing. Thus, information on stock structure is an important consideration for defining and evaluating management measures applied to finer spatial scales. A variety of information types can be used to infer stock structure, including age and length compositions, growth patterns, early life-history studies, and genetic studies. A review of these types of studies is presented below.

Information from age and length compositions and growth patterns

Spatial differences in age or length compositions can be used to infer differences in recruitment patterns that may correspond to population structure. In Queen Charlotte Sound, British Columbia, Gunderson (1972) found substantial differences in the mean lengths of POP in fishery hauls taken at similar depths which were related to differences in growth rates and concluded that Pacific ocean perch (POP) likely form aggregations with distinct biological characteristics. In a subsequent study, Gunderson (1977) found differences in size and age composition between Moresby Gully and two other gullies in Queen Charlotte Sound. Westrheim (1970, 1973) recognized "British Columbia" and "Gulf of Alaska" POP stocks off the western coast of Canada based upon spatial differences in length frequencies, age frequencies, and growth patterns observed from a trawl survey. In a study that has influenced management off Alaska, Chikuni (1975) recognized distinct POP stocks in four areas – eastern Pacific (British Columbia), Gulf of Alaska, Aleutian Islands, and Bering Sea. However, Chikuni (1975) states that the eastern Bering Sea (EBS) stock likely receives larvae from both the Gulf of Alaska (GOA) and Aleutian Islands (AI) stock, and the AI stock likely receives larvae from the GOA stock.

Of particular interest to Bering Sea-Aleutian Islands (BSAI) rockfish is whether length-frequency data suggests stock structure between the eastern Bering Sea management area and the management subareas of the Aleutian Islands. Length frequencies by area and year were obtained from the Aleutian Islands trawl survey for POP (Figure 1), northern rockfish (Figure 2), rougheye rockfish (Figure 3), and shortraker rockfish (Figure 4). This survey was conducted in 1991,1994,1997,2000, and 2002, and covers a portion of EBS management area. With the exception of POP, it is difficult to interpret the data for some species in some year-area combinations because of low sample sizes; this problem is especially apparent for shortraker rockfish. Consistent trends in these data are difficult to visually separate from the sampling variability; for example, the modes of POP length distributions in the western AI appears to be smaller than other AI subareas in the 1997 and 2002 surveys, but this does not appear to the case for the 2000 survey. A statistical analysis of this data will be pursued in the future.

Differences in growth patterns could also correspond to discrete stocks. von Bertalanffy growth curves fit to northern rockfish show a progression of larger predicted size at age from the western AI to the eastern AI (Figure 5); this progression continues into the GOA where northern rockfish show even higher predicted size at age (Heifetz et al. 2002). Given the current research on northern rockfish genetics, it is not clear whether these changes in growth across areas reflect stock structure or phenotypic responses to varying environments.

Information from life-history studies

Stock differentiation occurs from separation at key life-history stages, and another approach to evaluating stock structure involves examination of rockfish life-history stages directly. Because many rockfish species are not thought to exhibit large-scale movements as adults, movement to new areas and boundaries of discrete stocks may depend largely upon the pelagic larval and juvenile life-history stages. Knowledge of specific areas where parturition occurs and the spatial extent of larval drift are therefore important not only to defining stock structure but also to the creation of marine protected areas with appropriate spatial boundaries.

In 2002, the rockfish working group contracted with Dr. Art Kendall to undertake an analysis of archived *Sebastes* larvae collected by Alaska Fisheries Science Center (AFSC). The goals of the study were to investigate a subset of the preserved larvae to assess whether larvae could be identified to groups and species based upon morphological characteristics, and identify the seasonal and geographical variations in distributions of the identified groups. The data used for the analysis originates from two sources: 1) a group of 650 larvae collected off southeast Alaska in 1990 by Dr. Bruce Wing; and 2) the AFSC ichthyoplankton database, containing 16,895 *Sebastes* larvae collected on 58 cruises from 1972 to 1999. The larvae collected by Dr. Wing all showed the same morph, and were too small to have characteristics that would allow species identification. A preliminary examination of the AFSC ichthyoplankton database indicates that most larvae were collected in the spring, the larvae were widespread in the areas sampled, and most are small (5-7 mm). The larvae were organized into three size classes for analysis: <7.9 mm, 8.0-13.9 mm, and >14.0 mm. A subset of the abundant small larvae was examined, as were all larvae in the medium and large groups. Species identification based on morphological characteristics is difficult because of overlapping characteristics among species, as few rockfish species in the north Pacific have published descriptions of the complete larval developmental series. However, all of the larvae examined could be assigned to four morphs identified by Kendall (1991), where each morph is associated with one or more species. Most of the small larvae examined belong to a single morph, which contains the species *S. alutus* (POP), *S. polyspinus* (northern rockfish), and *S. ciliatus* (dusky rockfish). Some larvae belonged to a second morph which has been identified as *S. borealis* (shortraker rockfish) in the Bering Sea.

Rockfish identification can be aided by studies that combine genetic and morphometric techniques and information has been developed to identify individual species based on allozymes (Seeb and Kendall 1991) and mitochondrial DNA (Gharrett et al. 2001, Rocha-Olivares 1998). The Ocean Carrying Capacity (OCC) field program, conducted by the Auke Bay laboratory, uses surface trawls to collect juvenile salmon and incidentally collects juvenile rockfish. These juvenile rockfish are large enough (approximately 25 mm and larger) to allow extraction of a tissue sample for genetic analysis without impeding morphometric studies. In 2002, species identifications were made for an initial sample of 55 juveniles with both morphometric and genetic techniques. The two techniques showed initial agreement on 39 of the 55 specimens, and the genetic results motivated re-evaluation of some of the morphological species identifications. Forty of the specimens were identified as POP, and showed considerably more morphological variation for this species than previously documented. Given the success of this initial examination of the OCC data with these techniques, a more comprehensive study is planned for the near future.

Studies on other life-history stages can also add basic information on rockfish biology. For example, identification of habitat associations of adult rockfish can be combined with habitat maps to identify locations where rockfish may be expected to occur, and such information may be helpful in identifying areas where fertilization or parturition occurs. The RWG has recently funded studies focused on identifying rockfish habitat associations using submersibles and habitat mapping using multibeam sonar. In 2002, the submersible *Delta* was used to conduct line transects to estimate rougheye and shortraker densities near Adak Island in the Aleutian Islands. The overall goal of the study was to estimate densities of rougheye and shortraker across various habitat types. A total 12 dives and 39 transects were completed in four days of field work, with a 20 minute duration for each transect. Also, habitat mapping studies were conducted in 2001 and 2002 in the GOA in conjunction with contractual work conducted by the National Ocean Survey. Some criteria that were considered in the selection of habitat to be mapped were 1) focus on rockfish grounds; 2) a wide variety of habitat, and 3) areas where we have good research trawl data. In 2001, a portion of Portlock Bank in the Gulf of Alaska was mapped. In 2002, a portion near Yakutat was mapped.

Information from genetic studies

Because stocks are, by definition, reproductively isolated population units, it is expected that different stocks would show differences in genetic material due to random drift or natural selection. Thus, analysis of genetic material from north Pacific rockfish is currently an active area of research.

Seeb and Gunderson (1988) used protein electrophoresis to infer genetic differences based upon differences in allozymes from POP collected from Washington to the Aleutian Islands. Discrete genetic stock groups were not observed, but instead gradual genetic variation occurred that was consistent with an isolation by distance model. The study included several samples in Queen Charlotte Sound where Gunderson (1972, 1977) found differences in size compositions and growth characteristics. Seeb and Gunderson (1988) concluded that the gene flow with Queen Charlotte Sound is sufficient to prevent genetic differentiation, but adult migrations were insufficient to prevent localized differences in length and age compositions. However, recent studies of POP using microsatellite DNA indicate population structure at small spatial scales, consistent with the work of Gunderson (1972, 1977), and suggest that adult POP do not migrate far from their natal grounds and larvae are entrained by currents in localized retention areas (Withler et al. 2001).

Interpretations of stock structure are influenced by the particular genetic analysis conducted, as illustrated by the differing conclusions produced from the POP allozyme work of Seeb and Gunderson (1988) and the microsatellite work of Withler et al. (2001); note that these two components of the genome diverge on very different time scales and that, in this case, microsatellites are much more sensitive. Protein electrophoresis examines DNA variation only indirectly via allozyme frequencies, and does not recognize situations where differences in DNA may result in identical allozymes (Park and Moran 1994). In addition, many microsatellite loci may be selectively neutral or near-neutral, whereas allozymes are central metabolic pathway enzymes and do not have quite the latitude to produce viable mutations. The mutation rate of microsatellite alleles can be orders of magnitude higher than allozyme locus mutation rates.

Most current studies on rockfish genetic population structure involve direct examination of either mitochondrial DNA (mtDNA) or microsatellite DNA.

Genetic research on rockfish population structure in the Gulf of Alaska and the BSAI area is an ongoing research activity of Dr. A.J. Gharrett and his colleagues at the University of Alaska's Juneau Center for Fisheries and Ocean Sciences (JCFOS). An initial study, supported by Saltonsall-Kennedy funding, had the objective of conducting a broad survey of genetic population structure of rougheye and shortraker rockfish, and initiating studies on northern rockfish. The northern rockfish research was considered preliminary due to small samples of 20 fish from each of three locations (Kodiak Island, Unimak Pass, and Stalemate Bank). There was no evidence of population structure in these samples from either mtDNA or microsatellite analysis. Although the sample sizes were small and had little power, the authors concluded that the analysis was sufficient to conclude that existing structure is not pronounced. However, this study looked at only a portion of the mtDNA genome and a handful of microsatellite loci, and had small sample sizes. If subtle differences occur, much larger sample sizes would be required in order to identify stock structure.

For rougheye rockfish, both mtDNA and microsatellite analyses indicate evidence of population structure. The microsatellite work was conducted on six collections in the Gulf of Alaska and eastern Aleutian Islands and showed nearly fixed differences in alleles at one loci between the Kodiak and Yakutat samples. In the mtDNA analysis, there were two major clusters of mtDNA haplotypes which correlate nearly perfectly to two homozygous microsatellite genotypes. If there were any interbreeding, there would be a large portion of heterozygous microsatellite genotypes. Some specimens are captured in the same hauls and the overall distributions of the two types overlaps, but are not coincident. These strong differences are suggestive of two species of "rougheye rockfish" that are reproductively isolated, and a further study (described below) supported by the RWG has examined whether color variations in rougheye rockfish correspond to genetic differences.

For shortraker rockfish, population structure was observed in the mtDNA analysis, and weak evidence of population structure was observed in the microsatellite analysis. The pattern of mtDNA haplotypes in northern rockfish was similar to that in shortraker rockfish in that each species was dominated by a single haplotype that was associated with several closely related haplotypes. However, the pattern among the peripheral haplotypes was more complex for shortraker rockfish. In both northern and shortraker rockfish, the relationships among the mtDNA haplotypes suggest a population decline followed by a relatively recent (in geological time) population expansion. A subsequent "phase 2" of the Saltonsall-Kennedy research will increase the sample sizes and sampling locations of shortrakers and rougheye rockfish.

The RWG has funded a separate study, via the CIFAR program, that has two distinct objectives: 1) conduct a thorough examination of mtDNA for POP on samples collected in the GOA and BSAI, and conduct a preliminary analysis of POP microsatellite variation in these regions; and 2) evaluate the genetic characteristics of two distinct color morphologies of rougheye rockfish. The POP mtDNA analysis was performed on 124 fish collected from six regions ranging from southeast Alaska to the Bering Sea slope and central Aleutian Islands. No population structure was observed, as most fish (102) were characterized by a common haplotype. However, the preliminary work with 10 microsatellite loci from the six regions resulted in 7 loci with significant heterogeneity in the distribution of allele frequencies. Additionally, the sample in each region was distinct from those in adjacent regions, suggesting population structure on a relatively fine spatial scale consistent with the results on Gunderson

(1972, 1977) and Wither et al. (2001). Future work with POP will focus on increasing the sample sizes and collection sites for the microsatellite analysis in order to further refine our perception of stock structure.

The second objective of the CIFAR study is motivated by the finding of nearly fixed differences between rougheye rockfish at some loci in a preliminary analysis (cited above). In addition, two color morphologies have also been reported for rougheye rockfish, and Seeb (1986) suggested a correlation of the color morphs to allozyme differences but had small sample sizes. Thus, an important question to be addressed in the CIFAR study is whether the color morphs correspond to genetic differences based on mtDNA or microsatellite patterns. Based on the mtDNA analyses, rougheye rockfish can be classified into distinct "type a" and "type b" haplotypes, with these haplotypes corresponding to distinct differences in microsatellite DNA as well. In a sample of 96 fish from the eastern Gulf of Alaska containing both color morphs (light and dark colored "rougheye" rockfish), most lightly colored fish corresponded to mtDNA haplotype *b* and more of the haplotype *a* fish had the dark morphology. Thus, the color morphs show some correlation to genetic differences but are not an unequivocal indicator. Future research questions include examining spatial distributions of the two types of rougheye rockfish, and whether separation occurs from water masses or depth zones.

Correspondence between stock structure and spatially explicit ABC and OFL levels

Current fisheries management practices are designed to provide effective conservation of rockfish stocks through harvest quotas designed to reduce the likelihood of overfishing. Therefore, biological studies on stock structure are essential in defining the appropriate spatial scales of fisheries management (i.e., establishing ABC and OFL levels by management area), and as new information on stock structure becomes available the question of effective management strategies will need to be revisited. Other factors beyond biological stock structure may also be important in the conservation of rockfish stocks; for example, a disproportionate amount of harvest in one area of the stock may cause concern over the potential of localized depletion. ABC levels by subarea in the Aleutian Islands were created for POP and Atka mackerel in order to spatially disperse the harvest, as much of the harvest of these species was taken from the eastern AI subarea. As presented in the rockfish discussion paper presented at the December, 2002, SSC meeting, disproportionate harvest levels are not apparent for shortraker and rougheye rockfish; this may be in part because they are often taken as bycatch in the POP and Atka mackerel fisheries that have spatially allocated ABC levels.

The current information on stock size and demographics can also influence the establishment of ABC and OFL levels. For example, in 2001 the BSAI POP assessment model was changed from having separate models for the AI and EBS subareas to a combined model that treats the entire BSAI POP population as a single stock. Although the existence of a single stock could not be determined from the data available in 2001, the existing biological information was viewed as not supporting a separate age-structured model for EBS POP. Again, as new information on stock structure, population size, and population biology (i.e., growth and maturity) becomes available for POP in this region, the establishment of ABC and OFL levels will need to be revisited. In the section below, we discuss the some of the information necessary to manage stocks, the nature of our resource surveys from which much of this information is obtained, and the current information status for some rockfish species.

Information necessary to assess the population status of north Pacific rockfish stocks

The establishment of fisheries management quotas in the north Pacific requires an estimate of population size and an estimate of a fishing harvest rate that will optimize harvest levels while reducing the likelihood of overfishing. In data-rich situations, this information need is generally supported by age-structured models which incorporate fishery-independent resource surveys, age and length compositions, estimates of maturity and length at age, and natural mortality estimates. If stock structure is thought to occur on spatial scales finer than currently assumed, then this information would also be necessary on these finer scales.

Trawl survey biomass estimates of rockfish show particularly high sampling variability compared to other groundfish species, and this has been an obstacle for management. For example, the coefficient of variation (CV) of EBS flatfish stocks from the EBS shelf survey are generally on the order of 0.10, whereas rockfish CVs from the 2002 AI trawl survey ranged from 0.16 (POP) to 0.27 (northern rockfish). The RWG has been involved in several studies aimed at improving trawl survey biomass estimates, and this information is summarized below. Additionally, the state of our current knowledge regarding age and length composition data, growth, and maturity is also presented, with an aim of identifying data gaps for BSAI rockfish species.

Trawl survey gear and design studies

The imprecision of the area-swept trawl surveys is likely a function of the tendency of rockfish to be patchily distributed, the occurrence of rockfish in habitats difficult to sample, and the vast areas to be surveyed in a limited time. In particular, there are at least two primary problems that may occur in the trawl surveys:

1) *Inadequate sampling of rockfish habitat.* If the trawl survey does not sample areas commonly used by rockfish because the habitat is too rugged for the trawl gear, then the area-swept method would underestimate biomass.

2) *Disproportionate sampling of patchily-distributed rockfish concentrations.* Rockfish may be patchily distributed, perhaps in particular habitat types. If the trawl survey happens to catch large concentrations of rockfish in habitats that constitute a minor fraction of the strata, then the area-swept expansion would overestimate biomass. Conversely, if the trawl survey happens to miss the rockfish patches, then the survey would underestimate biomass (as in problem 1 above). Disproportionate over-sampling or under-sampling of rockfish patches would be exacerbated by inadequate sample size, leading to large interannual variability in estimated biomass levels.

Note that these two problems are not likely to be mutually exclusive. For example, it is reasonable to expect that NMFS trawl surveys do not sample all the areas commonly used by rockfish because of gear restrictions, and that rockfish are patchily distributed. Strategies for addressing the first problem involve evaluating more rugged sampling gear, whereas strategies for the second problem involve developing survey designs that produce more representative sampling of rockfish patches within the time and cost constraints of our resource surveys. The

RWG originated with research on survey gear and design, and has conducted several studies addressing the two problems above.

Research evaluating survey gear

The ability to trawl in steep slope habitat was evaluated in a 1993 study on the *Unimak Enterprise*. This study was conducted on the eastern GOA slope from the Fairweather Grounds to the W-Grounds primarily at depths occupied by shortraker and rougheye rockfish (300-500m) using commercial rockfish trawl gear. All haul locations selected randomly along the slope were successfully trawled except for one location where soft mud clogged the net. Bottom that was too rough or too steep was not encountered. This study demonstrated that a net designed for rough bottom could be fished in a random or uniform design over most shortraker/rougheye habitat and untrawlable bottom would not be a major concern. Haul locations were uniformly distributed over the study area, whereas those of the *Miller Freeman* during the 1993 triennial trawl survey were located at gully openings and absent from steep slope habitat. The *Miller Freeman* hauls tended to have proportionately more zero catches, particularly for shortraker rockfish. The coefficient of variation of the log catch rates was lower for the *Unimak Enterprise* than for the *Miller Freeman.*

A trawl with a rugged footrope designed to sample rough shortraker and rougheye habitat was evaluated in field trials conducted by Ito (1999). The trawl performed well, as the proportion of shortraker and rougheye in the path of the trawl that were captured was about 80% (as inferred from video observations).

Research evaluating survey design

Knowledge of the relationship between physical and environmental variables and fish distribution and abundance is needed to improve survey sampling design and increase the precision of population estimates. Rockfish are believed to have seafloor habitat preferences and the RWG recognized that knowledge of these preferences and knowledge of the distribution of seafloor types could lead to improved survey efficiency and accuracy. The development of acoustic bottom typing techniques could greatly expedite the daunting task of characterizing sediment types on spatial scales meaningful for north Pacific rockfish populations. Two separate studies on using hydroacoustic systems to characterize bottom types have been conducted in recent years.

One approach to classifying bottom type is to interpret the signal from the vessel's echosounder relative to prior signals from known bottom types. This approach, utilized in the QTC View system, was evaluated by von Szalay (1998). Ship speeds between 3 and 12 knots did not significantly impact the consistency of seabed classification, and depths of at least 220 meters did not adversely affect classification performance. However, slope gradient apparently had a major impact on classification accuracy. The study concluded that the ship-mounted transducer would not be feasible in classifying bottom type on sloped habitat. These concerns led to studies in which the transducer is mounted directly on the headrope of a trawl, as in the Biosonics DTX system. Research conducted by Michael Martin has deployed this unit on the headrope of a poly-noreastern trawl at depths ranging from 50 to 770 m off the coast of Alaska, Oregon and California. Concomitant information on depth, temperature, geographic location, and the species composition of the catch has also been collected. The recorded acoustic information is processed and categorized into discrete bottom types using the Impact software package from Quester-Tangent Corporation.

There are several advantages of a self-contained acoustic data collection system over a shipboard system. The surveys are generally conducted aboard chartered fishing vessels, each having a unique combination of hull-mounted transducers, echosounders and frequencies making inter-vessel data comparison difficult, if not impossible. The Biosonics DTX system can be easily moved between vessels with no need to recalibrate or otherwise change the system. High quality, high resolution data are collected at a constant distance from the bottom making data directly comparable regardless of the depth of sampling. Tows are generally made along a depth contour allowing the face of the transducer to remain constantly parallel to the bottom, thus minimizing problems associated with classifying sediments on sloped bottoms. In addition, the acoustic data are collected over exactly the same bottom as the fish information, allowing for an exact correspondence between the acoustic and fish data. This is not possible with shipboard systems, particularly in deeper water. The system was designed to allow the user to easily switch to a different transducer frequency, making it a very versatile tool with many potential applications.

Evaluating the "patchiness" of rockfish distributions is an important step in formulation of survey design. In a study conducted by Chris Lunsford, GOA survey and commercial fishery data were analyzed to determine POP distribution patterns. The survey and the fishery appear to encounter POP in the same areas throughout the GOA, and POP distribution does not appear to change temporally. Analysis of CPUE data indicates POP exhibit a tightly aggregated distribution pattern which is related to habitat type. The improvement of the survey design, or relative efficiency, compared to a random estimate was 65%. Altering the allocation and stratification of the current design may improve the precision of POP biomass estimates but may be limited by the clustered distribution exhibited by POP in the GOA and the need to assess other species.

An effective allocation of sampling effort may be gained from adaptive sampling, in which greater sampling efforts are expended in clusters of high rockfish density. After an initial 1996 field study in the Kodiak area found high density clusters of POP that would be amenable to adaptive sampling, a two year study of adaptive cluster sampling of rockfish was conducted by the UAF-JCFOS and AFSC in 1998-1999. In 1998 the method was tested on POP and shortraker/rougheye in the Kodiak area of the Gulf of Alaska (Quinn et al 1999, Hanselman et al. 2001). In 1999, the method was further tested for these three species in the Yakutat area (Hanselman et al., in press). Adaptive cluster sampling was not found to be more effective than simple random sampling for shortraker rockfish and rougheye rockfish, which are considered to have a less aggregated distribution than POP. For POP, the biomass estimates obtained from random sampling were slightly less precise than for adaptive cluster sampling, primarily due to one very large catch which was mediated by the additional adaptive samples. The benefits of adaptive cluster sampling alone are not clear cut. The effort in determining edge units (low-CPUE hauls defining the extent of the high-CPUE clusters) was not considered in the variance comparison and CV, and the total number of hauls needed for adaptive cluster sampling was not considered in the efficiency comparison of time per haul. Hanselman (2000) suggests that hydroacoustics might be used for determining edge units. Determining edge units (and the cluster) with hydroacoustics would be similar to TAPAS (see below).

Several survey sampling designs involve the combined use of echosounder and trawl information data, with the general rationale being that the echosounder can provide information over relatively broad areas with low effort as compared to the more expensive trawl sampling. During the 1998 and 1999 studies of adaptive sampling, recordings of sonar fish sign were collected during trawl hauls. Sonar categorization criteria were developed on a subset of the 1998 data based on signal patterns and shapes and color. Between scientist agreement of high and low categories varied from 76-87% in 1998; for 1999, onboard scientists agreed with categorizations done by a shoreside scientist on 65% of 49 categorizations. High and low sonar categorizations corresponded with high and low catch rates 66-78% of the time in 1998 and 59-61% of the time in 1999.

Echosounder categorizations can be used to define strata in a simple double sampling design (Cochran 1977). Variance estimates that would result from this sampling design were predicted using the observed within category variances at various levels of first stage (sonar) sampling (Fujioka et al. 2000). Sonar samples are assumed to be considerably less expensive in time and cost than trawl sampling and if 10 times as many sonar samples are taken to stratify the trawl samples, variance improved 18-37% compared to simple random sampling, depending on the data set and the categorizer. If trawl hauls were allocated optimally, the improvement increased from 44%-60% over simple random trawl hauls. To match the variance obtained by double sampling with sonar primary sampling, the number of random trawl hauls would have to be increased 1.8-2.5 fold depending on data set and categorizer. This approach differs from TAPAS (described below) or adaptive double sampling because it does not rely on the concept of clusters or patches. It can be thought of as 2- phased sampling or double sampling for stratification where the first sample would be the sonar samples, indicating which stratum has been encountered, and the second sample would be a trawl haul allocated at a rate specific to each stratum.

A double sampling design, the Trawl and Acoustic Presence/Absence Survey (TAPAS), was developed by United Kingdom scientists design to improve bottom trawl surveys of patchily distributed fish such as the mackerel icefish *Champsocephalus gunnari* (Everson et al. 1996). The design uses echosounder data to estimate the presence and size of possible high density patches of the species. Trawl samples are then made in each high-density patch and in the low-density background. TAPAS is a variation of adaptive double sampling (Thompson 1992). It differs from the adaptive cluster sampling approach examined by Quinn et al. (1999) by using sonar to determine the presence of a cluster. TAPAS, like the double sampling with sonar stratification method, can use a simple binomial categorization of the echosounder signal that correlates with catch rate. Unlike the approach used to assess pollock and hake, it does not rely on a quantified interpretation or integration of the hydroacoustic signal, but a binomial (or multinomial) categorization of the signal.

The sample stratification approaches described above classified sonar signals into as few as two categories (for e.g., high vs. low, present vs. absent). If the signal can be quantified in more detail, a regression approach may provide increased efficiency. Ito (1999) was able to correlate echosign with catch rates of shortraker and rougheye rockfish during a depletion experiment at a site in the central GOA. Krieger et al. (2001) found correlations between data processed from an echosounder and trawl survey catches of rockfish during a triennial survey leg off Southeast Alaska. Ito (1999) describes an approach by Ona (1991) using a hydroacoustic signal regressed with trawl catch rates to increase survey efficiency. This approach would require more sophisticated equipment, as well as more sophisticated training and data processing than the TAPAS and sonar stratification approaches.

Age and length-frequency data, and other biological information for BSAI rockfish

In addition to reliable estimates of survey biomass, the development of age-structured population models requires information on the age and length composition of the fishery and survey catches. Reliable age information is preferred, although the age-structure of populations can be inferred from length data if an age-length growth relationship has been determined. A reasonable number of otoliths have been collected in the AI trawl surveys, although not all of these otoliths have been read (Table 1). Adequate numbers of otoliths in the fishery generally were not collected prior to 1999, when the sampling of otoliths by observers was focused largely upon identified target species and not bycatch species. For example, there were not more than 54 otoliths collected, per species and year, for northern rockfish, rougheye rockfish, shortraker rockfish from the domestic fishery during 1988-1998, and many years had zero otoliths for these species (Table 2). Since 1999, length and otoliths sampling has been based upon the predominant species group in the haul, and when the dominant species group is rockfish, more than one rockfish species is sampled. Although this change has increased rockfish otolith samples, the sample size per species per year (excluding POP) generally remains below 200.

Many of the otoliths sampled from the AI trawl survey have not been read, which is a function of limited personnel and development of reliable aging techniques. Recently, the number of rockfish otoliths which could be read in a given year has dropped from ~ 4500 to ~ 3000 due to personnel losses, although this number should increase as new age readers are currently being trained. In addition, the difficulty of reading shortraker and rougheye otoliths has motivated research on aging techniques and limited the amount of otoliths aged for these species. Species for which age-structured models exist, such as BSAI POP, GOA POP and GOA northern rockfish, generally receive priority for age reading, leading to a limited ability to age archived otoliths of other species. However, since 2000 much of the archived northern rockfish otoliths from the AI survey have been read in preparation for development of an age-structured model.

Relatively small sample sizes for rockfish lengths from the fishery are observed in several years due to the sampling protocols discussed above (Table 3). Although sampled lengths of POP exceed 2000 for each year since 1990, northern rockfish sampled lengths are below 600 from 1990-1992 and from 1997-1998. In addition, rougheye rockfish sampled lengths exceed 600 only in 1990 and 1992-1993, and shortraker rockfish lengths exceed 600 only in 1993. Considerably larger sample sizes for rockfish length frequency distributions are available from the AI trawl survey (Table 4).

Predicted size at age and maturity at age are also required for age-structured population modeling. Sufficient northern rockfish otoliths now allow computation of growth curves, as mentioned above (Figure 5). However, maturity studies are required for all species of BSAI rockfish. Field observations of POP maturity state taken in the 2000 AI trawl survey produced a length at 50% maturity of approximately 40 cm, substantially larger than previously published estimates of approximately 28 - 35 cm (Chikuni 1975, Westrheim 1975). Recent work in the GOA indicates an estimated length at 50% maturity of approximately 36 cm, and this maturity curve is currently used in the BSAI POP assessment. Northern rockfish maturity data collected on a 1996 research cruise in the GOA has also been used to develop a maturity curve for this species in this region (Chris Lunsford, AFSC-Auke Bay Laboratory, pers. comm.).

Finally, estimates of natural mortality are essential for stock assessment modeling. The advent of the break and burn method of reading otoliths has increased our perception of the longevity of POP from about 30 years to approximately 90 years, along with lowering estimates of instantaneous natural mortality (*M*) rates to about 0.05 yr^{-1} (Chilton and Beamish 1982, Archibald et al. 1981). Estimates of *M* for northern rockfish, based upon catch curve analysis, are thought to be about 0.06, whereas estimates of *M* for rougheye and shortraker rockfish to thought to be lower at 0.025 and 0.03, respectively (Alverson and Carney 1975).

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Table 1. Rockfish otoliths collected from the Aleutian Islands trawl survey, by year and species.

				Species		Shortspine
Year	Data	POP	Northern	Rougheye	Shortraker	Thornyhead
1980	Otoliths read	890	0	0	0	
	Otoliths collected	1851	726	36	139	
1983	Otoliths read	2495	0	0	0	0
	Otoliths collected	4082	437	93	499	535
1986	Otoliths read	1860	565	0	0	0
	Otoliths collected	1986	631	535	251	499
1991	Otoliths read	1015	456	0	0	0
	Otoliths collected	1028	466	480	346	437
1994	Otoliths read	849	409	0	0	0
	Otoliths collected	865	419	729	772	694
1997	Otoliths read	1224	652	0	0	0
	Otoliths collected	1237	670	866	1090	456
2000	Otoliths read	1238	725	0	0	0
	Otoliths collected	1269	736	492	629	468
2002	Otoliths read	0	0	0	0	0
	Otoliths collected	1377	522	473	571	534

Table 2. Rockfish otoliths collected from domestic fisheries in the BSAI area, by year and species.

		Species				
Year	Data	POP	Northern	Rougheye	Shortraker	Shortspine Thornyhead
1988	Otoliths read	0				
	Otoliths collected	73				
1989	Otoliths read	19				
	Otoliths collected	20				
1990	Otoliths read	328		0		
	Otoliths collected	346		54		
1992	Otoliths read	0		0		
	Otoliths collected	20		50		
1993	Otoliths read	0				
	Otoliths collected	100				
1996	Otoliths read	0				
	Otoliths collected	39				
1997	Otoliths read	0				
	Otoliths collected	70				
1998	Otoliths read	823	29			
	Otoliths collected	848	30			
1999	Otoliths read	0	0	0	0	0
	Otoliths collected	279	50	8	24	18
2000	Otoliths read	487	0	0	0	0
	Otoliths collected	539	166	26	21	36
2001	Otoliths read	524	0	0	0	0
	Otoliths collected	576	136	78	27	10
2002	Otoliths read	0	0	0	0	0
	Otoliths collected	705	200	67	45	192

Table 3. Rockfish length measurements from domestic fisheries in the BSAI area, by year and species.

Year	POP	Northern	Rougheye	Shortraker
1988	624			
1989	1048			
1990	69426	403	1961	27
1991	16468	145	144	576
1992	38009		1243	413
1993	34812	1809	1048	736
1994	14200	767	27	125
1995	11724	833	42	
1996	16113	4554	14	
1997	10545	1		
1998	12095	543		
1999	4128	917	57	306
2000	3666	976	164	94
2001	2715	661	287	96
2002	3749	889	336	183

Table 4. Rockfish length measurements from Aleutian Island trawl surveys, by year and species.

	Species			
Year	POP	Northern	Rougheye	Shortraker
1980	20796	3351	5449	1945
1983	22873	6535	3914	3514
1986	14804	5881	4390	2255
1991	14262	4853	1060	782
1994	18922	6252	2375	2335
1997	22823	7554	1817	2458
2000	21972	7779	1673	1626
2002	20285	9459	1288	1299

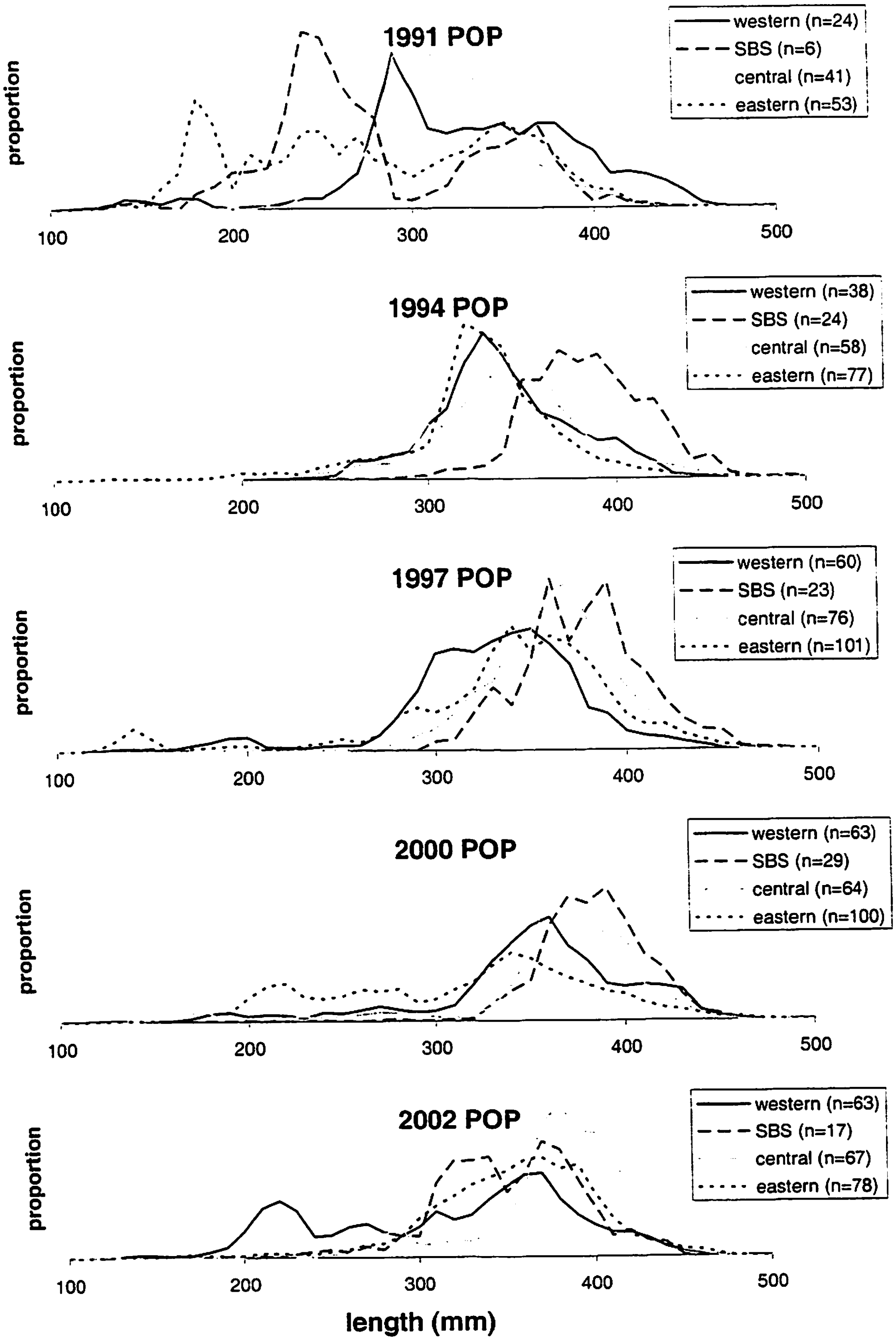

Figure 2. POP length frequencies, by area, from the Aleutian Island surveys; the number of hauls for each area-year cell is shown in the legend.

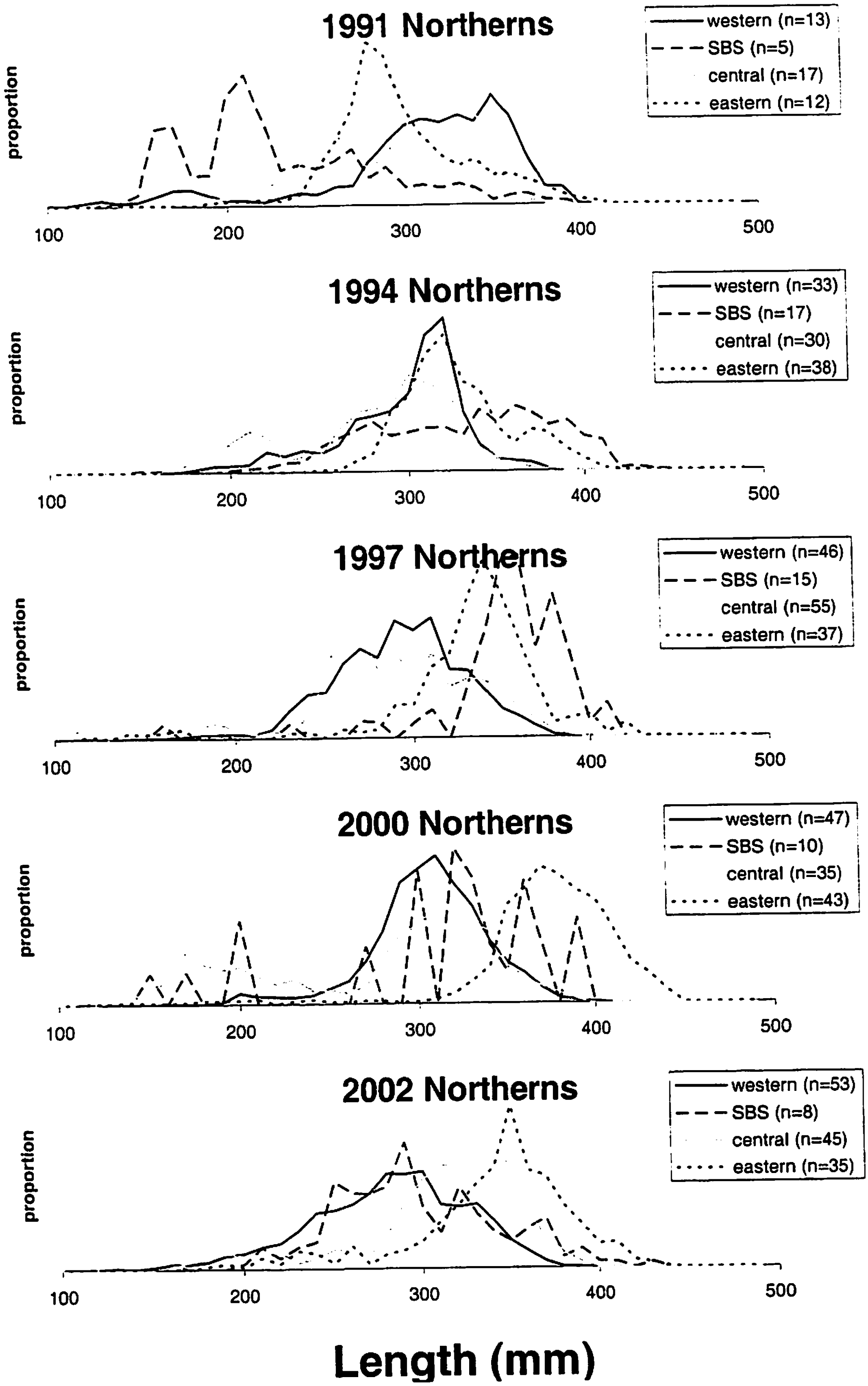

Figure 3. Northern rockfish length frequencies, by area, from the Aleutian Island surveys; the number of hauls for each area-year cell is shown in the legend.

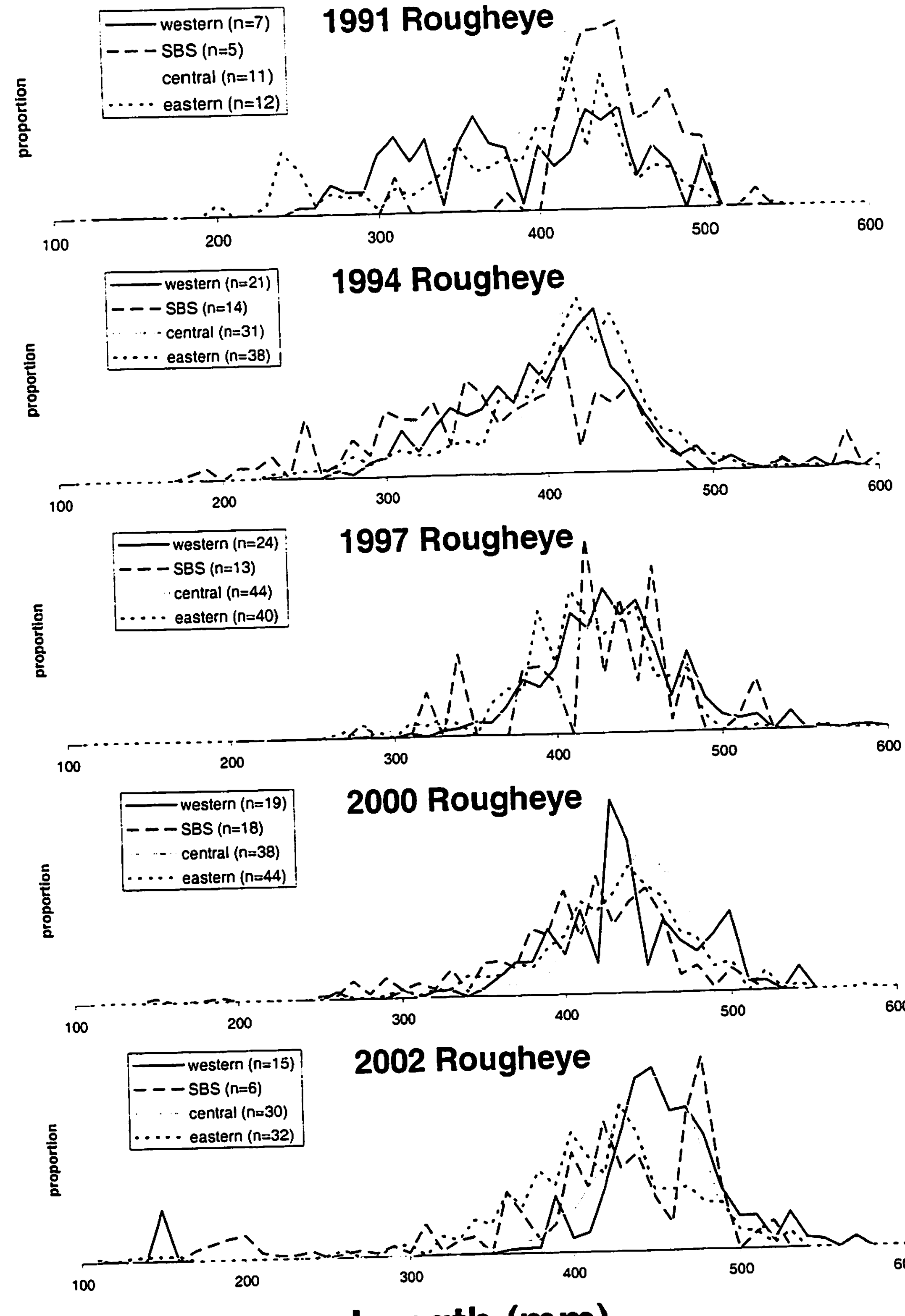

Figure 3. Rougheye rockfish length frequencies, by area, from the Aleutian Island surveys; the number of hauls for each area-year cell is shown in the legend.

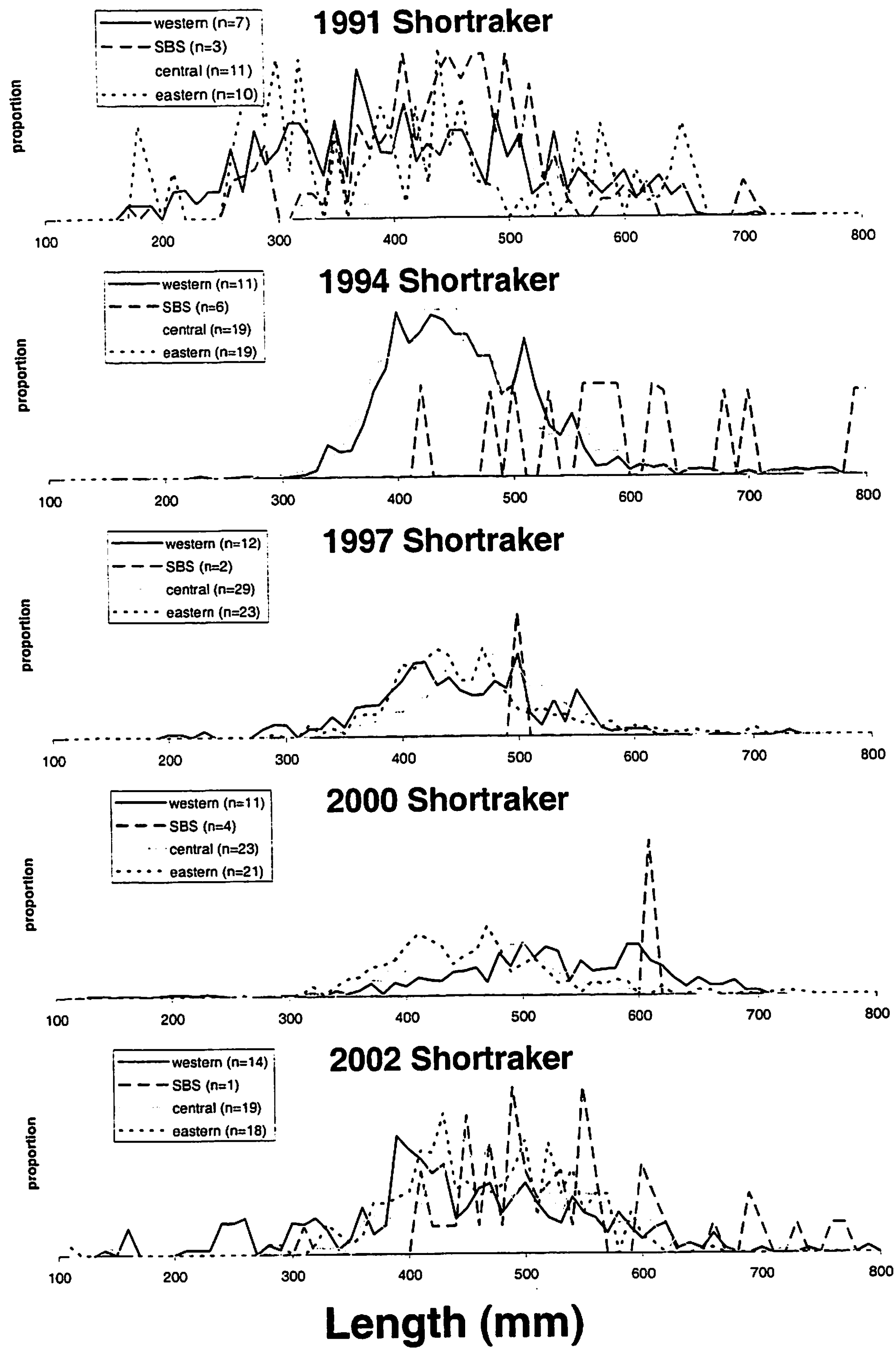

Figure 4. Shortraker rockfish length frequencies, by area, from the Aleutian Island surveys; the number of hauls for each area-year cell is shown in the legend.

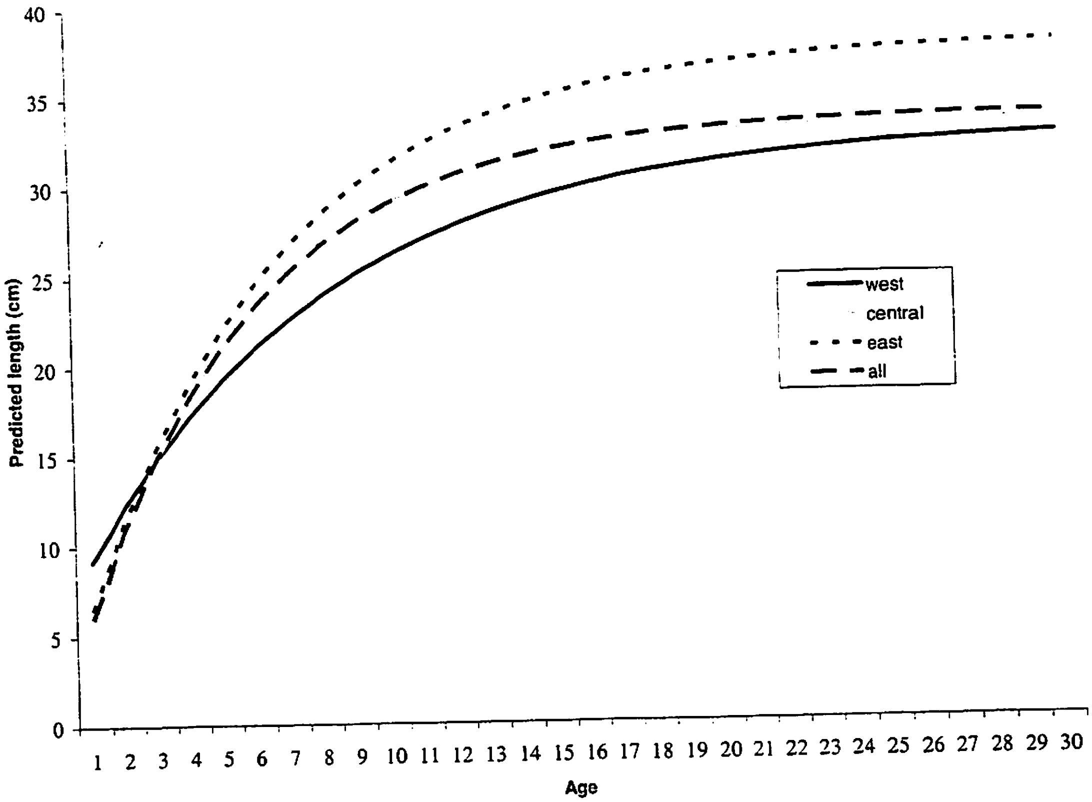

Figure 5. Northern rockfish growth curves by subarea within the Aleutian Islands; data were obtain in trawl surveys conducted from 1986-2000.

Discussion Paper on Rockfish Research and Management

Rockfish Working Group

Information requested by the Council (October 2002):

1) *"the scientific information/research necessary to support separate species management by area;*

2) *management implications of separate species OFLs/ABCs/TACs;*

3) *adequacy of existing survey methodology for these species and potential enhancements to existing protocol to address shortcomings;*

4) *potential management response to ongoing and perhaps unavoidable bycatch"*

Information requested by the SSC (December 2002):

1) *Are current management approaches appropriate; do they effectively provide for conservation of rockfish resources?*

2) *Are surveys effectively estimating stock abundance and providing requisite demographic data?*

3) *What are the strengths and weaknesses of survey data and how might surveys be improved?*

4) *Is knowledge of individual species life history adequate? Do we have reliable estimates of natural mortality, maturity, and growth?*

5) *Do we know the stock structure for managed species?*

6) *Where data deficiencies are noted, the white paper should identify the specific steps to be taken to acquire the needed data.*

Organization of the discussion paper

1) **What information is necessary to scientifically assess the stock structure of rockfish?**
    a) Age and growth patterns
    b) Life-history studies
    c) Genetic research
    d) What is the relationship between stock structure and spatial fisheries management?

2) **What information is necessary to assess the population status of rockfish stocks?**
    a) Survey biomass estimates strengths and weaknesses
    b) Age and length frequency data
    c) Growth, maturity, and natural mortality information

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FEBRUARY 2005

Do we know the stock structure for managed species?

Pacific Ocean Perch –

Length composition and growth patterns suggest stock structure on fine spatial scales off British Columbia (Gunderson 1972, 1977).

Allozyme analyses does not show stock structure over broad areas (Seeb and Gunderson 1988).

Microsatellite DNA analyses suggest stock structure on fine spatial scales off British Columbia (Withler et al. 2001); some preliminary microsatellite work with Alaska POP also suggests this (A.J. Gharrett, UAF-JCFOS, pers. comm.).

Do we know the stock structure for managed species?

Northern rockfish –

Preliminary mitochondrial and microsatellite DNA work suggests little structure over broad areas

Rougheye rockfish –

Mitochondrial and microsatellite DNA work suggest two different species of "rougheye rockfish"

Shortraker rockfish –

Microsatellite DNA analyses suggest weak structure over relatively broad spatial areas.

Genetic Research Considerations

If population structure is not observed, that does not necessarily imply that population structure does not exist.

In both northern and shortraker rockfish, the relationships among the mtDNA haplotypes suggest a population decline followed by a relatively recent (in geological time) population expansion.

How do genetic considerations factor into our definition of stocks for fishery management purposes?

Is knowledge of individual species life history adequate?

We know virtually nothing about the areas of reproduction and the mortality and duration of pelagic life stages.

Analysis of FOCI larvae specimens (conducted by Art Kendall)

- Three sizes (<8.0 mm, 8.0 – 13.9 mm, > 14.0 mm).
- All larvae could be assigned to one of four "morphs" identified by Kendall (1991).
- Most small larvae were a single morph, which could be POP, northern rockfish, or dusky rockfish.
- Species identification based upon morphology alone is difficult.

Analysis of Ocean Carrying Capacity (OCC) larvae specimens (conducted by Art Kendall and Tony Gharrett)

- Rockfish juveniles taken incidentally in salmon studies off SE Alaska.
- 55 species, each identified with morphometric and genetic methods.
- Agreement on 39 specimens. Forty specimens were POP, which showed a wider range of morphological variation than previously observed.

What are the strengths and weaknesses of survey data and how might surveys be improved?

Two issues in using trawl survey to estimate rockfish biomass:

1) Inadequate sampling of rockfish habitat due to gear design

- a) Unimak study (1992)
- b) Ito dissertation (1999)

2) Disproportionate sampling of patchily-distributed rockfish concentrations

- a) Classification of bottom types (Paul von Szalay, Micheal Martin)
- b) Adaptive sampling (Dana Hanselman)
  Slight improvement in precision for POP, but no improvement for rougheye or shortraker rockfish.
- c) Use of sonar to classify fish trawls (Fujioka, Everson et al. 1996)
- d) Active area of research – considerable data was collected on the 2002 AI and EBS trawl surveys.

Are surveys providing requisite demographic data? Do we have reliable estimates of natural mortality, maturity, and growth? Where data deficiencies are noted, the white paper should identify the specific steps to be taken to acquire the needed data.

Survey data provides collect adequate number of otoliths and length measurements over broad areas.

Fisheries data does not generally provide adequate number of otoliths and lengths over broad areas for non-POP rockfish.

Change in sampling methods in 1999 improved collections, but more changes may be necessary to increase collections.

Aging techniques, not sample sizes from the survey, are a limitation for rougheye, shortraker, and shortspine thornyhead.

Maturity studies are need for all managed rockfish in the BSAI area.

Otoliths collected from the AI trawl surveys
(Red = <100, Yellow = 100- 300, Green > 300)

				Species		
year	Data	POP	Northerns	Rougheye	Shortraker	SST
1980	Otoliths read	890	0	0	0	
	Otoliths collected	1851	726	36	139	
1983	Otoliths read	2495	0	0	0	0
	Otoliths collected	4082	437	93	499	535
1986	Otoliths read	1860	565	0	0	0
	Otoliths collected	1986	631	535	251	499
1991	Otoliths read	1015	456	0	0	0
	Otoliths collected	1028	466	480	346	437
1994	Otoliths read	849	409	0	0	0
	Otoliths collected	865	419	729	772	694
1997	Otoliths read	1224	652	0	0	0
	Otoliths collected	1237	670	866	1090	456
2000	Otoliths read	1238	725	0	0	0
	Otoliths collected	1269	736	492	629	468
2002	Otoliths read	0	0	0	0	0
	Otoliths collected	1377	522	473	571	534

Otoliths collected from the BSAI domestic fishery
(Red = <100, Yellow = 100- 300, Green > 300)

				Species		
year	Data	POP	Northern	Rougheye	Shortraker	Shortspine
1988	Otoliths read	0				
	Otoliths collected	73				
1989	Otoliths read	19				
	Otoliths collected	20				
1990	Otoliths read	328		0		
	Otoliths collected	346		54		
1992	Otoliths read	0		0		
	Otoliths collected	20		50		
1993	Otoliths read	0				
	Otoliths collected	100				
1996	Otoliths read	0				
	Otoliths collected	39				
1997	Otoliths read	0				
	Otoliths collected	70				
1998	Otoliths read	823	29			
	Otoliths collected	848	30			
1999	Otoliths read	0	0	0	0	0
	Otoliths collected	279	50	8	24	18
2000	Otoliths read	487	0	0	0	0
	Otoliths collected	539	166	26	21	36
2001	Otoliths read	524	0	0	0	0
	Otoliths collected	576	136	78	27	10
2002	Otoliths read	0	0	0	0	0
	Otoliths collected	705	200	67	45	192

Rockfish measured from the BSAI domestic fishery (Red = <200, Yellow = 200- 600, Green > 600)

Year	POP	Northern	Rougheye	Shortraker
1988	624			
1989	1048			
1990	69426	403	1961	27
1991	16468	145	144	576
1992	38009		1243	413
1993	34812	1809	1048	736
1994	14200	767	27	125
1995	11724	833	42	
1996	16113	4554	14	
1997	10545	1		
1998	12095	543		
1999	4128	917	57	306
2000	3666	976	164	94
2001	2715	661	287	96
2002	3749	889	336	183

Future stock assessment improvements

1) Examine longline survey data to get biomass estimates for rougheye and shortraker rockfish.

2) Investigate whether a BSAI northern rockfish model can be developed with existing data.

3) Investigate state-space models for species where little age-structure information exists, as in Ianelli and Gaichas (1999).

Are current management approaches appropriate; do they effectively provide for conservation of rockfish resources?

Current management procedures are designed to provide protection from overfishing given our perception of stock structure, population size, and life-history information. As new data becomes available, our management may have to adapt.

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FEBRUARY 2005

Rockfish Research Plan

Rockfish Working Group
Alaska Fisheries Science Center
2003/2004

Outline

- January 2003 report to the NPFMC
- Request for an update on research planned for 2003 and long-range research plans.
  - Description new research activities funded for 2003 (3 projects)
  - Description of Stock Assessment Improvement Plan research initiatives for 2004 (11 projects)

2003 Survey Activities

- Problem: In EBS northern rockfish occur in depths not well sampled by either the EBS shelf or slope surveys.
- Objective: Conduct exploratory field work near the Pribilof Islands to evaluate feasibility of rockfish survey.
- Method: Five day supplement to trawl survey
  - characterize the distribution and size of rockfish patches
  - gain some information on the gross habitat features (slope, bottom roughness)
  - evaluate diurnal patterns of any rockfish patches observed.

2003 Pilot studies to improve SR/RE sampling on longliners

- Problem: Shortraker and rougheye rockfish are classified using a complex code
- Objective: Improve species identification and life history collections of SR/RE rockfish in commercial fisheries
  - Collect SR/RE on Pacific cod and sablefish longliners
  - Randomly collect 30 SR/RE specimen, ID to species
  - Weigh and measure each specimen
  - Collect 1 pair of otoliths for every 10 rockfish collected

2003 Pilot studies to improve SR/RE sampling on Catcher Processors and Catcher Vessels

- Problem: Shortraker and rougheye rockfish classified using a complex code
- Objective: Improve species identification and life history collections of SR/RE rockfish in commercial fisheries
  - Reserve rockfish during tally period
  - ID to species
  - Weigh and measure 30 specimen
  - Collect otoliths

Rockfish Long-Range Research Plan

- 11 projects, responding to issues outlined in January report to NPFMC
- Goal 1: Improve our knowledge of rockfish stock structure
- Goal 2: Develop and implement protocols to improve the collection and analysis of rockfish life history information.
- Goal 3: Improve existing surveys or implement new surveys to improve biomass estimates of adult and juvenile rockfish.
- Goal 4: Expand and improve stock assessments.

Goal 1: Improve our knowledge of rockfish stock structure – Project 1

- Objective: Identification of regional partitions for stock assessment and management.

- Methods: Collect and process genetic samples from Aleutian Islands, Eastern Bering Sea and Gulf of Alaska.
- Target species: northern rockfish, POP, and shortraker rockfish.

Goal 1: Juvenile rockfish stock identification and interannual variability – Project 8

- Objectives:
  - Assess spatial and interannual variation in juvenile species abundance
  - Examine genetic variation in YOY rockfish
  - Develop morphological methods for species identification
  - Estimate source of YOY rockfish
- Methods:
  - Field sampling from OCC surveys and laboratory analysis
  - Estimate probable location of parturition using PMEL's three dimensional flow models of the Gulf of Alaska and Bering Sea Aleutian Islands

Goal 2: Improve the collection and analysis of rockfish maturity information – Project 2

- Objectives:
  - Evaluate of the accuracy of RACE visual scans for evaluation of rockfish maturity stages
  - Evaluate regional differences in the maturity schedule
  - Evaluation of regional differences in GSI.
- Methods: Field collections and laboratory analysis

Goal 2: Improve the collection of rockfish length, weight, and age data – Project 4

- Objectives:
  - Improve the collection of rockfish length frequency
  - Expand the collection of rockfish age compositions
- Methods:
  - Collect additional biological samples on AI Atka mackerel vessels
  - Train and deploy experienced observers in fisheries with high rockfish bycatch

Goal 2: Improve rockfish aging – Project 5

- Objectives:
  - Production ages for BSAI northern rockfish, BSAI dusky rockfish, BSAI and GOA rougheye rockfish
  - Develop aging criteria for shortraker rockfish and , BSAI and GOA thornyheads
  - Estimate of maximum age for selected minor rockfish species. This estimate could be used as a baseline estimate of the natural mortality rate.
- Methods:
  - Laboratory analysis

Goal 3: Improve rockfish surveys – Project 6

- Objectives:
  - Improved precision in rockfish biomass estimation and indices.
- Methods:
  - Design and implement rockfish dedicated surveys that augment existing groundfish trawl survey efforts in the GOA and BSAI.
  - Design and implement rockfish longline surveys that augment existing groundfish longline survey efforts in the GOA and BSAI.

Goal 3: Evaluate rockfish trawl catchability – Project 7

- Objectives:
  - Improved precision in rockfish biomass estimation
- Methods:
  - Compare rockfish densities in the two regions using area swept and line transect abundance estimation methods.
  - Evaluate the habitat associations of selected rockfish species.

Goal 3: Juvenile rockfish surveys – Project 11

- Objectives:
  - Improved understanding of recruitment dynamics for slope rockfish
  - Improvement of morphological methods for species identification
  - Improved stock assessment methodology
- Methods:
  - Develop methods to locate age 1+ slope rockfish
  - Describe characteristics of nursery habitat
  - Monitor the spatial distribution and abundance of post settlement juvenile rockfish

Goal 4: Expand and improve rockfish assessments – Project 3

- Objectives:
  - Improved stock assessments for rockfish
  - Improved stock assessment methodology
  - Support for impacts analysis as required under NEPA.
- Methods:
  - Retrospective data analysis
  - Model development
  - Model evaluation and testing

Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish Fishery Management Plans

(excerpted pages)

Draft Report

by

Daniel Goodman (Chair)
Marc Mangel
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Terry Quinn
Victor Restrepo
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With assistance from

Grant Thompson

Prepared for:

North Pacific Fishery Management Council

November 21, 2002

We see that for the most part there is not a clear systematic progression in increasing conservatism in the targets or in the width of the margin between target and limit, in moving from the Tiers with more information to those with less. Similarly, there is not, for the most part, a clear systematic incentive, in terms of potential for greater harvest, to improve the information base in order to move a stock from Tiers with less information to Tiers with more. Finally, the control rule provisions to accelerate rebuilding of stocks from an overfished condition do not apply to the 3 Tiers with the least information, and which, therefore, are subject to the greatest uncertainties. Within Tier, almost all the inputs to the control rule are point estimates, and so these do not adjust in response to uncertainty either.

Over time, the evolution of this management system has been in the direction, overall, of greater conservatism. By the standards of most of the world's large commercial fisheries, this management system is conservative.

The adequacy (and safety) of $F_{35\%}$ as a surrogate for F_{MSY} depends on the inherent productivity of the stock. For most of the BSAI/GOA target stocks this surrogate appears to be adequate, though the case of the GOA pollock stock, which has declined from its 1985 stock size under this management system, warrants a closer look. This surrogate is now believed to be inappropriate for less productive stocks, such as sharks and rockfish, and it is now thought that considerably lower harvest rates (considerably lower than $F_{40\%}$ as well) should be applied for those stocks.

In practice, this management system seems to have worked well, judged simply by the continuing productivity of the target stocks, for the bulk of the BSAI/GOA stocks in recent decades, most of which period has corresponded to a regime phase which began in 1976 and is thought to have ended only recently. The definite exceptions to this empirical record of success are the rockfish, which were overfished early on, and have not recovered (except that GOA Pacific ocean perch have rebuilt above the $B_{40\%}$ level). A further possible exception is the GOA pollock which has declined since 1985. The robustness of the management system to large regime changes is largely untested in practice, and has been explored in models only in a limited way. If the regime has in fact recently changed it is possible that some of the stocks are entering a period of lower productivity, which may itself cause some populations to decline. Overall, there has been only limited modeling analysis of the theoretical performance of the system as a whole, in realistic scenarios. Realistic scenarios should include realistic representation of the spatial distribution of stock abundances and the spatial distribution of fishing, with various possible underlying stock-recruitment relationships, and various kinds of uncertainty in the input information that becomes the basis for the stock assessments which in turn are the sources of the estimates that are used to assign stocks to Tiers and to generate the values for F_{OFL} and F_{ABC} according to the rules for that Tier.

1.1.4 Single Species Considerations

The $F_{35\%}$ and $F_{40\%}$ proxies for MSY used in the groundfish FMPs are defensible, for this purpose, in that these values are supported by a body of scientific literature as being reasonable F_{MSY} proxies for "typical groundfish" species. However, the Council should be aware that harvests taken at these levels may be too high for species that have very low productivity and changes for particular species, and to attribute causation convincingly, require a major undertaking. Furthermore, with the exception of species listed under the ESA, there are no general policy standards for whether effects of this kind, or of any particular magnitude, are acceptable consequences of management.

The $F_{40\%}$ approach to estimating the ABC, by itself, is inherently a single species approach. It is thought that for most of the target species in the FMP, a fishing mortality rate of $F_{35\%}$ would be appropriate for achieving long-term catches near MSY, under the condition of an unchanged oceanographic regime. The main exceptions among the target species are the rockfish, which apparently need a considerably lower fishing mortality rate to avoid overfishing. That the actual target fishing rate is $F_{40\%}$ rather that $F_{35\%}$ creates some additional margin of safety, from a single species perspective, for target species excluding rockfish. The decision to use $F_{40\%}$ rather than $F_{35\%}$ was deliberately protective, and was intended to function as a buffer against several sources of uncertainty, including the concern that theoretical models have shown that managing each species for its single species MSY will not achieve MSY for the aggregate. Nevertheless, it is not clear *how much* of the margin between $F_{35\%}$ and $F_{40\%}$ was "allocated" to ecosystem considerations. Nor was a calculation carried out to demonstrate what amount of escapement is needed for ecosystem purposes, or to assess whether the margin between fishing at $F_{35\%}$ and $F_{40\%}$ supplies this amount.

The TAC setting process has provisions for adjusting the allowed catch downward from the ABC, and in practice the TAC is adjusted downward. Such adjustments are made for considerations of by-catch, protected species, and general concern about the ecosystem. Again, except for the adjustments in response to the very specific requirements of ESA, it is not clear how the magnitude of this downward adjustment of the TAC from a $F_{40\%}$-based ABC is chosen, how much of it is attributed specifically to ecosystem considerations, and whether there are specific grounds for believing the magnitude is enough for those purposes.

It is easy enough to say that a management system could be made more protective of ecosystem properties by building additional margins of safety into a fishing mortality rate rule (such as shifting to $F_{50\%}$ or $F_{60\%}$ for example) or stipulating a more stringent threshold on the total allowed depression of equilibrium biomass (such as the limit adopted in the Commission for the Conservation of Antarctic Marine Living Resources Convention). But current knowledge does not allow precise scientific specification of what margin or threshold would be appropriate to achieve what level of protection of various ecosystem properties.

Modeling can offer up hypothetical scenarios to illustrate various possible outcomes, but multispecies ecosystem modeling has not yet developed to the point where it has documented predictive power in real applications. Nevertheless, this modeling is very interesting on several grounds, and continued investment in developing and testing such models is warranted.

At present, we essentially face a sliding scale of possible ecosystem protective measures, where the choices are largely policy choices. Current policy guidance is insufficiently specific, and the available science is insufficiently conclusive about the precise magnitudes of expected effects. Given the scientific uncertainty, there is merit in approaching ecosystem management in the

On the question of what value of $F_{\%SPR}$ should be used as an F_{MSY} proxy, Clark (1991) simulated a variety of life history types and concluded that $F_{35\%}$ was a reasonable proxy, unless recruitment presented strong serial correlation, in which case $F_{40\%}$ would be more appropriate (Clark 1993). However, a recent study by MacCall (2002) suggests that harvest policies that used $F_{35\%}$ to $F_{40\%}$ as targets may have been "too aggressive" for several groundfish stocks off the west coast of the U.S. Furthermore, Clark (2002) suggested that it may be necessary to have targets of $F_{50\%}$ to $F_{60\%}$ for stocks with low resilience in order to maintain a proper balance between average yields and average abundance. Here, "resilience" refers to a stock's capability to recover from overfishing. Long-lived stocks that are characterized by an old age at first maturity—such as many rockfish—have low resilience.

There is also the question of what F_{MSY} proxies should be used for other non-groundfish species in the groundfish FMPs such as squid or octopus. However, we are not aware of any studies that recommend alternatives for these species.

It is difficult to evaluate the appropriateness of a specific F_{MSY} proxy for a specific stock because such evaluation requires the analyst to make assumptions about key population parameters (e.g., the stock-recruitment relationship) that will determine the outcome of the evaluation. For the most part, the guidance that has been provided has been generic and based on simulating hypothetical life history types. Nevertheless, the current scientific reasoning can be summarized by the advice on default F_{MSY} proxies provided by Restrepo *et al.* (1998):

- $F_{30\%}$ for stocks with high resilience
- $F_{35\%}$ for stocks with "average" resilience
- $F_{40\%}$ for stocks with moderate to low resilience
- $F_{50\%}$ to $F_{60\%}$ for stocks with very low productivity (such as rockfish and most elasmobranches).

In cases where there is so little information about a stock's population parameters that it is not possible to estimate spawning potential ratios, the options for using proxies are very few. The natural mortality rate (M) or a fraction of M, have been advocated as proxies for F_{MSY}. Thompson (1993) suggested that F=0.8M could provide reasonable protection against overfishing, and Deriso (1987) showed that M was approximately equal to $F_{0.1}$, a reference point that is advocated as an F_{MSY} proxy when selectivity and maturity schedules coincide.

Collie and Gislason (2001) showed in a multispecies context that commonly used biological reference points, including F_{MSY}, $F_{0.1}$, $F_{40\%}$, B_{MSY}, and $B_{40\%}$, are much more sensitive to changes in natural mortality (i.e., predators) than to growth changes (i.e., prey). They recommend for a species that is primarily a prey item, that conservative BRPs must be conditioned on the level of predation. For a species that is primarily a predator, the usual reference points are amenable to conservation needs.

3.1.3 $F_{\%SPR}$ and other Proxies in the BSAI and GOA Fishery Management Plans

Six Tiers are used to determine the overfishing level (OFL) and the maximum Allowable Biological Catch (ABC) for North Pacific groundfish stocks (as explained in chapter 2). These Tiers are harvest control rules in which the OFL definitions set the absolute maximum harvest levels, while the maximum ABC definitions (maxABC) set maximum intended harvest levels. At least for Tier 1, the difference between the maxABC and OFL levels is a function of uncertainty. This within-tier link to uncertainty is not explicit in other Tiers, but the concept of a safety buffer between OFL and ABC remains. Since the Tiers themselves are arranged in order of uncertainty (higher numbered Tiers have less information available), there should ideally be an increased safety buffer between OFL and ABC in moving from one Tier to the next higher numbered one. Whether this between-tier link to uncertainty results in increased conservatism for higher numbered Tiers has not been analyzed.

Tiers 3 and 4 (in which the majority of the assessed stocks have been categorized--see Table 3.2) make use of $F_{35\%}$ and $F_{40\%}$ to determine upper limit and default target fishing mortality rates, respectively. A simplistic interpretation of this system is that $F_{35\%}$ is being used as the default proxy for F_{MSY}, while $F_{40\%}$ is used as an estimator of a target F that is safely below F_{MSY}.

For the most part, the $F_{35\%}$ level as a proxy for F_{MSY} is in line with the values suggested in the literature (see the previous section). However, it should be noted that direct comparisons with literature studies are difficult to make for Tier 3 because the OFL and ABC control rules are not constant-F strategies. In these control rules, fishing mortality decreases linearly with stock size if the biomass falls below a threshold equal to $B_{40\%}$ (the B_{MSY} proxy). In contrast, the simulation studies mentioned in the previous section evaluated harvest rates that were kept constant, even when the simulated populations reached a low size. While average long-term yields may be similar in simulations using both shapes of control rules, it is likely that the average biomasses will differ. All else being equal, the control rules in Tier 3 are more conservative than the strategies analyzed by Clark (1993) and others and labeled as $F_{35\%}$ or $F_{40\%}$. For a more complete evaluation of the performance of Tier 3, it is recommended that the simulation study of Clark (1993) be carried out applying the F_{OFL} and F_{ABC} harvest rates of Tier 3.

The tier system in the groundfish FMPs is a blanket system that covers all stocks in the two Plans without making allowances for the diversity in life-history types present. As suggested by Clark (2002), $F_{35\%}$ harvest rates may not be sufficiently conservative for stocks with very low productivity, such as rarely-recruiting and long-lived rockfish species. Lower rates, on the order of $F_{50\%}$ to $F_{60\%}$, may be more appropriate to balance yield and conservation objectives for such species. Another potential problem has to do with stock complexes. Because productivity of each species in the complex is likely to be different, a single $F_{\%SPR}$ proxy will not perform equally well for all stocks in the complex.

The OFL values that are set according to Tiers 5 and 6 seem reasonable as conservative estimates of F_{MSY} levels in data-poor situations. While it may be possible to set up simple simulation studies to evaluate the performance of Tier 5 and 6 proxies, it is better to improve the general knowledge about these stocks in order to facilitate their classification into more data-rich tiers.

have low predictive power, and the intensity of monitoring required to document such changes for particular species, and to attribute causation convincingly, require a major undertaking. Furthermore, with the exception of species listed under the ESA, there are no general policy standards for whether effects of this kind, or of any particular magnitude, are acceptable consequences of management.

4.4.1 Adjusting the $F_{40\%}$ Role for Ecosystem Needs

The $F_{40\%}$ approach to estimating the ABC, by itself, is inherently a single- species approach. It is thought that, for most of the target species in the FMP, a fishing mortality rate of $F_{35\%}$ would be appropriate for achieving near MSY, under conditions of unchanged oceanographic regime. The main exceptions among the target species are the rockfish, which apparently need a considerably lower fishing mortality rate to avoid overfishing. That the actual target fishing rate is $F_{40\%}$ rather that $F_{35\%}$ creates some additional margin of safety, from a single- species perspective, for target species excluding rockfish. The decision to use $F_{40\%}$ rather than $F_{35\%}$ was deliberately protective, and was intended to function as a buffer against several sources of uncertainty, including the concern that theoretical models have shown that managing each species for its single -species MSY will not achieve MSY for the aggregate. Nevertheless, it is not clear *how much* of the margin between $F_{35\%}$ and $F_{40\%}$ was "allocated" to ecosystem considerations. Nor was a calculation carried out to demonstrate what amount of escapement is needed for ecosystem purposes, or to assess whether the margin between fishing at $F_{35\%}$ and $F_{40\%}$ supplies this amount.

The TAC setting process has provisions for adjusting the allowed catch downward from the ABC, and in practice the TAC is adjusted downward. Such adjustments are made for considerations of by-catch, protected species, and general concern about the ecosystem. Again, except for the adjustments in response to the very specific requirements of ESA, it is not clear how the magnitude of this downward adjustment of the TAC from a $F_{40\%}$-based ABC is chosen, how much of it is attributed specifically to ecosystem considerations, and whether there are specific grounds for believing the magnitude is enough for those purposes.

4.4.2 Alternative Approaches to Accommodating Ecosystem Needs

It is easy enough to say that a management system could be made more protective of ecosystem properties by building additional margins of safety into a fishing mortality rate rule (such as shifting to $F_{50\%}$ or $F_{60\%}$ for example) or stipulating a more stringent threshold on the total allowed depression of equilibrium biomass (such as the CCAMLR limit). But current knowledge does not allow precise scientific specification of what margin or threshold would be appropriate to achieve what level of protection of various ecosystem properties.

Modeling can offer up hypothetical scenarios to illustrate various possible outcomes, but multispecies ecosystem modeling has not yet developed to the point where it has documented predictive power in real applications. Nevertheless, this modeling is very interesting on several grounds, and continued investment in developing and testing such models is warranted.

Comments on the 2002 Independent Scientific Review of the Harvest Strategy Currently Used in the BSAI and GOA Groundfish FMPs

Staff
Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle, WA 98115
September 30, 2003

Introduction

At its October 2001 meeting, the North Pacific Fishery Management Council passed a "final motion on Steller sea lions" (Council Newsletter, October 2001, Attachment 1). As part of this action, the Council moved "to seek an independent scientific review of the F40 harvest policy relative to national standards". At its February 2002 meeting, the Council broadened the purpose of the review as follows:

> "To critically review the current harvest strategies applied to our FMP fisheries with an emphasis on accounting for ecosystem needs."

Also at the February 2002 meeting, the Council approved the following list of charges to be addressed by the reviewers:

a) Define and explain the harvest strategy currently used in the management of the BSAI and GOA groundfish fisheries; i.e., develop an educational primer on the Council's current procedure.
b) Determine if the current quota setting approach (tier ABC determination, OFL derivation, and TAC specification) is consistent with the Magnuson-Stevens Act. Determine if $F_{40\%}$ is an appropriate MSY substitute for all species? If not, what are the alternative(s) and are data available to determine the value(s) of the substitute?
c) Is the approach considerate of ecosystem needs in the BSAI and GOA?
    i. If not, how should it be changed?
    ii. Are sufficient data available to allow implementation of the alternative approach?
    iii. How would the transition from the current approach to the proposed revised one be handled?

In addressing the above questions, the reviewers were asked to:

a) use whatever scientific information or methodology is appropriate and practicable within the time allotted for the review;
b) describe the role played by the $F_{40\%}$ reference point in their findings; and
c) relate their findings to the MSFCMA's National Standards, particularly NS 1.

Overview

Overall, the reviewers have done a very good job of addressing the charges presented to them by the Council. While there are a number of specific points to which some objection could be made, for the most part, AFSC agrees with the Panel's depiction of our current harvest system. The Council was extremely fortunate to obtain reviewers of the caliber represented on the review panel.

The review is divided into four main sections: Section 1 (15 pages) consists of the executive summary, introduction, terms of reference, and glossary. The other three sections correspond approximately to the reviewers' three charges. Section 2 (43 pages) contains a primer on fishery management as conducted in the BSAI and GOA groundfish fisheries. Section 3 (22 pages) discusses single-species issues. Section 4 (51 pages) discusses multispecies and ecosystem issues.

The report addresses the first two charges in the Sections 2 and 3. Section 2 not only contains the requested primer on the current harvest strategy (CHS), but a helpful introduction to the subject of fishery management in general. The discussion of single-species issues in Section 3 describes the use of both $F_{35\%}$ and $F_{40\%}$ in the current harvest strategy, discusses consistency with the MSFCMA, and contains recommendations for possible improvements.

The authors conclude that they are unable to define "ecosystem needs," let alone determine the extent to which the current approach is "considerate" of ecosystem needs. In the event that the reviewers determined that the current approach was not sufficiently considerate of ecosystem needs, they were asked to suggest changes to the current approach, including specification of needed data and a method for transitioning to the new approach. Although the reviewers were not able to determine whether the current approach was sufficiently considerate of ecosystem needs, they nevertheless produced a great deal of material on possible alternative approaches. It is not always clear which parts of the possible alternative approaches the reviewers are actually recommending and which parts they are simply mentioning in an effort to be thorough.

The spirit of the "primer" runs throughout the report. That is, much of the material is presented in the form of an introductory course. The major advantage of such a presentation is that it makes the material relatively simple to understand. However, one disadvantage is that, in an effort to make the material as simple as possible, the authors occasionally overstate things or otherwise make conclusions sound more general than they truly are. Readers should be cautioned that some of the material in the report is best viewed as an introduction to the subject, not as the final word on the subject.

Summary of Conclusions

The report does not identify a comprehensive list of major conclusions. However, the following list appears to be a fair summary of the major conclusions given at various locations in the report.

1) The current harvest strategy (CHS) is consistent with many/most aspects of the MSFCMA but inconsistent in some aspects.
   (Sections 1.1.4, 1.1.5. 3.5, 3.5.1, 3.7, and 4.4)
2) The CHS performs adequately with respect to most target stocks.
   (Sections 1.1.4, 3.1.3, 3.2, 3.6.1, 3.7, and 3.9)
3) The CHS does not perform adequately with respect to rockfish.
   (Sections 1.1.3, 1.1.4, 1.1.5, 3.1.3, 3.2, 3.12, and 4.4.1)
4) A management strategy evaluation is necessary to provide additional assurance that the current NPFMC ABC harvest stategy is a robust one and is likely to meet the objectives of MSFCMA and of NPFMC itself.
   (1.1.4, 3.10.5, 3.11.1, 3.11.2, 3.12, 4.3.3)
5) The performance of the CHS with respect to the ecosystem is unclear.
   (Sections 1.1.3, 1.1.5, 4.1.1, 4.4, 4.4.1, and 4.4.2)

Our response will evaluate each of these conclusions.

Summary of Recommendations

The report does not identify a comprehensive list of major recommendations. However, the following list appears to be a fair summary of the major recommendations given at various locations in the report.

1) The harvest control rules should be improved.
   1.1.3, 1.4, 3.1.3, 3.2
2) The OY specifications should be improved.
   1.1.4, 3.6, 3.7
3) A management strategy evaluation should be conducted.
   1.1.4, 3.10.5, 3.11.1, 3.11.2, 3.12, 4.3.3
4) Adaptive management should be tried.
   1.1.5, 4.4.2, 4.3.1, 4.3.3
5) Ecosystem modeling should be done the right way.
   1.1.5, 4.3.2, 4.4.2
6) Monitoring efforts should be continued and expanded.
   1.1.5, 3.12, 4.3.6, 4.4.2
7) Marine reserves should be investigated.
   1.1.5, 4.3.5, 4.4.2

The agency agrees with these recommendations and staff are pursuing research that focuses on these issues. The recently completed draft Programmatic Supplemental Environmental Impact Statement (PSEIS) and the Essential Fish Habitat Environmental Impact Statement (EFHEIS) represent a comprehensive evaluation of the impact of status quo and alternative harvest practices that supplement on-going research in support of fisheries and ecosystem assessment The PSEIS and EFHEIS provide the foundation for proposals for improved harvest policy which are likely to include many of the panel recommendations .

Evaluation of Conclusions

Conclusion 1) The current harvest strategy (CHS) is consistent with many/most aspects of the MSFCMA but inconsistent in some aspects.

Background

From the perspective of this exercise, the most important part of the MSFCMA is National Standard 1, which states, "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry." The MSFCMA defines overfishing to mean "a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis." The MSFCMA defines optimum yield (OY) as the amount of fish which:

- "will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems";
- "is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor"; and
- "in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in such fishery."

Note that the definitions of both overfishing and optimum yield refer to maximum sustainable yield (MSY). The MSFCMA does not define MSY, but the National Standard Guidelines (NSGs) define it as "the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions." The NSGs also introduce the concept of the "MSY control rule," defined as "a harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY." The MSY control rule can take a wide variety of forms. The NSGs offer the following advice regarding MSY control rules:

> "In choosing an MSY control rule, Councils should be guided by the characteristics of the fishery, the FMP's objectives, and the best scientific information available. The simplest MSY control rule is to remove a constant catch in each year that the estimated stock size exceeds an appropriate lower bound, where this catch is chosen so as to maximize the resulting long-term average yield. Other examples include the following: Remove a constant fraction of the biomass in each year, where this fraction is chosen so as to maximize the resulting long-term average yield; allow a constant level of escapement in each year, where this level is chosen so as to maximize the resulting long-term average yield; vary the fishing mortality rate as a continuous function of stock size, where the parameters of this function are constant and chosen so as to maximize the resulting long-term average yield. In any MSY control rule, a given stock size is associated with a given level of fishing mortality and a given level of potential harvest, where the long-term average of these potential harvests provides an estimate of MSY."

Under the NSGs, the MSY control rule plays a key role in making the MSFCMA's definitions of overfishing and OY operational. In the case of overfishing, the MSY control rule serves as an upper limit on permissible specifications of the "maximum fishing mortality threshold" (MFMT). The MFMT specifies the fishing mortality rate (F) above which overfishing is defined to be occurring (i.e., if F>MFMT, overfishing is occurring). The MFMT, in turn, plays a role in defining the "minimum stock size threshold" (MSST). The MSST specifies the biomass (B) below which the stock is defined to be overfished (i.e., if B<MSST, the stock is overfished). Specifically, the MSST is defined as whichever of the following is greater: one-half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock or stock complex were exploited at the MFMT. Taken together, the MFMT and MSST constitute the set of "status determination criteria" which the NSGs require each FMP to specify whenever possible.

In the case of OY, the MSY control rule is key to interpreting the MSFCMA's requirement that OY must be prescribed "on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor." According to the NSGs, this requirement means, in part, that the OY in any given year "must always be less than or equal to the harvest level that would be obtained under the MSY control rule." Therefore, if the MSY control rule were of the "constant catch" form, then a constant OY might be permissible, but if the MSY control rule were to associate different levels of catch with different stock sizes, then a constant OY would not be permissible (unless, perhaps, OY was set *very* conservatively).

As noted earlier, the MSFCMA states that OY is to be prescribed "on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor." According to the NSGs, this requirement means, in part, that the OY in any given year "must always be less than or equal to the harvest level that would be obtained under the MSY control rule." Thus, in order to determine whether the OY specification complies with the MSFCMA, it is necessary to know the form of the MSY control rule. This is problematic in the case of the BSAI and GOA Groundfish FMPs, because the Council declined to specify an MSY control rule in Amendment 56. Based on the methods used to specify the current OY range and the fact that it does not vary with biomass, it could be inferred that the Council's implicit MSY control rule is of the "constant catch" form. However, this interpretation would mean that the OFL control rules in at least some of the tiers violate the NSGs' requirement that the MFMT not exceed the MSY control rule (in Tiers 1-2, for example, OFL exceeds MSY whenever biomass exceeds B_{MSY}). On the other hand, if it is assumed that the OFL control rules correspond to the Council's implicit MSY control rule, then the adequacy of the current OY specification is called into question, because the entire OY range will exceed the harvest associated with the MSY control rule if biomass is low enough.

<u>Evaluation of Specific Statements</u>

1A) "*In terms of Optimum Yield, there is uncertainty about the conformity of the FMP definitions with the MSFCMA.*" (Sections 1.1.4 and 3.7)

We agree with Conclusion 1A . We recommend that the Council should revisit the OY specifications. To some extent, this recommendation is already being considered in the context of the PSEIS. Depending on the preferred alternative that emerges from the PSEIS, a more thorough evaluation of the OY specifications could be conducted.

1B) "*The MSY based approach in the setting of F_{ABC} in the current NPFMC system for groundfish management ... is consistent with the explicit OY goals of the MSFCMA....*" (Sections 1.1.5 and 4.4)

It is not clear how to reconcile Conclusion 1B with Conclusion 1A. Perhaps Conclusion 1B is simply meant to imply that the current procedure for setting ABC does not prevent OY from being achieved. This is accurate, given the fact that the FMPs do not prescribe any particular relationship between catch and ABC (i.e., the FMPs allow catch to be higher than, lower than, or equal to ABC).

1C) "*The MFMT definitions ... in the Tier system are consistent with the NSGs.*" (Section 3.5)

We agree with conclusion 1C.

1D) "*While the FMPs specify only one of the two status determination criteria that are required by NMFS' National Standard Guidelines, the FMPs are sufficiently conservative, with respect to the target stocks evaluated from a single-species perspective, and incorporate automatic rebuilding plans to such a degree ... that this lack of conformity with the Guidelines should not pose a conservation danger from a single species viewpoint....*" (Sections 1.14 and 3.7)

We agree with conclusion 1D.

1E) "*The Tier system used by the groundfish FMPs has no explicit definition of Minimum Stock Size Threshold (MSST) and, therefore, one would conclude that the Plans are inconsistent with this aspect of the NSGs. But this conclusion has to be examined in a larger context in order to understand its relevance. The reasons for not including an explicit definition of MSST in the FMP were explained in a May 10, 2000, memorandum from the Council to NMFS. In it, the Council argues that the NSGs' requirement for an MSST definition is more of a suggestion from NMFS than a requirement of the law (MSFCMA). The memorandum also highlights some of the scientific and logistical difficulties that the Council has in defining an MSST.... All of the issues raised by the Council are important and largely valid from a single-species perspective....*" (Section 3.5.1)

Consideration of the impact of explicitly defining MSSTs in the FMP is being considered in the context of the PSEIS. Depending on the preferred alternative that emerges from the PSEIS, a more thorough evaluation of the need for explicit definitions of MSSTs could be conducted.

2) The CHS performs adequately with respect to most target stocks.

Evaluation of Specific Statements

2A) *"In a single-species/target-stock context, the TAC-setting process employed by the Council is a very conservative one ... and the in-season monitoring and management system seems adequate for implementing the TACs with little risk of exceeding them."* (Sections 1.1.4 and 3.7)

We agree with Conclusion 2A.

2B) *"Overall, target catches, as measured by TACs, are set very conservatively, from a single-species/target-stock standpoint, and they are implemented conservatively from this same standpoint."* (Section 3.6.1)

We agree with Conclusion 2B.

2C) *"Although there have been changes in the detail of NPFMC harvest strategies over time (Section 2.12 of this report, and Witherell et al. 2000), it can be argued that the basic approach has delivered good outcomes with no groundfish stocks currently classified as overfished according to NMFS' Guidelines."* (Section 3.9)

We agree with Conclusion 2C.

2D) *"The $F_{35\%}$ and $F_{40\%}$ proxies for MSY used in the groundfish FMPs are defensible, for this purpose, in that these values are supported by a body of scientific literature as being reasonable F_{MSY} proxies for "typical groundfish" species."* (Section 3.2)

Considerable confusion continues to exist as to the use of F_{MSY} proxies in the current harvest strategy. According to the EA/RIR for Amendments 56/56, $F_{35\%}$ is used as a proxy for FMSY, but $F_{40\%}$ is not. However, Conclusion 2D is correct in the sense that either $F_{35\%}$ or $F_{40\%}$ *could* be defended as an appropriate F_{MSY} proxy for "typical" groundfish stocks.

2E) *"The OFL values that are set according to Tiers 5 and 6 seem reasonable as conservative estimates of F_{MSY} levels in data-poor situations. While it may be possible to set up simple simulation studies to evaluate the performance of Tier 5 and 6 proxies, it is better to improve the general knowledge about these stocks in order to facilitate their classification into more data-rich tiers."* (Section 3.1.3)

While the OFL values defined by Tiers 5 and 6 could be viewed as reasonably conservative proxies for MSY, the FMPs do not define them as such. Whether resources should be expended in an effort to promote all stocks into Tiers 1-3 is an open question which is currently being investigated by a Council working group.

Comment 3) The CHS does not perform adequately with respect to rockfish.

Background

Currently, all BSAI and GOA rockfish are managed under Tiers 3-5. Eight rockfish stocks or stock complexes are currently managed under Tiers 3-4:

1) BSAI Pacific ocean perch (Tier 3b)
2) GOA POP (Tier 3a)
3) GOA northern rockfish (Tier 3a)
4) GOA thornyheads (Tier 3a)
5) GOA rougheye rockfish (Tier 4)
6) GOA sharpchin rockfish (Tier 4)
7) GOA dusky rockfish (Tier 4)
8) GOA demersal shelf rockfish (Tier 4)

Seven rockfish stocks or stock complexes are currently managed under Tier 5:

1) BSAI northern rockfish
2) BSAI shortraker and rougheye rockfish
3) BS "other" rockfish
4) AI "other" rockfish
5) GOA shortraker rockfish
6) GOA "other slope" rockfish excluding sharpchin rockfish
7) GOA pelagic shelf rockfish excluding dusky rockfish

Spawning per recruit (SPR) is a key quantity in the current harvest strategy. It is usually expressed in relative terms. Specifically, relative SPR is the ratio between lifetime egg production of two hypothetical cohorts, one of which is fished and one of which is not. The cohort that is fished produces fewer eggs over the course of its lifetime than the cohort that is not, because the process of fishing removes some fish from the cohort and these removed fish are no longer able to contribute to egg production. Thus, relative SPR is a number that ranges between 0 (obtained in the case of extremely intense fishing) and 1 (obtained in the case of no fishing), and is often displayed as a percentage. For example, $F_{35\%}$ is the fishing mortality rate that reduces the lifetime egg production of a cohort to 35% of what it would be in the absence of fishing, $F_{40\%}$ is the fishing mortality rate that reduces the lifetime egg production of a cohort to 40% of what it would be in the absence of fishing, and so forth. For a given stock, $F_{35\%}$ will always be higher than $F_{40\%}$, because more fishing is required to reduce lifetime egg production to 35% of the unfished level than is required to reduce lifetime egg production to 40% of the unfished level.

Evaluation of Specific Statements

The following statements within the report provide the foundation for conclusion 3. These statements raise issues that are interrelated, thus, we developed a single comprehensive response to the statements.

3A) *"This surrogate [$F_{35\%}$] is now believed to be inappropriate for less productive stocks, such as sharks and **rockfish**, and it is now thought that considerably lower harvest rates (considerably lower than $F_{40\%}$ as well) should be applied for those stocks."* (Section 1.1.3)

3B) *"It is thought that for most of the target species in the FMP, a fishing mortality rate of $F_{35\%}$ would be appropriate for achieving ... MSY.... The main exceptions among the target species are the* ***rockfish****, which apparently need a considerably lower fishing mortality rate to avoid overfishing. That the actual target fishing rate is $F_{40\%}$ rather that $F_{35\%}$ creates some additional margin of safety, from a single-species perspective, for target species excluding* ***rockfish****."* (Sections 1.1.5 and 4.4.1)

3C) *"A recent study by MacCall (2002) suggests that harvest policies that used $F_{35\%}$ to $F_{40\%}$ as targets may have been "too aggressive" for several groundfish stocks off the west coast of the U.S. Furthermore, Clark (2002) suggested that it may be necessary to have targets of $F_{50\%}$ to $F_{60\%}$ for stocks with low resilience in order to maintain a proper balance between average yields and average abundance. Here, "resilience" refers to a stock's capability to recover from overfishing. Long-lived stocks that are characterized by an old age at first maturity-such as many* ***rockfish****-have low resilience."* (Section 3.1.2)

3D) *'In practice, this management system seems to have worked well.... The definite exceptions to this empirical record of success are the* ***rockfish****, which were overfished early on, and have not recovered (except that GOA Pacific ocean perch have rebuilt above the $B_{40\%}$ level)."* (Section 1.1.3)

3E) *"The tier system in the groundfish FMPs is a blanket system that covers all stocks in the two Plans without making allowances for the diversity in life-history types present. As suggested by Clark (2002), $F_{35\%}$ harvest rates may not be sufficiently conservative for stocks with very low productivity, such as rarely-recruiting and long-lived* ***rockfish*** *species."* (Section 3.1.3)

The development of the current harvest strategy for Alaska groundfish was motivated by the need to develop harvest strategies that provided yields approximating MSY in cases where MSY could not be calculated with sufficient reliability. The concept of $F_{xx\%}$ strategies was evaluated by Clark (1991), which refers to fishing at a rate that reduces the potential spawning biomass per recruit to *xx%* of the value for an unfished stock. Because such a policy is intended to be used in lieu of estimation of a stock-recruitment curve and MSY, it would be best if such a policy were robust to a wide variety of stock-recruitment relationships. In deterministic calculations, Clark (1991) found that a fishing rate of $F_{35\%}$ closely approximated F_{MSY} for a wide variety of stock-recruitment curves. When stochastic variability is considered, $F_{40\%}$ is preferable because it reduces the likelihood of low spawning biomass (especially when faced with autocorrelated recruitment) (Clark 1993).

Goodman et al. (2002) suggest that $F_{35\%}$ is too high to serve as an appropriate F_{MSY} proxy for BSAI and GOA rockfish, citing research by MacCall (2002) and Clark (2002) indicating that $F_{35\%}$ and $F_{40\%}$ rates were too aggressive for several species of West Coast rockfish. The relationship between sustainable yield and relative spawning per recruit has not been directly investigated for most BSAI and GOA rockfish stocks because age-structured stock assessments cannot be conducted for most of these stocks.

The relationship between sustainable yield and relative spawning per recruit has been investigated for one or more of the Alaskan Pacific Ocean Perch (POP) stocks (Ianelli and Heifetz,1995; Ianelli and Heifetz, unpublished; and Dorn, 2002). Neither of the studies by Ianelli and Heifetz attempted to estimate F_{MSY} per se. Rather, the aim was to estimate an "optimal" harvest rate, which the authors, following Clark (1991), defined as the harvest rate "which maximizes the minimum yield over a range of plausible stock-recruitment relationships." The first study by Ianelli and Heifetz focused on GOA POP and concluded that $F_{44\%}$ was the optimal harvest rate for that stock. The second study by Ianelli and Heifetz repeated the analysis conducted in the first study using updated data and estimated an optimal harvest rate that was well in excess of $F_{40\%}$ i.e. $F_{40\%}$ was estimated to be too conservative Heifetz et al. (1996) pointed out that the concept of an optimum implies some stationarity of the stock recruitment relationship where historical data is used to provide a reliable basis for determining future stock productivity. The estimate of optimum F appeared to be very sensitive to each update of data which can be interpreted as "unreliability" of the estimate. Based on these considerations Heifetz et al recommended that $F_{40\%}$ be used to compute ABC for POP

The only research that simultaneously evaluates harvest rates for Alaska rockfish stocks and West Coast rockfish stocks is that of Dorn (2002). The three Alaskan stocks included in this study were BS, AI, and GOA POP (at the time of the study, the BSAI POP stock was assessed separately in the BS and AI). Dorn concluded that F_{MSY} for the AI and GOA POP stocks probably exceeded $F_{30\%}$, whereas F_{MSY} for the BS POP stock was probably in the $F_{40\%}$-$F_{50\%}$ range. (For the West Coast rockfish stocks, Dorn's study confirms other studies which show that these stocks appear to be less resilient than typical groundfish stocks.) Thus, the most recent studies indicate that $F_{35\%}$ is a safe estimate of F_{MSY} for GOA POP and, given the fact that the bulk of the BSAI POP stock appears to reside in the AI, $F_{35\%}$ is probably a safe estimate of F_{MSY} for the BSAI POP stock as well.

None of the other six rockfish stocks and stock complexes managed under Tiers 3-4 has been subjected to an analysis of this type, and the available data are insufficient to subject any of the seven rockfish stocks and stock complexes managed under Tier 5 to an analysis of this type. Also worth remembering is the fact that F=based ABCs for stocks in Tier 5 are the product of our estimates of biomass and these biomass estimates have a great deal of uncertainty.

Apart from the question of the appropriateness of the $F_{35\%}$ rate for Alaska rockfish, Goodman et al. (2002) also suggest that general $F_{xx\%}$ policies are inappropriate because they do not account for a variety of life-history types. However, it must be recalled that the computation of $F_{40\%}$ explicitly involves several life-history parameters, including growth rates, maturity ogives, and natural mortality rates. Thus, the absolute fishing mortality rate at $F_{40\%}$ will differ between species with differing life-histories. This point is clearly illustrated by Clark (2002), who reproduced the analysis of Clark (1991) but with the instantaneous natural mortality rate (M) set at 0.05, and the age at 50% recruitment and maturity set at 10 years; the original values in Clark (1991) were $M = 0.2$ and age at 50% recruitment and maturity set at 5 years. For stocks with similar stock-recruitment relationships but differing in these life-history parameters, the relationships of yield and biomass to each other and to spawning biomass per recruit show nearly identical patterns, with differences only in the absolute value of instantaneous fishing rate.

Clark (2002) also evaluated $F_{xx\%}$ policies for stocks with differing stock-recruitment relationships (but otherwise similar life-history parameters), and demonstrated that $F_{40\%}$ may be too aggressive for stocks with low resilience. However, this analysis does not necessarily imply that stocks with older ages of maturity and increased longevity have lower resilience, as will be discussed in detail in the paragraphs below. Clark's (2002) analysis implicitly assumed that each stock had identical $F_{xx\%}$ rates, thus allowing the focus on the shape of the stock-recruitment curve. However, when comparing two or more actual stocks with respect to their ability to withstand $F_{40\%}$ fishing rates, it is likely that both the absolute value of fishing mortality associated with $F_{40\%}$ and the estimated stock-recruitment curve differ, thus complicating the analysis.

Resilience can be defined in many ways. Because Goodman et al. (2002) seem to suggest that fishing at $F_{40\%}$ may be dangerous for stocks with low resilience, it is most convenient to define resilience in a way that pertains to SPR and that permits identification of a "danger" level. For example, it is possible to define resilience in terms of the relative SPR that results in extinction. Consider two hypothetical stocks A and B. For stock A, reducing the lifetime egg production of a cohort to 10% of the unfished level causes the stock to be unable to sustain itself, meaning that continual fishing at a rate of $F_{10\%}$ would cause the stock to go extinct. For stock B, reducing the lifetime egg production of a cohort to 15% of the unfished level causes the stock to be unable to sustain itself, meaning that continual fishing at a rate of $F_{15\%}$ would cause the stock to go extinct. Resilience can be computed by subtracting the relative SPR corresponding to extinction from 100%. Thus, the resilience of stock A is 100%-10%=90% and the resilience of stock B is 100%-15%=85%. Stock A is more resilient than stock B because stock A can sustain itself at a lower relative SPR than stock B.

Goodman et al. (2002) imply that rockfish stocks are inherently less resilient than other groundfish stocks. Some simple examples will show that this is not the case. Consider four hypothetical stocks called Flatfish1, Flatfish2, Rockfish1, and Rockfish2. Rockfish1 and Rockfish2 have a lower natural mortality rate, higher age at first recruitment, and lower stock-recruitment slope than Flatfish1 and Flatfish2. More specifically, the four hypothetical stocks have the following characteristics:

Stock:	Flatfish1, Flatfish2	Rockfish1, Rockfish2
Natural mortality rate:	0.20	0.05
Age at first recruitment:	3	12
Stock-recruitment slope:	0.80	0.20

In terms of the above parameters, Flatfish1 and Flatfish2 are indistinguishable from one another, as are Rockfish1 and Rockfish2. Furthermore, *except* for the above parameters, Flatfish1 and Rockfish1 are indistinguishable from one another, as are Flatfish2 and Rockfish2. The sustainable yield of each stock is maximized by fishing at a rate equal to natural mortality. Figure 1 compares some of the life history characteristics of Flatfish1 and Rockfish1, and Figure 2 compares some of the life history characteristics of Flatfish2 and Rockfish2. In these figures, blue lines or curves correspond to the flatfish stocks and red lines or curves correspond to the rockfish stocks. The curves in each figure represent stock-recruitment relationships. The solid lines in each figure show the slope of the respective stock-recruitment relationship at the origin.

The dashed lines in each figure show how much spawning biomass would be generated by any given level of recruitment in the absence of fishing (these are sometimes called "replacement lines," because the stock can replace (i.e., sustain) itself at a given level of spawning biomass only if the stock-recruitment relationship is above the line).

The relative SPR corresponding to extinction can be computed for any of the four stocks by dividing the slope of the dashed line by the slope of the solid line and expressing this ratio as a percentage. Resilience is then computed by subtracting this value from 100%. According to Goodman et al. (2002), both of the flatfish stocks should be more resilient than either of the rockfish stocks. However, the resiliences of the four stocks are as follow:

Stock	Resilience	Relative SPR @ extinction
Flatfish1	89%	11%
Rockfish1	90%	10%
Rockfish2	91%	9%
Flatfish2	93%	7%

Three features in the above table are worthy of note: First, the resiliences of the four stocks are quite similar (the coefficient of variation for the resiliences in the above table is less than 2%). Even though the life history characteristics of the four stocks are very different, the four stocks have approximately the same resilience when measured in terms of relative SPR, which helps to illustrate the usefulness of the SPR approach. Second, fishing at a rate of $F_{40\%}$ would not be at all dangerous for any of the stocks, including the two rockfish stocks, because the numbers in the right-hand column are all much less than 40% (in fact, the relative SPR corresponding to MSY for each of the four stocks is less than 40%, with values ranging from 32% to 36%, meaning that $F_{40\%}$ would be an underestimate of F_{MSY} for all four stocks). Third, there is no consistent relationship between resilience and life history type. For example, Flatfish2 has greater resilience than either of the two rockfish stocks (as suggested by Goodman et al.), but Flatfish1 has *lower* resilience than either of the two rockfish stocks (opposite to the relationship suggested by Goodman et al.)

Finally, Goodman et al. (2002) state that Alaska rockfish have been overfished and have failed to recover from overfishing. Note that a definition of overfishing can only be made for a stock classified in tiers 1-3 of Amendment 56 to the Alaska groundfish FMPs, which include GOA POP, GOA thornyheads, GOA northern rockfish, and BSAI POP. All of these stocks are above the $B_{35\%}$ proxy for B_{MSY}, and would thus not be classified as overfished. Although GOA and BSAI POP were below $B_{35\%}$ until the late 1990s and mid-1990s, respectively, relatively rapid growth beginning in the late 1980s have allowed these stocks to increase to their current levels. This pattern of recovery is considerably different than that observed in west coast rockfish, resulting from the strong estimated recruitment at low stock sizes that led Dorn (2002) to conclude that Alaskan POP stocks have exhibited greater resilience than west coast rockfish

It is important to note that the control rules under the current harvest policy specify only a *maximum* ABC level, and that the recommended ABC may be lowered when extra caution is warranted. In fact, this is a common process in Alaska groundfish stock assessments, and in recent years several stocks (e.g., sablefish, BSAI Atka mackerel, and some rockfish) have implemented ABCs lower than the maximum allowable ABC due to uncertainty or conservation concerns. The statement of Goodman et al. (2002) that "*the Council should be aware that harvests taken at these levels [i.e., $F_{35\%}$ and $F_{40\%}$] may be too high for species that have very low productivity and that are characterized by highly episodic recruitment*" is thus technically correct, and is the reason why the harvest control rules define an upper bound to ABC rather than ABC itself. It is important to note that, of the eight BSAI and GOA rockfish stocks or stock complexes currently managed under Tiers 3-4, only two (GOA POP and GOA northern rockfish) currently set F_{ABC} equal to $F_{40\%}$. For the other six rockfish stocks or stock complexes, F_{ABC} is lower than $F_{40\%}$.

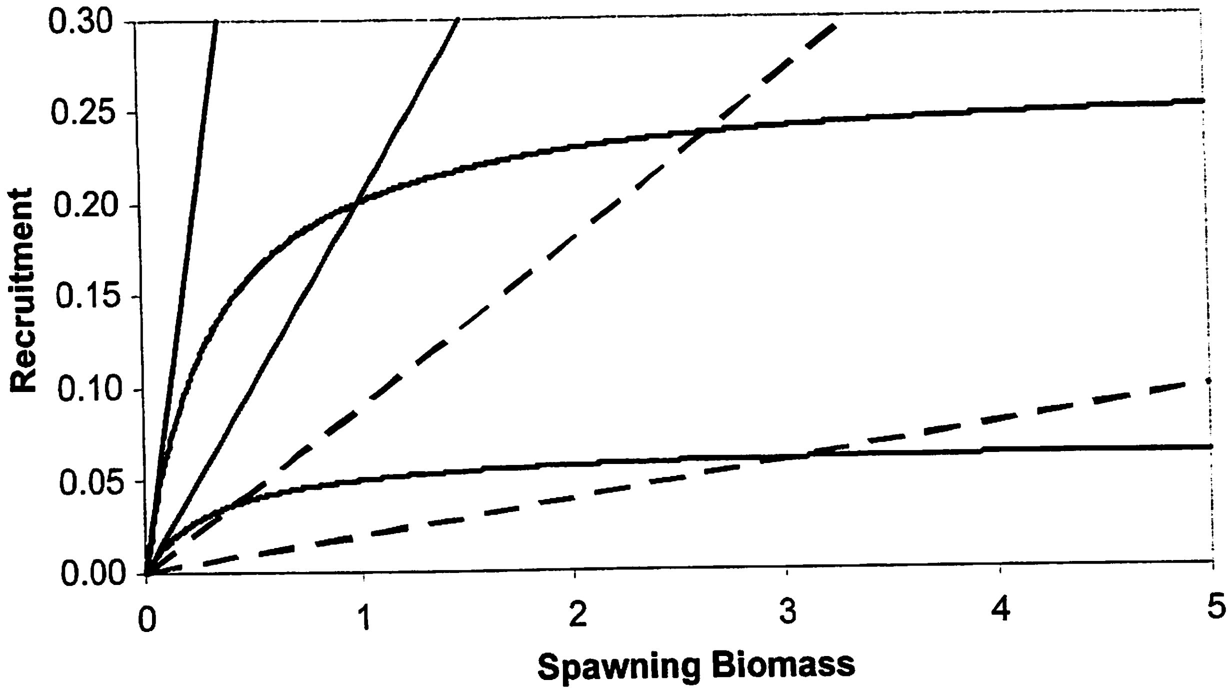

Figure 1. Features used to compute resilience of Flatfish1 (blue) and Rockfish1 (red). Curves represent stock-recruitment relationships. Solid lines show the slope of the stock-recruitment relationship at the origin. Dashed lines show how much spawning biomass would be generated by any given level of recruitment in the absence of fishing.

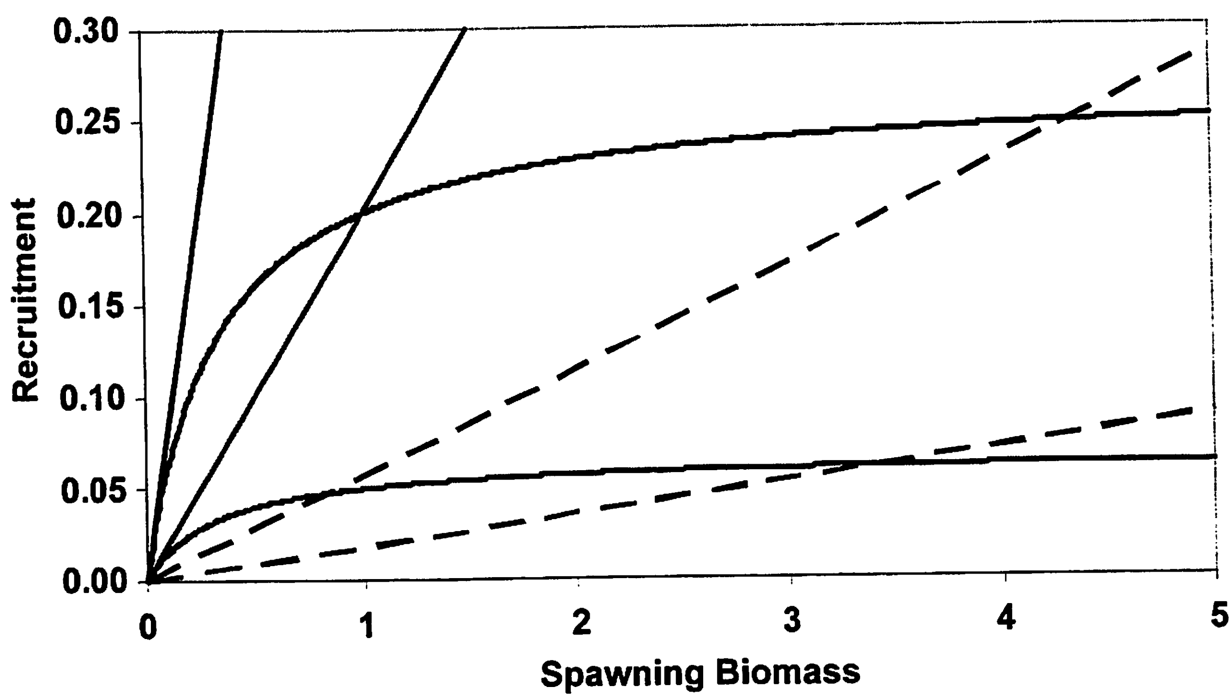

Figure 2. Features used to compute resilience of Flatfish2 (blue) and Rockfish2 (red). Curves represent stock-recruitment relationships. Solid lines show the slope of the stock-recruitment relationship at the origin. Dashed lines show how much spawning biomass would be generated by any given level of recruitment in the absence of fishing.

Conclusion 4) A management strategy evaluation is necessary to provide additional assurance that the current NPFMC ABC harvest stategy is a robust one and is likely to meet the objectives of MSFCMA and of NPFMC itself.

The Panel's Recommendation

Goodman et al. (2002, pages 5 and 74) state:

> "*We recommend that a management strategy evaluation ... be undertaken to provide additional assurance that the current NPFMC ABC harvest strategy is a robust one and is likely to continue to meet the objectives of MSFCMA and of NPFMC itself.... We recognize that an MSE analysis can be potentially a time consuming and technically difficult undertaking. Sufficient resources in time and people would need to be allocated to undertake the work. The skills and expertise to undertake the work already reside within AFSC.*"

What is a Management Strategy Evaluation?

Goodman et al. define a management strategy evaluation (MSE) as follows (p. 70) as follows:

> "*In its most general use, management strategy evaluation (MSE) involves assessing the performance of a range of (possibly adaptive) management strategies, and evaluating the tradeoffs across a range of management objectives (Smith et al. 1999). The approach involves explicitly testing the robustness of each strategy to a range of uncertainties (such as those listed in chapter 2 of this report).... This approach captures (albeit in a simulation) all aspects of the application of a harvest strategy (monitoring, assessment, control rule and implementation), and differs from the types of projections that are often undertaken in a stock assessment, which assume some fixed sequence of catches or fishing mortality rates into the future, but which do not capture the feedback nature of the decision making process.*"

Because it is explicitly concerned with uncertainties, MSE is closely related to risk analysis. In fact, Goodman et al. (p. 20) view MSE as a preferred method of conducting risk analysis:

> "*This sort of analysis [MSE], which is aimed at systematically revealing how different management approaches compare in meeting sets of objectives (but which does not necessarily forecast an expected outcome for any particular approach), in principle allows a better integration of risk assessment and risk management with clear roles for scientists and managers*" (term in square brackets added).

What is Risk Analysis?

Goodman et al. are somewhat unclear as to what they mean by risk analysis. Generally, there are two approaches to risk analysis. One approach is to measure the costs and benefits of the various possible outcomes, weight those costs and benefits by their respective probability of occurrence under each alternative harvest strategy, compare the expected net benefit ("utility") across alternative harvest strategies, then choose the harvest strategy with the highest expected net benefit. This is the approach, for example, was used to determine the upper limit on ABC in

Tier 1 of the current harvest strategy. Sometimes, Goodman et al. appear to endorse this approach. For example, on page 19 the authors state:

> *"The best that science can do is to use models to calculate the expected amount of utility ... that will result from a proposed management plan. If there is an agreed upon utility measure that can apply to all the various objectives, the science can also optimize the management plan by seeking plans that maximize utility, within the stated constraints."*

Similarly, on page 107 the authors state:

> *"The most sophisticated and rigorous approach to dealing with uncertainty is the fully quantitative statistical decision theory (Berger 1985), which takes account of costs of errors of omission and errors of commission, and is very formal about the quantification of uncertainty."*

The other approach to risk analysis is much less sophisticated and does not result in optimal decisions. This approach works as follows: First, the range of possible outcomes is divided into "good" and "bad" subsets. All "good" outcomes are treated as though they are equally good and all "bad" outcomes are treated as though they are equally bad. Second, a critical probability value (say, 5%) is chosen. Third, the probability of a "bad" outcome is computed for each alternative harvest strategy. Fourth, the harvest strategies which generate a "bad" outcome with probability greater than the critical value are eliminated. Finally, of the remaining harvest strategies, the one which produces the highest average yield (or some other performance measure) is chosen. Sometimes, Goodman et al. appear to advocate this approach. For example, in their discussion of the Tier 1 harvest control rules on pages 2-3 the authors state:

> *"The harmonic mean has the mathematical property that it is less than the simple average (roughly, the point estimate) by an amount that increases with the spread of the distribution, so this establishes a margin that increases with the uncertainty in the estimate. However, this mechanism for adjusting the F_{ABC} downward from the F_{OFL} does not have the statistical property of ensuring a constant specified confidence that the F_{ABC} does not exceed the true F_{MSY}, as would be ensured by using a lower confidence limit of the estimate of F_{MSY} for the F_{ABC}."*

One way to characterize the difference between the two approaches is that the first approach (i.e., the approach currently used in Tier 1) attempts to achieve an optimal result determined by the costs, benefits, and probabilities of the various possible outcomes, while the second approach (second sentence in the above quote) attempts to achieve an apparently arbitrary probability of avoiding F_{MSY} without regard to the costs or benefits of doing so. In the Center's view, moving from the current approach to the one described in the second sentence of the above quote would be a step backward.

Types of Management Strategy Evaluations Already Undertaken

Goodman et al. make several specific recommendations regarding MSE and risk analysis. Many of them have already been implemented. These are itemized below.

"There is obviously a wide range of alternative harvest strategies that might be considered, and MSE methods are a useful way to design and evaluate alternatives. If this "comparative" approach is used, a wider set of performance measures, including utilization as well as conservation objectives, should be evaluated and the tradeoffs across objectives highlighted. We suggest that wider stakeholder discussion ... on alternative approaches be held before embarking on a major exercise to evaluate alternatives" (p. 5 and 75). The new draft PSEIS analyzes a wide range of alternative harvest strategies, using MSE as the main analytical tool. Utilization as well as conservation objectives are evaluated and the tradeoffs across objectives are highlighted. The alternative approaches were developed through an exhaustive process of which broad stakeholder discussion was a central feature.

"Apart from exploring and evaluating generic harvest strategies, several of the target species in the BSAI/GOA groundfish fishery are of sufficient value (and importance) to warrant the effort to formally evaluate species-specific harvest strategies (e.g., for pollock)" (p. 5 and 76). The new draft PSEIS analyzes species-specific harvest strategies for several individual species such as walleye pollock, Pacific cod, and Atka mackerel.

"We recommend that additional work be undertaken to more formally test the robustness of the current NPFMC harvest strategy to various uncertainties, and to explore alternative harvest strategies that may be more appropriate for some groups of species or individual species" (p. 6 and 76). The new draft PSEIS tests the robustness of the current harvest strategy and several alternatives to various uncertainties, including uncertainty due to random natural variability in future recruitment and uncertainty in future annual estimates of abundance and age structure. In addition to the species-specific harvest strategies noted above, the new draft PSEIS also explores alternative harvest strategies that may be more appropriate for groups of species such as rockfish.

"Alternatives to F40%: Section 3.1 noted that $F_{40\%}$ may be too high a harvest rate for some species or groups of species. Alternative values should be evaluated for these groups" (p. 75). The new draft PSEIS evaluates alternatives to $F_{40\%}$ for several individual species and groups of species, including those for which Goodman et al. felt that $F_{40\%}$ was too high.

"Form of harvest control rule: The location of thresholds in the current harvest control rules could be altered (e.g., value of biomass threshold at which zero ABCs are set; use of BMSY as a breakpoint in Tiers 1-3). Note that to speed up the "search" for improved values, the utility function approach suggested and previously used by Thompson (ref) might be used to identify candidate control rules. These should then be further evaluated using the MSE approach" (p. 75). The new draft PSEIS uses a utility function approach, incorporating a formal definition of risk aversion, to compute an optimal harvest rate for Tier 3 stocks. This optimal rate is then incorporated into a control rule which is evaluated along with the other harvest alternatives using the MSE approach.

"Multi-annual catch limits: MSE methods have been used to evaluate the costs and benefits of annual versus multi-annual TAC setting (e.g., Punt et al. 2001). Some work along these lines has already been done in the NPFMC setting, because NPFMC is considering a Plan Amendment to change the TAC-setting process." (p. 75). Goodman et al. are correct that much

work has already been done in this area as part of the proposed plan amendment dealing with the annual specifications process.

In addition to the above recommendations which have already been implemented, the new draft PSEIS also incorporates into its MSE a number of features that go far beyond those recommended by Goodman et al. For example, whereas Goodman et al. suggest that the MSE should assume that TAC=ABC for all stocks regardless of the OY cap (p. 5 and 74), the MSE used in the new draft PSEIS uses a state-of-the-art model incorporating bycatch and technical interactions and which adjusts TACs downward in a way that satisfies the OY cap and mimics the pattern of such adjustments observed in recent years (although Goodman et al. acknowledge the existence of such models, the authors mistakenly conclude that "there appears to be little or no use of these models in framing management advice for the BSAI/GOA FMP" (p. 73)).

Of course, Goodman et al.'s MSE recommendation also contains some features which were *not* implemented in the new draft PSEIS, largely due to time constraints. The Center looks forward to considering these features for use in future MSEs. An appropriate opportunity for future development of MSEs will likely arise when the Council moves toward implementing a preferred alternative following finalization of the PSEIS.

Conclusion 5) The performance of the CHS with respect to ecosystem needs is unclear

The reviewers considered ecosystem needs to be interpreted as needs of the species that are part of the ecosystem. As such, species needs include those related to predation, competition, habitat and environment.

The reviewers are essentially correct that the present tier system does not necessarily take explicit account of needs related to predation, competition, or habitat. Environmental aspects are taken into account in a variety of ways in the calculation of biological reference points, such as using the time period since the 1977 regime shift in the estimation of average recruitment. The tier system provides a mechanism for protection of target species. As such, the tier system does provide a key role in protecting those ecosystem components that are the main focus of our harvesting activities.

Although the review panel did a good job at outlining the present aspects of the current harvest policy that address ecosystem concerns, they could have emphasized more the importance of these other strategies in providing protection to other ecosystem components in the face of uncertain knowledge of the quantitative links between species. They acknowledged that our present strategies include a whole suite of measures such as: the OY cap on BSAI groundfish harvest, restrictions to prevent targeting on forage fish, bycatch and discard controls, spatial closures to protect marine mammal foraging areas, minimum biomass thresholds for Steller sea lion prey, short-tailed albatross take restrictions, gear modifications to protect seabirds, trawl closures, pollock bottom trawling restrictions, and EFH designations. These conservation and management measures provide protection with regard to important species such as forage fish, top predators such as birds and mammals, nontarget species, and habitat.

The recent draft PSEIS and EFH EIS evaluated the present management system with respect to its performance with regard to the ecosystem indicators relating to predator/prey relationships, energy removal, and biodiversity to be largely successful at protecting most target, forage species, prohibited and endangered species. Possible improvements in the policies for protecting nontarget species and habitat have been identified in the EIS alternatives. Improvements in the present harvest strategy with regard to many of these issues are ongoing and linked to research and monitoring on Steller sea lions, monitoring effectiveness of seabird protection devices, the role of climate in influencing species production, evaluation of predator/prey relationships, life history characteristics of nontarget species, and effects of gear on bottom habitat.

One aspect of employing the precautionary approach in an ecosystem context was recommended by the panel, with regard to possible adverse impacts that might arise due to quickly developing fisheries with little information prior to the onset of fishing. The panel recommended a fisheries development framework that incorporates a number of regulatory requirements that might be employed to avoid adverse impacts in these situations. The work of the NPFMC ad hoc working group on revising the management of target and non-target groundfish species, and the newly appointed Council working group on non-target species is working on this issue.

The panel also acknowledged that our current state of knowledge *"does not allow precise scientific specification of what margin or threshold would be appropriate to achieve what level of protection of various ecosystem properties."* The panel offers multispecies and ecosystem modeling of hypothetical scenarios to illustrate various possible outcomes, acknowledging that these models may not be fully developed but that continued investment and testing of such models is warranted along with expanded regular monitoring in the ecosystem. Ultimately, the panel offers the expectation that this research and monitoring (including oceanographic monitoring) will improve our general understanding of the BSAI/GOA ecosystems that may allow us to specify more quantitative ecosystem control rules, thus allowing us to move from the more implicit ecosystem effects being managed to a more explicit management procedure that takes predator/prey and environment into consideration.

The AFSC is continuing with its improvement of information contained in the Ecosystem Considerations section of the BSAI and GOA SAFE documents. This information provides a quantitative historical perspective on trends in important ecosystem indicators at species, community, and ecosystem levels. A qualitative assessment procedure using this information in single species stock assessments has been developed and will lead to quantitative additions to stock assessment models when these improvements are warranted and data are available.

The AFSC is continuing with development and improvement of several multispecies and ecosystem models that may be used to evaluate hypothetical future scenarios to illustrate possible effects of fishing and/or climate on ecosystem processes. In the short term, these models can be used to provide additional indicators of possible future ecosystem impacts of various management strategies or climate regimes. Research is also continuing on developing statistically-based ecosystem indicators such as regime shift predictions. Continuation and improvements to our ecosystem monitoring system including climate, lower trophic level, habitat and predator/prey relationships are important in making progress in these areas.

AGENDA D-1(b)(4)
FEBRUARY 2005

Comments on the 2002 Independent Scientific Review of the Current Harvest Strategy (CHS)

Alaska Fisheries Science Center

(The written report is official;

these slides are not)

Purpose of the Review

- "To seek an independent scientific review of the F40 harvest policy relative to national standards"
  - October 2001
- "To critically review the current harvest strategies applied to our FMP fisheries with an emphasis on accounting for ecosystem needs"
  - February 2002

Charges to the Panel

- Define and explain the CHS
  - Develop an "educational primer"
- Is the CHS consistent with MSFCMA?
  - Is $F_{40\%}$ an appropriate F_{MSY} surrogate?
  - If not, is there a better alternative?
- Is the CHS considerate of ecosystem needs?
  - If not, how should it be changed?
  - Are data sufficient to implement new approach?
  - How would transition be handled?

AFSC's general impressions

- We were lucky to get such a good panel
- Report contains wealth of good information
- Report is mostly positive about CHS
- Contains very little new analysis
  – many recommendations for new analysis
- "Primer" flavor permeates document
  – statements should be viewed in that context

Panel's conclusions (red)

- The CHS is consistent with most parts of the MSFCMA, but inconsistent with some others
- The CHS performs adequately with respect to most target stocks
- The CHS does not perform adequately with respect to rockfish
- Management Strategy Evaluation (MSE) needed to show that the CHS is robust and meets objectives
- The performance of the CHS with respect to the ecosystem is unclear

The CHS is consistent with most parts of the MSFCMA

- OY should be reexamined
- Lack of MSST is inconsistent technically, but does not pose a risk to the stocks
- Other aspects of CHS are consistent
- AFSC agrees with the above
- Lack of MSY control rule is also problematic
  - it is the basis for specifying MFMT
  - it is the basis for specifying OY≤MSY

The CHS performs adequately with respect to most target stocks

- ABCs are set at safe levels for most stocks
- TACs are often set well below ABCs
- Catches are usually below TACs
- AFSC agrees with the above
- Some difficulties in Report's interpretation
  - identification of MSY proxies where none exist
  - misidentification of $F_{40\%}$, $B_{40\%}$ as MSY proxies

The CHS does not perform adequately with respect to rockfish

- Rockfish were overfished in the past and have not recovered
- In particular, $F_{35\%}$ is too high for rockfish
- CHS does not accommodate diversity of life history types
- Low *M* and high age of maturity necessarily imply low resilience
- AFSC does not necessarily agree with above

Some problems with Report's conclusions about rockfish

- No evidence to support claim that rockfish were overfished and have not recovered
- Studies cited in support of claim that $F_{35\%}$ is too high do not pertain to Alaska stocks
- Studies that *do* pertain to Alaska stocks and which show that $F_{35\%}$ is OK were not cited
- Apparent misunderstanding about the role of life history in resilience and SPR rates

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Four hypothetical stocks

- Two flatfish stocks
  - M = 0.20
  - Recruit age = 3
  - SRR slope = 0.80
  - Other parameters vary
  - Resilience #1 = 89%
  - Resilience #2 = 93%
  - FMSY > F40%
- Two rockfish stocks
  - M = 0.05
  - Recruit age = 12
  - SRR slope = 0.20
  - Other parameters vary
  - Resilience #1 = 90%
  - Resilience #2 = 91%
  - FMSY > F40%

MSE needed to show that the CHS is robust and meets objectives

- "In its most general use, MSE involves assessing the performance of a range of ...management strategies, and evaluating the tradeoffs across a range of management objectives.... The approach involves explicitly testing the robustness of each strategy to a range of uncertainties...."
  - New draft PSEIS does this
- "This sort of analysis …in principle allows a better integration of risk assessment…."
  - CHS was a pioneer in use of risk analysis
  - New draft PSEIS makes further advances

The performance of the CHS with respect to the ecosystem is unclear

- Current knowledge and policy are not sufficient to tell whether CHS is "considerate"
  - It is not even possible to define "ecosystem needs"
- The above has nothing to do with $F_{40\%}$
- Although the need for them has not yet been established, there are *lots* of ideas we could try
  - We should evaluate ideas before we try them

There's more to FMPs than ABCs

- The Panel focused on the harvest control rules. However, the CHS also includes other ecosystem protective measures, such as
  - OY caps
  - restrictions to prevent targeting on forage fish
  - bycatch and discard controls
  - spatial closures to protect marine mammal foraging areas
  - minimum biomass thresholds for Steller sea lion prey
  - short-tailed albatross take restrictions
  - gear modifications to protect seabirds
  - trawl restrictions
  - EFH designations

Ecosystem protection: progress and potential

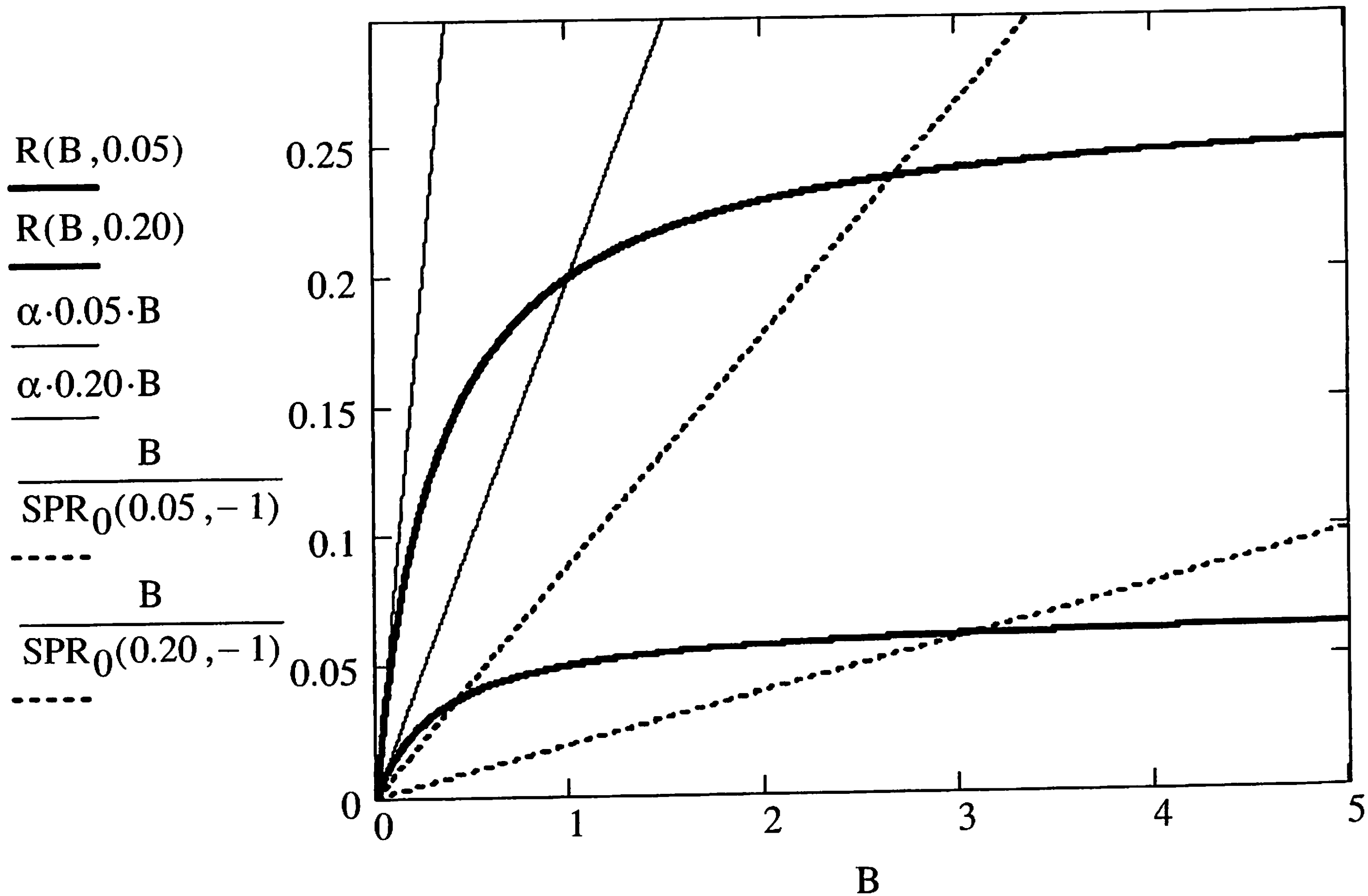
- New draft PSEIS and EFH EIS evaluate impacts of CHS on predator/prey relationships, energy removal, and biodiversity.
- CHS appears to be largely successful at protecting most target, forage, prohibited, and endangered species.
- Improvements are ongoing and linked to research regarding:
  - Steller sea lions
  - effectiveness of seabird protection devices
  - role of climate in influencing species production
  - evaluation of predator/prey relationships
  - life history characteristics of nontarget species
  - effects of gear on bottom habitat

Summary

- Panel's report is helpful
- Affirms many aspects of CHS
- Anticipates/affirms much that is in PSEIS
- Some rockfish conclusions need testing
  - We're doing it
- Presents many ideas for future consideration
  - These should be considered when the Council moves forward to implement a preferred PSEIS alternative

Which stock is more resilient?

(Flatfish1 resilience = 89%, Rockfish1 resilience = 90%)



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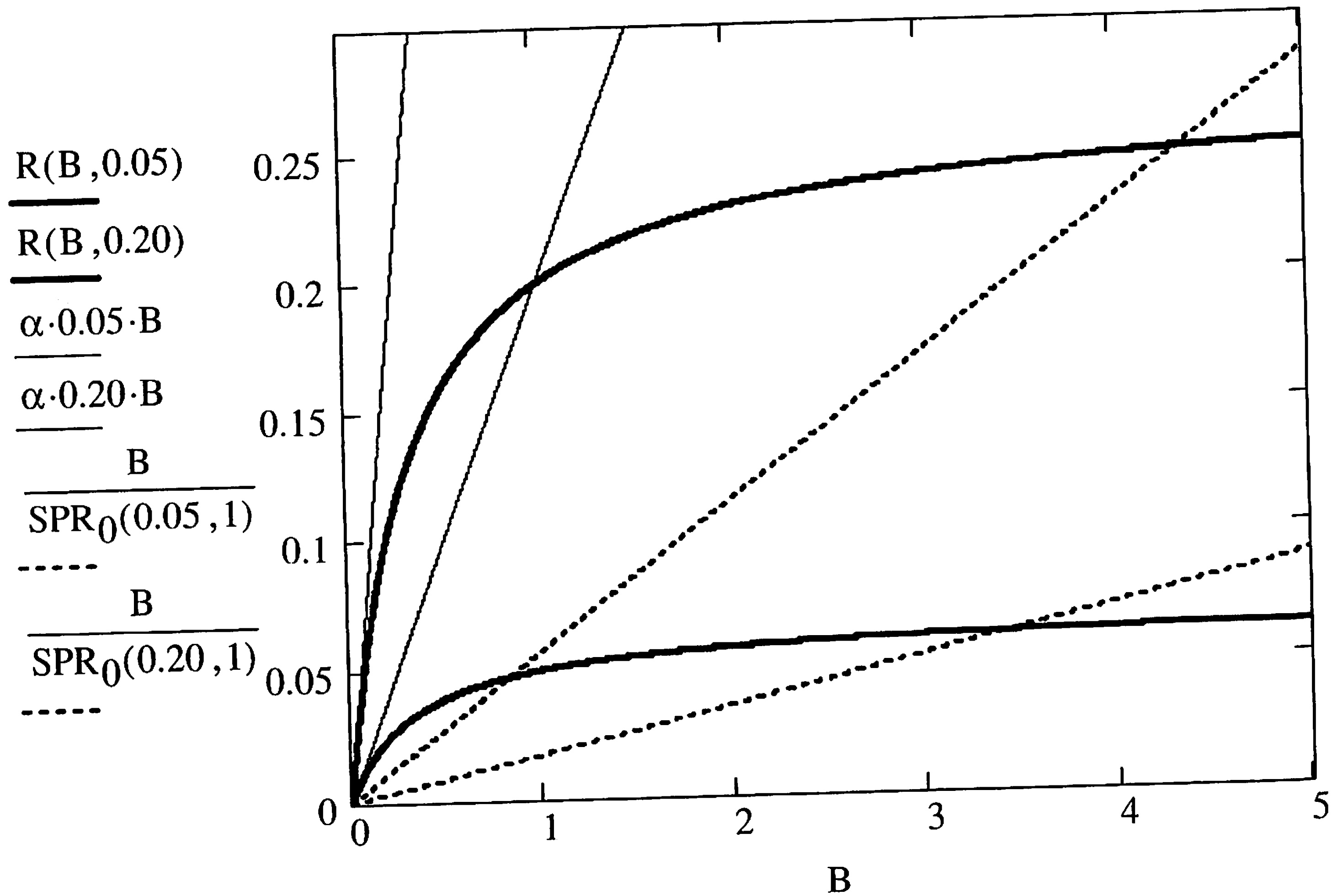
Which stock is more resilient?

(Flatfish2 resilience = 93%, Rockfish2 resilience = 91%)



AGENDA D-1(b)(4)
FEBRUARY 2005

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MATERNAL AGE AS A DETERMINANT OF LARVAL GROWTH AND SURVIVAL IN A MARINE FISH, *SEBASTES MELANOPS*

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Abstract. Relative body size has long been recognized as a factor influencing reproductive success in fishes, but maternal age has only recently been considered. We monitored growth and starvation resistance in larvae from 20 female black rockfish (*Sebastes melanops*), ranging in age from five to 17 years. Larvae from the oldest females in our experiments had growth rates more than three times as fast and survived starvation more than twice as long as larvae from the youngest females. Female age was a far better predictor of larval performance than female size. The apparent underlying mechanism is a greater provisioning of larvae with energy-rich triacylglycerol (TAG) lipids as female age increases. The volume of the oil globule (composed primarily of TAG) present in larvae at parturition increases with maternal age and is correlated with subsequent growth and survival. These results suggest that progeny from older females can survive under a broader range of environmental conditions compared to progeny from younger females. Age truncation commonly induced by fisheries may, therefore, have severe consequences for long-term sustainability of fish populations.

Key words: *larval quality; lipid allocation; maternal effects; reproductive trade-offs;* Sebastes melanops.

REPORTS

INTRODUCTION

Many species of marine fish exhibit surprisingly long life spans, with the maximum age of species in a diverse range of families often exceeding 100 years (Cailliet et al. 2001). An association of longevity with variability in recruitment was initially documented for clupeiform fishes by Murphy (1968), and appears to be widespread in teleosts (Longhurst 2002). The adaptive value of a long life span is that reproductive output is allocated across many years, a bet-hedging strategy that ensures some reproductive success despite potentially long periods of environmental conditions unfavorable for larval survival (Leaman and Beamish 1984, Secor 2000*a*). At the population level, longevity provides a storage effect similar to the seed bank of plants, ensuring extended survival of adults until favorable recruitment conditions recur (Warner and Chesson 1985).

While the advantage of longevity for persistence of a population in a variable environment is intuitive, a growing body of evidence suggests that a broad age distribution can also reduce recruitment variability (Lambert 1990, Marteinsdottir and Thorarinsson 1998, Secor 2000*b*). There are at least two mechanisms by which this buffering could occur: (1) there may be age-related differences in the time and location of spawning (Lambert 1987, Hutchings and Myers 1993), effectively spreading larval production over temporally and spatially variable environmental conditions, and (2) older fish may produce more fit eggs and larvae (Hislop 1988, Marteinsdottir and Steinarsson 1998), which can survive under conditions inadequate for survival of progeny from younger fish. Theoretical analyses suggest that even slightly enhanced rates of early survival and growth have a cumulative effect that can translate into a greatly increased probability of subsequent recruitment (Houde 1987), and field studies have demonstrated a general trend of higher survival among faster growing individuals or cohorts during the larval stage (Meekan and Fortier 1996, Hare and Cowen 1997, Bergenius et al. 2002). Paradoxically, if older fish do produce larvae of better condition, thereby ensuring population viability, fishing obliterates this benefit by selectively removing larger, older individuals.

In this paper, we present results of rearing experiments that address the question of whether larval growth and survival rates are related to maternal age. Our study subject, black rockfish (*Sebastes melanops*), is a broadly distributed nearshore species in the northeast Pacific. The rockfishes in general are characterized by long life spans and slow adult growth compared to most other bony fishes, high recruitment variability, and a live-bearing reproductive pattern (Love et al. 2002). Females retain sperm in the lumen of the ovary for several months until the eggs are fertilized (usually December–February; Boehlert and Yoklavich 1984). Developing embryos receive nourishment from the fe-

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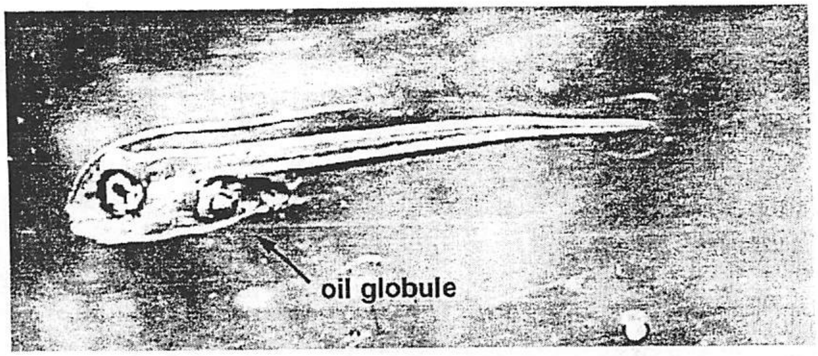

PLATE 1. Newly extruded black rockfish larva (~4.6 mm notochord length) with oil globule clearly visible. Photo credit: Colin Chapman.

male and are thus considered viviparous (Yoklavich and Boehlert 1991). Following a gestation period of ~37 days at 10°C (Boehlert and Yoklavich 1984), females extrude 500 000 to 1 000 000 larvae (S. J. Bobko and S. A. Berkeley, *unpublished manuscript*). Although this reproductive strategy provides maximum protection for progeny during the highly vulnerable egg and yolk-sac larval stages, at parturition the larvae are small (<5 mm in length), only five days posthatch (Yoklavich and Boehlert 1991), and only partially developed. Larvae are capable of feeding immediately after birth, but the period during which they can survive until adequate food becomes available is determined by the amount of endogenous energy stores at birth. Starvation during the initial feeding stage is thought to be a major source of larval mortality, contributing to fluctuations in year class strength (Lasker 1975), and may be a critical factor in recruitment variability in rockfishes (Moser and Boehlert 1991).

METHODS

Rearing experiments

From 1998 to 2000, we collected mature female black rockfish along the central Oregon coast close to the time of larval parturition (December and January). Fish were held individually in 750-L tanks for 1–3 months without food in a flow-through seawater system at ambient temperatures (mean = 12°C) and salinity. Larval development was monitored by anesthetizing the fish and withdrawing a sample of larvae using a catheter inserted into the oviduct. When parturition was imminent, we anesthetized the female and removed the larvae. Females were subsequently measured, weighed, and aged from their otoliths (MacLellan 1997). From fork length and wet mass (liver and ovaries removed) a condition index was calculated as (mass/length^3) × 100. A liver index was calculated as liver mass/wet mass, as a measure of energy reserves. A sample of ~500 larvae was rinsed in distilled water and frozen at −80°C for proximate analysis of body composition. Carbon, nitrogen, and ash were determined using the Dumas combustion method (Analytical Chemistry Laboratory, University of California, Santa Barbara) and used to calculate protein and lipid concentration. Another sample of 40–50 larvae was photographed, with the images used to determine notochord length of individual larvae and the diameter of their oil globule (from which we calculated oil globule volume: see Plate 1). A separate sample of 10 larvae was rinsed in distilled water, dried at 60°C for 24 h, and weighed to the nearest 1.0 μg to estimate larval mass. Initial larval condition was calculated from the mean length and mass data of larvae collected from each female.

For the rearing experiments, we stocked 500 larvae in each of six 50-L tanks, with two replicates of three food densities (0, 1, and 10 rotifers per mL). We report here only the results of the 0 and 10 rotifer rations because there was no statistical difference between the two treatments receiving food. Larvae were reared at constant temperature (10°C) under a 12:12, L:D photoperiod for 30 days or until all larvae had died. Growth rates were estimated from the fed tanks, based on a sample of 3–5 larvae removed every three days. Nitrate and ammonia levels were monitored every other day and remained below detectable levels.

Fed treatments received a diet of enriched marine rotifers (*Brachionus plicatilis*). Rotifer cultures were maintained on a combination of cultured live algae (*Isochrysis galbana*) and Rotimac (Aquafauna Bio-marine, Hawthorne, California, USA), a commercial rotifer diet supplement. Prior to larval feeding, rotifers were enriched with Algamac 3010 flake enrichment medium (Aquafauna Bio-marine). Food levels in the rearing containers were monitored and adjusted daily to maintain target concentrations. Dead rotifers were siphoned daily from the bottom of the rearing tanks.

Growth in length and mass were estimated with linear regression models $L_t = a + bt$ and $W_t = a + bt$, where L_t is the estimated length (mm) at time t, W_t is the estimated dry mass (mg) at time t, b is the growth rate (mm or mg/d), t is time (d), and a is the y-intercept. Growth in length and mass over the size range observed in these experiments was best described by a linear function. The slopes of these relationships were used

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as dependent variables in subsequent regression analyses.

Time to starvation in the unfed treatments was estimated as the number of days until 50% of the initial number of larvae remained. Data for each measure of larval performance were pooled from the two replicates for each female.

Age composition of wild populations

We estimated the age structure of female black rockfish in wild populations by examining fish from recreational and commercial fishery catches off the coast of central Oregon in 1996–2000. Fishing effort was largely concentrated on nearshore rocky reef habitats <60 m in depth. Most of our samples came from the discarded carcasses of recreationally caught fish. The majority of black rockfish we examined were either immature or male. All the mature females we encountered (n = 1643) were measured for length and aged from the otoliths. Ovary stage was determined and body condition was based on a liver index calculated as liver mass/length^3.

Data analysis

Our hypothesis that larval performance is positively related to maternal age was tested using stepwise multiple regressions run separately for each measure of larval performance (growth in length, growth in mass, and time to 50% mortality). Maternal age, length, condition factor, and liver index were included as potential independent variables. All regressions were run as forward stepwise procedures, with criteria of F = 4.00 for variable entry into the equation and F = 3.90 for removal (SigmaStat version 2.03, SPSS, Chicago, Illinois, USA).

Results of these regressions were used to determine which measures of maternal fitness or condition are associated with larval performance. However, these measures do not provide insight into the mechanistic relationship between female condition and larval performance. Measured larval traits more directly affecting performance included larval condition index, initial larval length, initial percentage of lipids, and oil globule volume at parturition. We used stepwise multiple regression to test the influence of these independent variables on our three measures of larval performance (growth in length, growth in mass, and time to 50% mortality). A final stepwise regression examined the influence of maternal age, length, condition index, and liver index in determining oil globule volume. Best-fit simple regressions (linear and nonlinear) were fit to all measures of larval performance and all potential explanatory variables and maternal characteristics to allow a simple evaluation of significant relationships.

Results

Effects of maternal traits on larval performance

Maternal age had a clear and striking effect on all three measures of larval performance. In the fed treat-

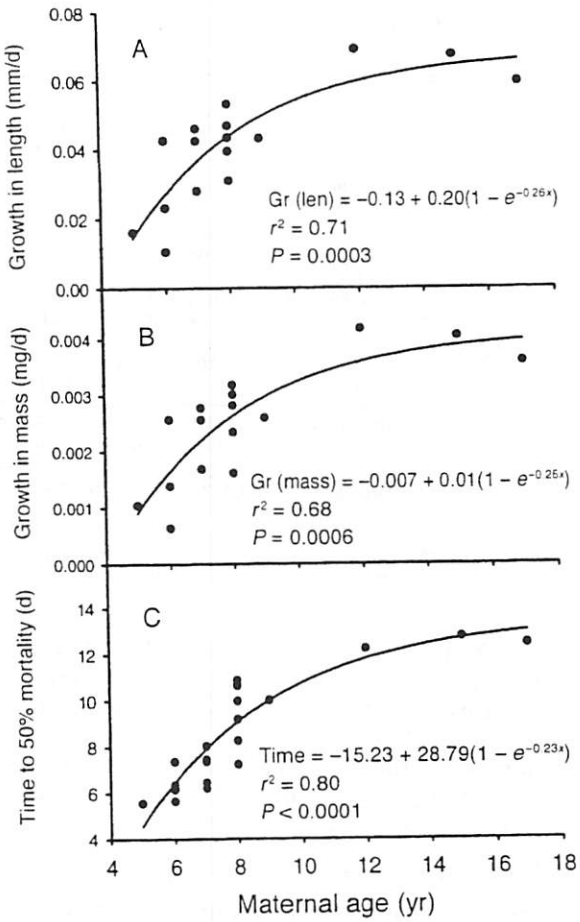

FIG. 1. Relationships in black rockfish between maternal age and (A) growth in length, (B) growth in mass, and (C) median time to starvation.

ments, larvae from the oldest females grew more than three times as fast in both length and mass as larvae from the youngest females (Fig. 1A, B). In the unfed treatments, larvae from the oldest females survived starvation more than twice as long as larvae from the youngest females (Fig. 1C). The three performance measures best fit an asymptotic relationship with maternal age, suggesting limited improvement in larval quality at maternal ages older than those in this study.

Although maternal age was strongly correlated with larval performance, stepwise multiple regressions determined whether other maternal traits potentially explained an additional proportion of the variance in performance (Appendix). These regressions were all highly significant (growth in length, P = 0.005; growth in mass, P = 0.001; survival, $P < 0.001$), and maternal age explained most of the variability observed. Maternal age was the only significant predictor of growth in mass. Maternal length was also a significant independent variable in the regression of larval growth in length (P = 0.035), increasing the goodness of fit (r^2)

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TABLE 1. Matrix of coefficients of determination (r^2) for all larval and maternal traits measured in black rockfish.

Trait	GL	GW	S	ILL	LC	%L	OGV	MA	ML	MC	LI
GL		***	0	0	0	0	***	***	**	0	0
GW	**0.99**		0	*	0	0	***	***	*	0	0
S	0.15	0.13		0	0	0	***	***	*	0	0
ILL	0.24	**0.27**	0.09		***	0	0	*	0	0	0
LC	0.12	0.16	0.06	**0.83**		0	0	*	0	0	*
%L	0.00	0.00	0.01	0.01	0.02		0	0	0	0	*
OGV	**0.59**	**0.56**	**0.82**	0.15	0.07	0.15		***	*	0	0
MA	**0.71**	**0.68**	**0.80**	**0.29**	**0.21**	0.00	**0.82**		*	0	0
ML	**0.51**	**0.43**	**0.38**	0.13	0.10	0.10	**0.25**	**0.24**		0	0
MC	0.06	0.06	0.05	0.00	0.00	0.14	0.06	0.02	0.01		** (−)
LI	0.15	0.16	0.06	0.12	**0.21**	**0.26**	0.01	0.10	0.07	**0.42**	

Notes: Results are based on best fits of simple linear and nonlinear regressions between each pair of traits. Positive relationships are designated by asterisks and nonsignificant relationships ($P > 0.05$) by 0. A negative relationship is designated with a minus sign (in parentheses). Coefficients of determination for significant regressions are shown in boldface type. Key to abbreviations: GL, larval growth rate in length; GW, larval growth rate in mass; S, time to 50% mortality (survival); ILL, initial larval length; LC, larval condition at parturition; %L, percentage of larval lipids; OGV, oil globule volume; MA, maternal age; ML, maternal length; MC, maternal condition; LI, liver index.

from 0.58 with only maternal age included to 0.71 with both variables included in the equation. In the regression of survival, maternal length was marginally significant ($P = 0.055$), and increased the goodness of fit from $r^2 = 0.67$ (including only maternal age) to 0.73. This result suggests that females that are both old and large produce the highest quality larvae.

Larval traits associated with larval performance

The larval trait most highly correlated with larval performance was the volume of the oil globule present at parturition (Table 1, see also Plate 1). Similar to the relationship of maternal age with larval performance, larvae from cohorts with the largest oil globules at parturition had growth rates in both length and mass that were more than three times faster and survival rates more than twice as high as cohorts with the smallest oil globules (Fig. 2).

In all three multiple regressions evaluating larval performance with four indices of larval condition, oil globule volume was the only significant predictor of larval performance, explaining 55%, 53%, and 79% of the observed variability in larval growth in length, growth in mass, and survival, respectively. Initial larval size, initial larval condition, and initial total larval lipids were all too weakly correlated with larval performance to be included in the regression equations (Appendix).

Maternal traits and oil globule volume

Maternal age was related to larval performance, and larval performance was related to oil globule volume at parturition, suggesting that oil globule volume was in turn a function of maternal age. The linear regression between oil globule volume and maternal age was highly significant ($r^2 = 0.82$, $P < 0.001$, Fig. 3). A stepwise

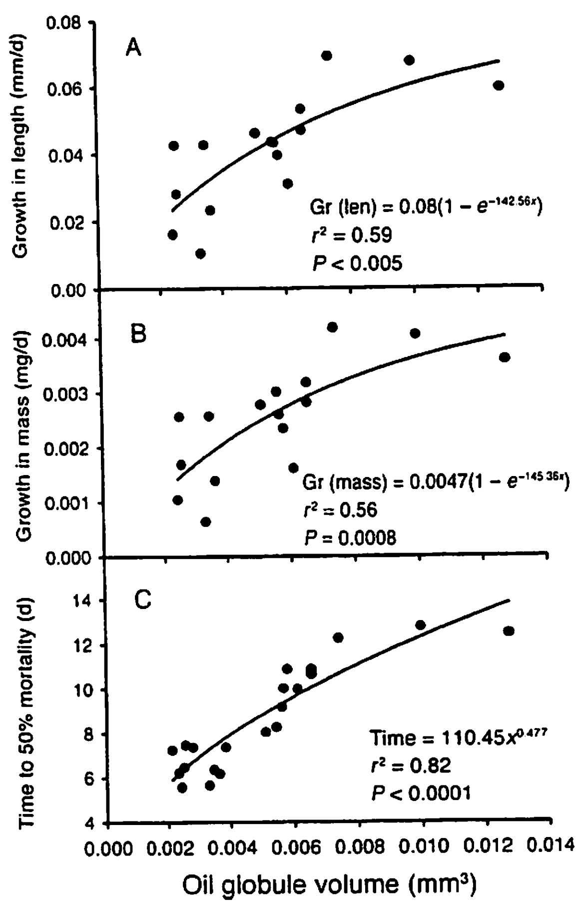

FIG. 2. Relationships in black rockfish between larval oil globule volume and (A) growth in length, (B) growth in mass, and (C) median time to starvation.

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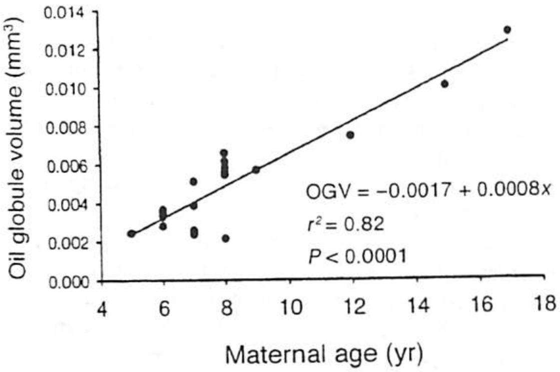

FIG. 3. Relationship between larval oil globule volume (OGV) and maternal age in black rockfish.

multiple regression was used to evaluate potential contributions of additional maternal traits of length, condition, and liver index in determining oil globule volume (Appendix). Only the liver index was significant ($P = 0.05$), increasing the r^2 from 0.82 to 0.85. However, the liver index was not related to maternal age (Table 1). To test for a laboratory effect on oil globule volume, we re-ran the multiple regression with time in captivity as an additional independent variable (Appendix). Although there was a weak negative correlation between time in captivity and age ($r^2 = 0.30$) because parturition often occurs earlier in older fish, there was no additional explanatory power and time in captivity was not included in the final model ($P = 0.21$). Our sample of wild females at comparable ovarian stages also did not exhibit any relation of liver index with age ($P = 0.835$), and they did not differ from our experimental fish (Mann Whitney U test, $P = 0.137$), suggesting that female condition was not influenced by our laboratory treatments.

Evidence for age truncation in nature

We observed a precipitous decline in the abundance of older age classes of black rockfish from 1996 to 1999 (Fig. 4). In 1996, the mean age of mature females retained by recreational fishermen in our sample was 9.3 years. By 2000, the mean age was only 7.4 years. There was no indication of a particularly abundant year class in the population that might have accounted for the decreased mean age of mature fish.

DISCUSSION

These results demonstrate a strong correspondence between maternal age and larval performance and indicate a likely mechanism for this relationship. Older black rockfish females provision their larvae with significantly larger oil globules than younger females, and the size of the oil globule appears to strongly affect larval growth and survival. At extrusion, most of the yolk has already been absorbed in rockfish larvae, but endogenous energy is available in the oil globule, which is primarily composed of triacylglycerol (TAG), the lipid fraction providing energy for metabolism and growth (Norton et al. 2001). The importance of measuring a direct index of TAG availability rather than total lipids is evident from the lack of correspondence of the latter with either growth or survival. High variability in oil globule volume at a given larval size is evident in other larval rockfish (Norton et al. 2001), suggesting a trait susceptible to selective mortality processes, although the role of maternal age in determining oil volume has not been previously reported. The oil globule is likely the major source of energy sustaining larvae during the difficult transition to exogenous feeding. The size of the oil globule has also been correlated with larval survival in capelin (Chambers et al. 1989), an unrelated species with a contrasting reproductive pattern of external fertilization and broadcast spawning. Our results for the unfed treatments revealed a close correspondence between available TAG and survival. For the fed larvae, enhanced growth rates of cohorts with larger oil globules at parturition suggested that greater stores of TAG provided important benefits even when ad libitum food was continually present.

It seems likely that such large differences in growth and starvation tolerance would have a profound effect on larval survival. The ability of larval fish to survive a period of starvation is often critical due to the spatial and temporal unpredictability of encountering patches of zooplankton prey (Hunter 1981). Fast growth has clear benefits in allowing larvae to pass more quickly through the most vulnerable life history stages and to develop faster in physical and physiological capabilities that improve detection and capture of prey, avoidance of predators, and resistance to environmental challenges (Fuiman and Cowan 2003). Field studies have demonstrated that relatively small differences in growth rate, especially in the youngest larvae, can have a profound effect on survival: a doubling of the growth rate in larval bluefish (*Pomatomus saltatrix*) and Atlantic cod (*Gadus morhua*) can increase survival by a factor of 5–10 (Meekan and Fortier 1996, Hare and

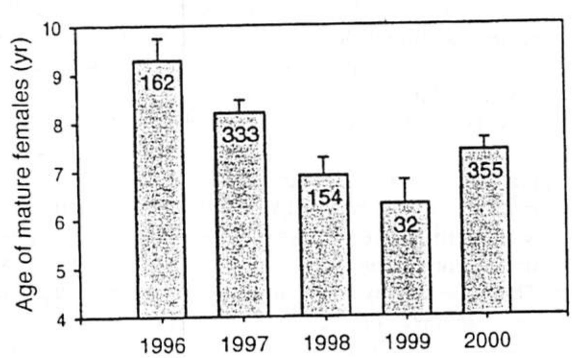

FIG. 4. Age (mean and 95% CI) of mature female black rockfish sampled off the central Oregon coast for five years. Sample size is shown inside bars.

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Cowen 1997). We observed increases in survival by nearly a factor of three and in growth by nearly a factor of four between the offspring of young and old black rockfish. These differences may be conservative since larvae were reared under constant environmental conditions, with ad libitum rations in fed treatments, and no exposure to predators or competitors (other than their siblings).

These findings have important ramifications for management of marine fish populations. Current management paradigms for a broad array of species assume that all larvae, regardless of parental age, have an equal probability of survival. Results of our experiments suggest that this assumption is not true for black rockfish. Comparable effects of maternal age on progeny quality are evident in haddock (*Melanogrammus aegelfinus*, Hislop 1988) and Atlantic cod (Marteinsdottir and Steinarsson 1998), unrelated species with very different reproductive strategies than the live-bearing rockfish we studied, suggesting a broad generality to such age effects. Age truncation induced by removing large fish via fishing can, therefore, have a much greater impact on the reproductive capacity of a population than the simple reduction in biomass of mature females. Maintaining a significant proportion of older fish may be critical to long-term replenishment and stability in exploited fish populations. Murawski et al. (2001) provide an elegant synthesis of these effects in Atlantic cod. Other studies have also concluded that the biomass of mature females without regard to their age structure may overestimate the production of viable larvae (Trippel et al. 1997, Scott et al. 1999, Vallin and Nissling 2000).

Age truncation in fished populations is a widespread problem. Our data on adult ages were derived from nearshore reefs on the coast of Oregon that received intensified recreational fishing pressure in conjunction with the decline and eventual prohibition of coho salmon recreational fishing during the 1990s. Port sampling data collected by the Oregon Department of Fish and Wildlife (*unpublished data*) indicate that groundfish catches by recreational fishermen doubled in the 1990s compared to the 1980s. Although this shift in fishing effort was highly localized and we have only a short time series, the rapid removal of older fish was particularly striking.

Although female size was correlated with all of our measures of larval performance, maternal age explained a much greater proportion of the variance. Female size was correlated with age, but the relationship was relatively weak. Like most long-lived fishes, post-maturation growth rates of black rockfish are slow. Thus, the improvement in larval quality with maternal age was likely due to factors other than an increase in body size. Maternal effects on progeny quality and performance have previously been associated with the female's health and condition (Chambers and Waiwood 1996, Kerrigan 1997), but a potential shift in allocation strategy with age has not been reported. Our indices of body and liver condition in females were derived from individuals postparturition (i.e., after exhaustion of maternal energy investment in reproduction), and revealed no correspondence with age. Assessment of female condition prior to egg fertilization will be needed to determine whether increased larval quality with increased age is a function of maternal energy reserves or some other trade-off in allocation. Increasing investment in larval TAG reserves with maternal age in black rockfish does not appear to be associated with a trade-off in fecundity. In fact, relative fecundity (number of larvae per gram of maternal body mass) increases with age (S. J. Bobko and S. A. Berkeley, *unpublished manuscript*). These age-related traits provide unequivocal support for the protection of older females in exploited fish populations.

Acknowledgments

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APPENDIX

The results of all stepwise multiple regressions are available in ESA's Electronic Data Archive: *Ecological Archives* E085-032-A1.

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feature fisheries management

Fisheries Sustainability via Protection of Age Structure and Spatial Distribution of Fish Populations

ABSTRACT

Numerous groundfish stocks in both the Atlantic and Pacific are considered overfished, resulting in large-scale fishery closures. Fishing, in addition to simply removing biomass, also truncates the age and size structure of fish populations and often results in localized depletions. We summarize recent research suggesting that an old-growth age structure, combined with a broad spatial distribution of spawning and recruitment, is at least as important as spawning biomass in maintaining long-term sustainable population levels. In particular, there is evidence that older, larger female rockfishes produce larvae that withstand starvation longer and grow faster than the offspring of younger fish, that stocks may actually consist of several reproductively isolated units, and that recruitment may come from only a small and different fraction of the spawning population each year. None of these phenomena is accounted for in current management programs. We examine alternative management measures that address these specific issues and conclude that the best and perhaps only way to ensure old-growth age structure and complex spatial structure in populations of groundfish is through interconnected networks of marine reserves.

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Introduction

The objective of U.S. fisheries management, as mandated by National Standard 1 of the Sustainable Fisheries Act of 1996, is to maintain fish stocks at levels sufficient to produce maximum sustainable yields (MSY). Mandated levels of fishing may be less than MSY but are not to exceed these levels. MSY, of course, has been a highly elusive goal (Larkin 1977). Operationally, National Standard 1 has been interpreted by most fisheries management plans to mean that fishing should maintain some minimum spawning biomass deemed adequate to ensure that recruitment is not limited by insufficient egg or larval production. In the Pacific groundfish fishery and elsewhere, management is based on maintaining egg or larval output per recruit at or above 40% of the unfished level, referred to as B_{40} (while the unfished level is B_0). Functionally this means maintaining the spawning biomass at 40% of the estimated virgin stock level, with adjustment for age-specific fecundity. Other biological reference points used in managing this fishery are B_{25} (25% of the unfished level), which is the overfishing threshold, and B_{10} (10% of the unfished level), which is the threshold at which the fishery is closed (even though bycatch mortality may continue).

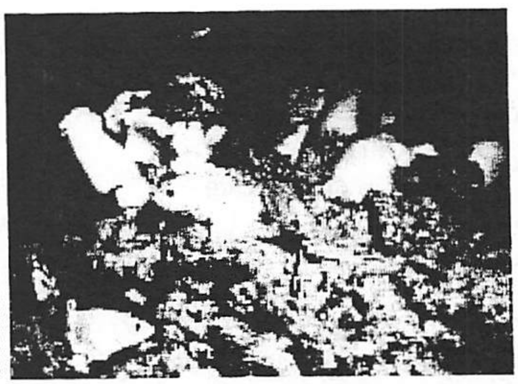
Despite these guidelines, periodic population assessments, and attempts at careful regulation of fisheries, many rockfish and other groundfish stocks declined, some severely, and consequently were declared "overfished" (Table 1). These declines have resulted in very restrictive rebuilding plans that include large-scale fishery closures. Estimated rebuilding times, even with no further fishing, are quite long and in some cases may not be achieved within our lifetimes (Table 1).

How did such widespread stock declines occur? Was this challeng-

Table 1. Overfished groundfish stocks on the west coast of the United States and estimated rebuilding times with no fishing mortality (PFMC 2003a,b). Of the 82 species in the Pacific Fisheries Management Council plan, 19 have undergone recent reliable stock assessments, so these 9 overfished species comprise about half the well-assessed species (S. Ralston, NOAA Fisheries, pers. comm.).

Species	Year Declared Overfished	Percent of B_0	Recovery Time (yr) if Fishing Mortality=0
Bocaccio rockfish (*Sebastes paucispinus*)	1999	7.4	18
Canary rockfish (*S. pinniger*)	2000	8	54
Cowcod rockfish (*S. levis*)	2000	7	59
Darkblotched rockfish (*S. crameri*)	2000	14	11
Pacific Ocean perch (*S. alutus*)	1999	21.7	8
Widow rockfish (*S. entomelas*)	2001	23.6	20
Yelloweye rockfish (*S. ruberrimus*)	2002	24	24
Lingcod (*Ophiodon elongates*)	1999	15–17	1–2
Pacific hake (*Merluccius productus*)	2002	24	1

ing situation a failure of science or management, or merely a result of naturally occurring environmental conditions? While it is likely that all of these factors were at work, we believe that at least part of the explanation for stock collapses is the result of our failure to appreciate the value of both large old fish and fine-scale spatial dynamics of recruitment in the replenishment of fish populations. We discuss recent research that provides what we believe to be a compelling case that the age structure of a stock combined with the spatial distribution of recruitment are as important as spawning biomass in maintaining long-term sustainable population levels. In particular, there are an increasing number of examples of complex population structure in species currently managed as a unit stock, and increasing evidence that only a small fraction of spawners in a stock—those that spawn in the right time and place, which varies annually—successfully contribute to each new cohort. Moreover, it is large, old female fish that produce offspring most likely to recruit successfully to these new cohorts. Based on this evidence, we believe that the best and perhaps only way to ensure old-growth age structure and complex spatial structure in populations of groundfish is through interconnected networks of fully protected marine reserves.


MARY NISHIMOTO

Miscellaneous rockfish.

Spatial heterogeneity and recruitment

Although marine populations are obviously affected by the vagaries of larval survival (Houde 1987), the spatial and temporal features of year-class formation are not yet clearly understood. Hedgecock (1994a,b) proposed the "sweepstakes hypothesis" to explain small-scale genetic heterogeneity observed in some widely distributed marine populations. According to this hypothesis, most spawners fail to produce surviving offspring because their reproductive activity is not matched in space and time to favorable oceanographic conditions for larval survival during a given season. As a result of this mismatch (sensu Cushing 1969, 1975), the surviving year class of new recruits is produced by only a small minority of adults that spawned within those restricted temporal and spatial oceanographic windows that offered good conditions for larval survival and subsequent recruitment. If this is indeed the case, then quotas that apply stock-wide (for most U. S. west coast groundfishes, that would be coastwide), without regard to how the catch is spatially distributed, could lead to increased recruitment variability and to occasional recruitment failure if concentrated fishing results in local depletions.

One testable prediction of Hedgecock's hypothesis is that a cohort of new recruits should show less genetic diversity than the adult population, reflecting the underlying pattern of only a few adults successfully passing their genome to each new cohort. This hypothesis was tested during 1994, when the National Marine Fisheries Service Tiburon Lab conducted a sampling survey of the entire pelagic stage of shortbelly rockfish (*Sebastes jordani*) combined with juvenile and adult surveys (Larson et al. 1995; Julian 1996). Results supported the Hedgecock hypothesis (Table 2): levels of genetic diversity were lower for later stage ("June" and "Farallon") pelagic juveniles and their haplotype frequencies were different from both adults and most of the earlier stages of larvae and juveniles. Results also indicated that these differences were not due to seasonal spawning by a unique portion of the adult population, but were in fact the result of differential survival during the pelagic larval stage. In contrast, Gilbert (2000) found no reduction in genetic diversity within a very strong year class of kelp rockfish (*S. atrovirens*). Burford (2001) also found no reduction in genetic diversity in a year class of blue rockfish (*S. mystinus)* but did find genetic differences among recruits from different locations that were not matched by differences among adult populations.

Gomez-Uchida and Banks (in press), studying the population genetics of darkblotched rockfish (*S. crameri*), found that the breeding population was several orders of magnitude smaller than the spawning stock size indicated by the stock assessment. Only several thousand breeders, rather than the millions of

Table 2. Genetic diversity (diagonals in bold) within samples and genetic differentiation between samples for different developmental stages of shortbelly rockfish. Single asterisk (*): p<0.10, and double asterisk (**): p<0.05 for Monte Carlo chi square contingency tests for differences in haplotype frequencies (Larson et al. 1995).

	Adults	Larvae	March Juveniles	Total June Juveniles	Farallon June Juveniles
Adults	**0.6844**				
Larvae	0.0070	**0.7355**			
March Juveniles	0.0148	0.0161	**0.6211**		
Total June Juveniles	0.0549*	0.0447*	0.0247	**0.5887**	
Farallon Juveniles	0.0677**	0.0572**	0.0316*	—	**0.5532**

adults in the whole population, would successfully reproduce. While not a direct test of Hedgecock's hypothesis, these results nevertheless suggest that recruitment is not uniformly distributed throughout the adult population.

Thus, although the generality of Hedgecock's hypothesis remains in question, indications are that it may be true under at least some circumstances, and that the genetic composition of recruits may otherwise be quite complicated spatially. This suggests that the geographic source of successful recruits may differ from year to year. Based on these considerations, management should strive to preserve a minimal spawning biomass throughout the geographic range of the stock (Larson and Julian 1999).

Complex population structure

Most continuously distributed groundfish species are assumed to comprise a unit stock throughout their range or at least throughout their range within the management unit. Recent studies using genetic and otolith microchemistry analytical techniques on a broad array of rockfish species indicates that there may be considerable reproductive isolation at regional spatial scales. Miller and Shanks (2004), using chemical signatures in the otoliths of black rockfish to infer larval origin, determined that larval dispersal was much more limited than previously believed, and showed that there were four different population subdivisions between southern Oregon and central Washington. Buonaccorsi et al. (2002), using microsatellite DNA, showed very similar results for copper rockfish (*S. caurinus*); significant population subdivision was detected among four coastal locations. Despite the wide distribution of this species, they concluded that there was limited oceanographic exchange among geographically proximate locations. Perhaps even more surprisingly, Withler et al. (2001) studying the genetics of Pacific Ocean perch (*S. alutus*), one of the most widely distributed of all rockfish species, being found from Japan and the Bering Sea through Baja California, discovered three genetically distinct populations just off the coast of British Columbia. Similarly, Gomez-Uchida and Banks (in press), found three population subdivisions in darkblotched rockfish along the U.S. west coast.

These results suggest that current stock assessments will not adequately represent the status of the "stock" for species that exhibit complex population structure. Overfishing of one reproductively isolated population unit can remain undetected if the reproductive units are not assessed individually, which currently they are not. Stock assessment and traditional quota or effort-based management at this level of population subdivision will be very problematic.

Age truncation and recruitment

Many marine fish species, such as those in the north temperate waters of the Pacific Ocean, exhibit long life spans, with the rockfishes being particularly striking in this regard (Table 3). The adaptive value of allocating reproductive output across many years (iteroparity) is generally thought to be a bet-hedging strategy that ensures some individual reproductive success despite long periods of environmental conditions unfavorable for larval survival (Leaman and Beamish 1984). At the population level, longevity ensures that there will be sufficient reproductive output for the population to maintain itself between favorable recruitment events (Longhurst 1999, 2002).

Table 3. Examples of long-lived fishes from the northeast Pacific (Cailliet et al. 2001; Love et al. 2002, O'Connell et al. 2003).

Family	Species	Common name	Estimated maximum age (yr)
Squalidae	*Squalus acanthias*	Spiny dogfish	75
Acipenseridae	*Acipenser transmontanus*	White sturgeon	104
Anoplopomatidae	*Anoplopoma fimbria*	Sablefish	114
Macrouridae	*Coryphaenoides acrolepis*	Pacific grenadier	73
Scorpaenidae	*Sebastes melanops*	Black rockfish	50
	Sebastes levis	Cowcod	55
	Sebastes pinniger	Canary rockfish	84
	Sebastes alutus	Pacific Ocean perch	100
	Sebastes crameri	Darkblotched rockfish	105
	Sebastes ruberrimus	Yelloweye rockfish	121
	Sebastes aleutianus	Rougheye rockfish	205
	Sebastolobus alascanus	Shortspine thornyhead	115

Age truncation—the removal of older age classes via fishing—occurs at even moderate levels of exploitation (Figure 1). Leaman and Beamish (1984) suggest that age truncation will be most detrimental when reproductive success is highly variable, since stock maintenance may be dependent on the relative stability of reproductive output that results from a broad spectrum of age classes. Most, if not all rockfish stocks on the U. S. west coast fall into this category of highly variable and episodic recruitment (Hollowed et al. 1987; Moser et al. 2000).

At the population level, longevity provides a storage effect similar to the seed bank of plants, ensuring extended survival of adults until favorable recruitment conditions return (Warner and Chesson 1985). MacCall (1996) also suggested that populations that are located near the extremes of their geographic ranges, such as the white seabass (*Atractoscion nobilis*) populations near San Francisco around the turn of the twentieth century, may be maintained by irregular recruitment during climatically favorable conditions. The longevity of such species may allow the populations to persist during extended periods of adverse climatic conditions, when recruitment is essentially absent, but truncation of the age distribution due to fishing may make such irregular replenishment impossible. If individuals at the extremes of the geographic range contribute recruits to the population in the center of the range, as proposed by Cowen (1985) and Pringle (1986) for California sheephead (*Semicossyphus pulcher*) and spiny lobster (*Panulirus interruptus*), respectively, then longevity of populations near the extremes allows the continued production of larvae from these stock components that helps to maintain the central portion of the population.

While the advantage of longevity for persistence of a population in a variable environment is intuitive, a growing body of evidence suggests that a broad age distribution can also reduce recruitment variability (Lambert 1990; Marteinsdottir and Thorarinsson 1998; Secor 2000a,b). There are at least two mechanisms by which stabilization of recruitment could occur: (1) there may be age-related differences in the time and location of spawning (Berkeley and Houde 1978; Lambert 1987; Hutchings and Myers 1993), thereby spreading larval production to cover temporal and spatial variability in favorable environmental conditions, and (2) older fish may produce larger, healthier, or otherwise more fit larvae (Hislop 1988; Marteinsdottir and Steinarsson 1998), which may survive under conditions that are inadequate for the survival of progeny from younger fish. Even slightly enhanced rates of early survival and growth have a cumulative effect that can translate into a greatly increased probability of successful recruitment (Houde 1987).

Long life spans are necessarily associated with low rates of mortality during the adult stage (Stearns 1992). For most teleosts, size-dependent processes, especially lower risk of predation with increasing body size, result in decreasing natural mortality as fish grow older and larger (Hare and Cowan 1997; Sogard 1997). Fishing, however, generally selects for larger, older fish, imposing a selection pressure that works opposite to that of most natural mortality agents. One of the more predictable effects of fishing is the reduction or removal of the older age classes, i.e., age truncation (Figure 1). Prior to reaching a size acceptable to the fishery (either due to market demand or minimum size regulations intended to allow fish to attain reproductive maturity), younger age classes are reduced only through natural mortality, but once vulnerable to fishing gear, a cohort is reduced through both natural and fishing mortality. These sources of mortality are cumulative throughout the life of the cohort. As illustrated in Figure 1, even at moderate levels of fishing (e.g., B_{40}, the target level), the number of age classes at equilibrium rapidly decreases. Although age truncation increases with increasing exploitation rates, it is essential to understand that older age classes are lost even at levels of fishing mortality that are currently considered sustainable (e.g., fishing at the target level, where spawning output is reduced to 40% of the level that would exist without fishing, or B_{40}). More important, loss

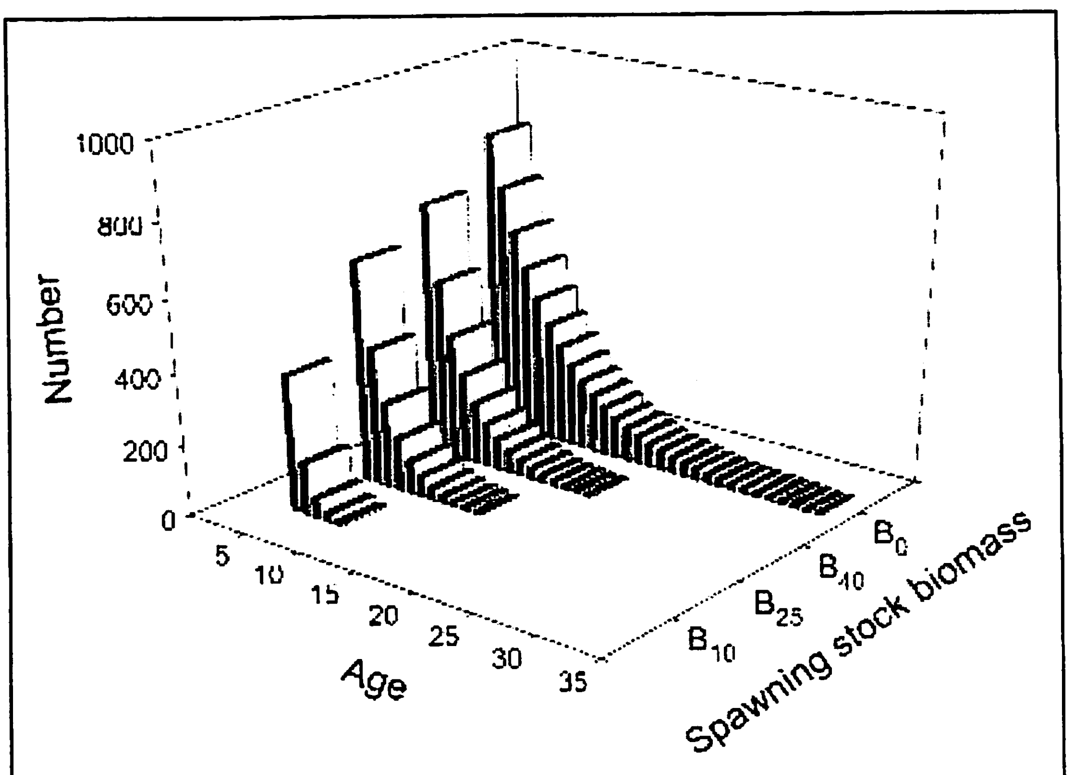


Figure 1. Example of age truncation under increasing rates of exploitation of a hypothetical population of fish at equilibrium. The modeled population has the same size, growth, natural mortality, maturation, and age-specific fecundity characteristics as black rockfish *(Sebastes melanops)*. Recruitment is assumed to remain constant (i.e., we start with the same number of fish at age 4 regardless of the population age structure). For simplicity we assume fishing mortality is knife-edged starting at age 4 (i.e., the cohort is reduced only through natural mortality until age 4 and through both fishing and natural mortality after age 4). Natural mortality, expressed as an instantaneous rate, is 0.18; instantaneous rates of fishing mortality that result in the biological reference points B_0, $B_{40\%}$, $B_{25\%}$, and $B_{10\%}$ are 0.000, 0.165, 0.295, and 0.775, respectively. The cohort is considered eliminated when less than 0.5% of the initial cohort (at age 4) remains.

of older age classes may have severely negative ramifications for subsequent recruitment. As reviewed below, there can be crucial differences between young and old spawning females.

Body Size and Adult Condition

In rockfishes and in other teleosts, body condition and deposition of lipid reserves increase disproportionately with fish length or stage of maturity (Iles 1974; Eliasson and Vahl 1982; Larson 1991). If volumetric variables such as body weight, liver weight, and weight of fat reserves grow proportionately to the rest of the fish, they would increase with the cube of body length. In rockfish, Guillemot et al. (1985) found varying relationships between mesenteric fat weight and fish length (often with low R^2 values). However, Larson (1991), benefiting from fish consistently collected in the same areas (in contrast to the fish available to Guillemot), found disproportionate relationships between measures of condition and fish length in kelp rockfish (*Sebastes atrovirens*) and black-and-yellow rockfish (*S. chrysomelas*). Body weight was proportional to slightly greater than the cube of length, liver weight to around the 4th power of length, and mesenteric fat weight to about the 6th power of length. Whether body reserves are utilized directly in reproduction (MacFarlane et al. 1993; Norton and MacFarlane 1994), for overwintering maintenance (Guillemot et al. 1985), or a combination of the two (Larson 1991), the amount of reserves may affect the timing (Lenarz and Wyllie Echeverria 1986) or amount (Eliasson and Vahl 1982; Lambert and Dutil 2000; Blanchard et al. 2003) of reproduction, and the potential for overwintering or post-spawning survival (Guillemot et al. 1985; Lambert and Dutil 2000). The positive allometry of reserves and body condition in fishes indicates that larger (and presumably older) fish may make greater reproductive contributions than smaller fish, and also that larger fish may be able to reproduce and survive reproduction under a greater range of environmental conditions than smaller fish.

Maternal age and timing of spawning

Older marine teleosts generally spawn earlier during the reproductive season than younger fish (Berkeley and Houde 1978; Pedersen 1984; Lambert 1987). In a recent study of black rockfish (*Sebastes melanops*) off Oregon, Bobko and Berkeley (2004) found that older fish gave birth earlier in the year than progressively younger fish (a trend also noted in yellowtail rockfish, *Sebastes flavidus*, off southern California, Love et al. 1990). Black rockfish, like other rockfishes, are primitive livebearers and normally produce a single batch of larvae annually. Parturition dates were estimated from advanced stage gonads sampled during the pre-parturition period (Bobko 2002). These data were applied to the age distribution of the population to estimate the percentage of larval production by age class for each week. Birthdates of young of the year benthic juveniles were then determined from daily growth rings on their otoliths, from which estimates were made of the relative contribution to recruitment by time period, and thus by implication, age group. By comparing birthdate distributions to adult spawning output, Bobko (2002) determined whether recruitment was proportional to spawning output or whether certain periods during the parturition season were responsible for a greater proportion of recruits. Results indicated that, in 1 of 3 years, significantly greater recruitment came from earlier in the spawning season, a time when few young fish were spawning.

Timing of spawning is likely to be a highly conserved trait in most fishes, as larval survival is highly dependent on larval production coinciding with peak zooplankton production (i.e., the "match-mismatch hypothesis" of Cushing 1969, 1975). For fishes that exhibit age-related temporal patterns of spawning, elimination of older age classes through fishing will effectively shorten the spawning season. In those years when successful recruitment is centered early in the season, elimination of older age classes could result in recruitment failure that would otherwise be avoidable if the age structure was intact. Indeed, Marteinsdottir and Thorarrisson (1998) found that strong year classes of Icelandic cod (*Gadus morhua*) occurred only when the population contained a broad age distribution, suggesting that this relationship may be applicable to a variety of species.

RYAN BOEREMA

Black rockfish
(*S. melanops*)

Maternal age and egg production

It is well documented that fecundity increases nearly linearly with body mass in adult teleost fishes, and geometrically with body length, which is a decelerating function of age (Weatherley 1972; Wootton 1990). This relationship is due to larger fish not only having a greater body volume for holding eggs, but also devoting a greater proportion of energy stores to egg production. Thus, a 40-cm TL (0.65-kg) bocaccio rockfish produces an average of just over 200,000 eggs per year, whereas an 80-cm (5.41-kg) fish at double the length produces nearly 2 million eggs, nearly 10 times the fecundity (Love et al. 1990). In other words, considering only fecundity per se—let alone egg or larval quality—a single 80-cm bocaccio is worth nearly ten 40-cm fish.

Maternal age and larval quality

A variety of studies indicate that egg and larval size and/or viability also increase with female size and age (Chambers et al. 1989; Zastrow et al. 1989; Buckley et al. 1991). Recent experiments with black rockfish by Berkeley et al. (2004), in which gravid females were held until parturition and the larvae reared under controlled conditions, revealed that maternal age was much more predictive of larval growth and survival than either maternal size or condition index. Larvae from the oldest fish (age 17) survived starvation 2.5 times longer than those of the youngest fish (age 5) (Figure 2b), and grew more than 3 times as fast on the same diet (Figure 2a). These differences may be conservative since larvae were reared under constant environmental conditions, with ad libitum rations in fed treatments and no exposure to predators or competitors (other than their siblings). Results of a multiple regression analysis indicated that maternal age accounted for most of the variability in larval survival and growth. Maternal length provided a small but significant increase in goodness-of-fit. These results suggest that older females produce higher quality larvae, and that females that are both old and large produce the highest quality larvae. The mechanism appears to be the volume of the larval oil globule at birth, which is strongly related to maternal age (Berkeley et al. 2004).

It seems likely that such large differences in growth and starvation tolerance have a profound effect on larval survival and subsequent recruitment (review by Heath 1992). The ability of larval fish to survive a period of starvation is often critical due to the spatial and temporal unpredictability of encountering patches of zooplankton prey (Letcher and Rice 1997). Fast growth has clear benefits in allowing larvae to more quickly pass through the most vulnerable life history stages and to develop more rapidly those morphological and physiological capabilities that improve detection and capture of prey, avoidance of predators, and resistance to other environmental challenges (Miller et al. 1988; Bailey and Houde 1989). Indeed, field studies on marine fish larvae have demonstrated that differences in growth rate, especially in the youngest larvae, can have a profound effect on survival. A doubling of the growth rate in larval bluefish (*Pomatomus saltatrix*) and Atlantic cod (*Gadus morhua*) can increase survival by a factor of 5-10 (Meekan and Fortier 1996; Hare and Cowen 1997). Larval quality can also vary in terms of behavioral attributes directly related to survival (Fuiman and Cowan 2003).

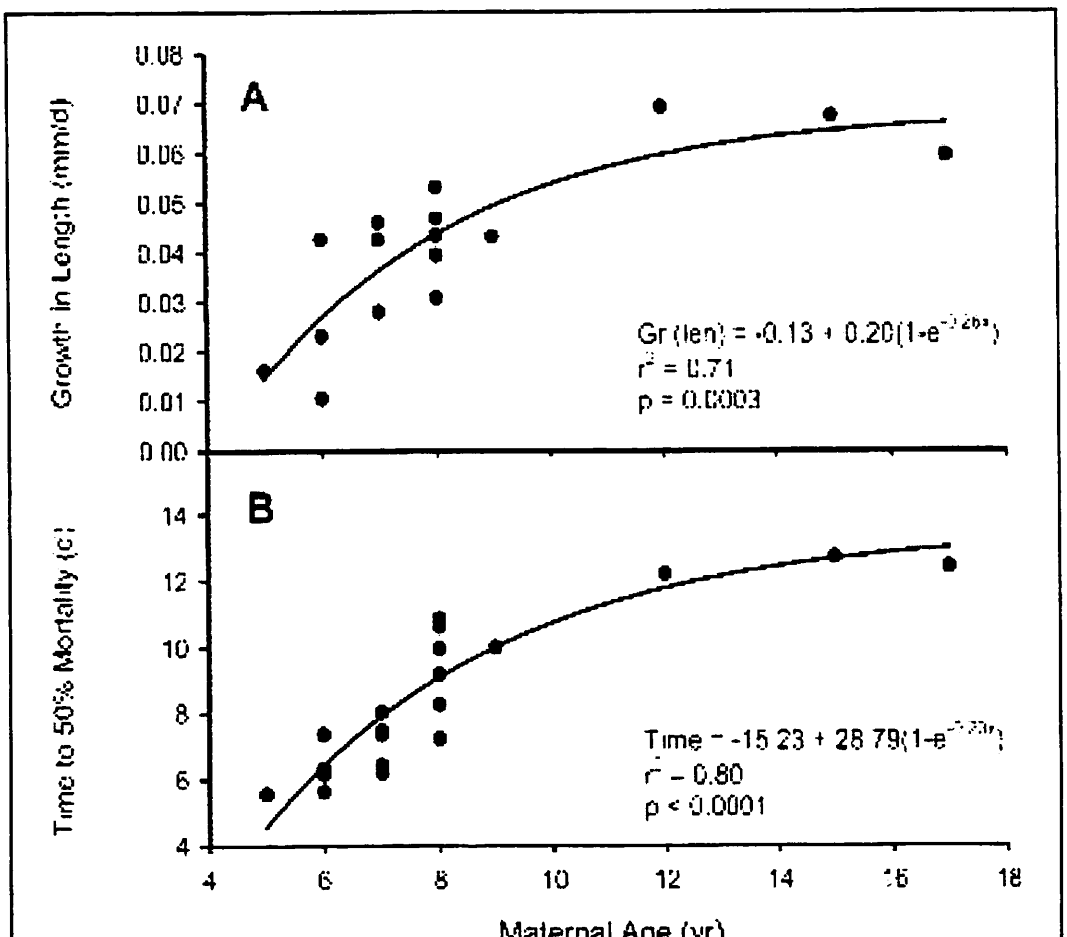


Figure 2. Relationships between maternal age and (A) larval growth rate in length and (B) median time to starvation in larval black rockfish (Berkeley et al. 2004).

AGENDA D-1(b)(4)
FEBRUARY 2005

Fishing Induced Genetic Change

As shown above, fishing generally results in age truncation of the population. It has long been recognized that fishing, by removing the largest and oldest fish inadvertently removes fish that are genetically predisposed to fast growth and late maturation, creating a selection pressure that should theoretically favor early-maturing, slow-growing individuals. Nevertheless, this question has been largely ignored in fisheries management, which tacitly assumes that exploited populations will always retain their inherent rates of productivity and tend to return to their previous levels of abundance. A recent paper by Olsen et al. (2004) challenges these long-held beliefs. Results of this study strongly suggest that heavy and continuous fishing pressure in northern cod resulted in a rapidly-evolved, genetically-based shift in maturation patterns towards earlier and smaller sizes at maturity. The implications of this finding for management are profound. If evolutionary change in response to fishing turns out to be the rule rather than the exception, then, as Hutchings (2004) observed, we must address issues of reversibility of these changes, and their consequences for sustainable harvesting, population recovery and species persistence. At the very least, we believe that these results suggest that some portion of the population should be protected from the impacts of fishing, providing a sanctuary for the genes of fast-growing, late-maturing individuals.

Implications for fisheries management

The findings discussed above have important implications for management of marine fish populations. Current management paradigms for a broad array of species assume, first, that each kilogram of spawning stock biomass is identical regardless of adult age, second, that all larvae have an equal probability of survival regardless of parental age, and third that the effects of fishing are reversible. Recent research reviewed here suggests that some or all of these simplistic assumptions are not true for rockfishes, cod, and striped bass (*Morone saxatilis*), and may not be true for other groundfish as well. Ongoing studies by the senior author are currently examining other species of *Sebastes* to determine whether there is a general pattern of maternal age effects among rockfishes. If so, fishing can have a much greater impact on the reproductive capacity of the stock than the simple reduction in spawning biomass. Maintaining a significant proportion of older fish may be critical to long term stability in exploited fish populations. Murawski et al. (2001) provide an elegant synthesis of these effects in Atlantic cod: fishing mortality rates estimated to cause a collapse in the population are markedly reduced if maternal effects on egg and larval quality are included in modeling analyses. Other studies have also concluded that spawner biomass alone may overestimate the production of viable larvae (Trippel et al. 1997; Scott et al. 1999; Vallin and Nissling 2000).

Age truncation in fished populations is clearly a widespread problem for a broad variety of species (Apollonio 1994; Marteinsdottir and Thorarinsson 1998; Longhurst 2002). For example, there was a severe decline in the abundance of older age classes of black rockfish off Oregon from 1996 to 1999 (Figure 3). These data were derived from nearshore reefs that received intensified recreational fishing pressure in conjunction with the decline and eventual prohibition of recreational fishing for salmon during the 1990s. Port sampling data collected by the Oregon Department of Fish and Wildlife (unpublished data) indicate that groundfish catches by recreational fishermen doubled in the 1990s compared to the 1980s after recreational fishing for coho salmon (*Onchorhynchus kisutch*) was prohibited in 1994. Although this shift in fishing effort was highly localized, and there was some evidence of partial recovery in 2000, the rapid removal of older fish was particularly striking.

Acceptance of the idea that older fish play a pivotal role in replenishing marine fish stocks in general is increasing, as evidenced by the recent reviews of Longhurst (2002) and Francis (2003). Although much of the data presented in this article are specific to Pacific rockfishes, similar findings in cod suggest that our conclusions are more generally applicable to other groundfish as well. Unfortunately, current fishery regulations under most methods of management generally do not protect older fish in the population. Three methods of management can help to conserve older fish in an exploited population: (1) very low rates of exploitation; (2) slot size limits in which there is both a minimum and a maximum size for retention; and (3) marine reserves that set aside areas in which fishing is prohibited and thus older fish can survive and spawn. Under the first scenario, reduced exploitation will allow more fish to reach old age. However, to be effective this strategy may need to reduce fishing to prohibitively low and economically unfeasible levels

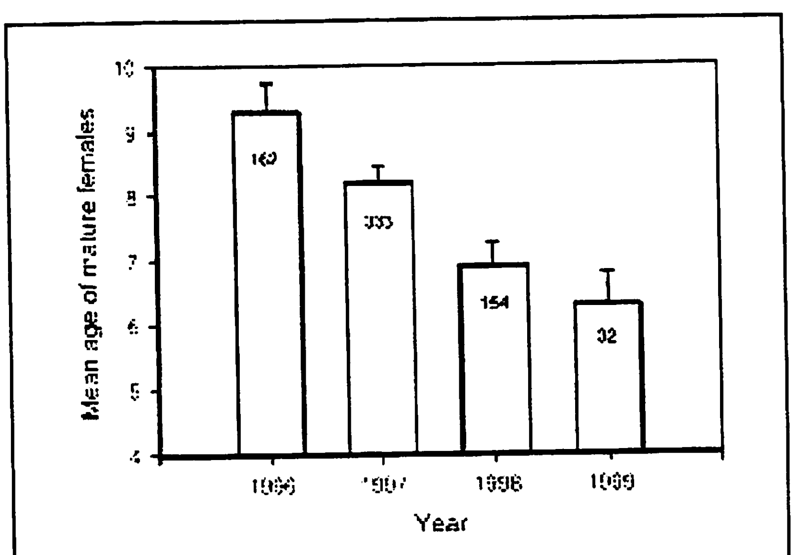
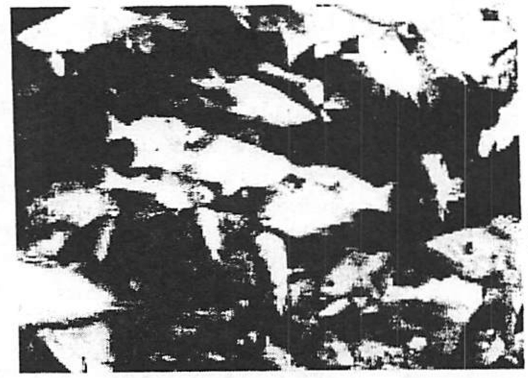


Figure 3. Mean age and 95% CI of mature female black rockfish sampled off the central Oregon coast. Sample size is shown inside bars. All mature fish sampled in each year were included in age calculations.

(see Figure 1). This approach was used successfully in rebuilding Atlantic striped bass populations and restoring age structure (Secor 2000a; Richards and Rago 1999), but involved severe fishing restrictions including a virtual harvest moratorium lasting 5 years (Secor 2000a; www.asmfc.org/).

The second option—a slot size limit—is available only for fishes that can be released unharmed after capture. Fishes that have a swimbladder (all *Sebastes* rockfishes, for example) typically do not survive due to the internal trauma of expansion and rupture of the swimbladder during capture. Swimbladder or not, the condition of many fishes after capture is too poor to ensure subsequent survival, generating the widespread fisheries issue of bycatch mortality (NMFS 1998). An example of the effect of a slot limit on the age composition of a population of fish similar to black rockfish is shown in Figure 4. In this example, we have assumed 25% release mortality for fish above the maximum size (age 12), which for rockfishes is almost certainly a conservative estimate. At B_{40}, a slot limit would increase the number of age classes in the population from 19 to 23 in this example, but the population would still be substantially age-truncated.

The final option to prevent age truncation—marine reserves where all fishing of target species (including bycatch) is prohibited— has the potential to allow at least a segment of the population to age naturally and export larvae produced by a broad age range of female spawners (Murray et al. 1999). These benefits are not limited to rockfishes, but would apply more generally to other groundfish as long as the adults tend to stay in the reserve. Further, as reviewed here, successful recruitment may come from restricted temporal and spatial oceanographic windows that change from year to year (Larson et al. 1995), suggesting that management measures should be implemented to preserve minimal spawning stock sizes over the entire geographic range of the stock (Larson and Julian 1999). Marine reserves, placed to represent different habitats within biogeographic and oceanographic regions, therefore offer benefits to stocks that *cannot be achieved by any other means*. No other method of management, even slot limits, can preserve the potential for longevity as well as marine reserves and allow the unique contributions of older fish to accrue to the population. We believe that the implementation of such spatially explicit management tools, combined with conventional approaches, is essential for the replenishment and sustainability of groundfish stocks.



DONNA SCHROEDER

Bocaccio (*Sebastes paucispinus*)

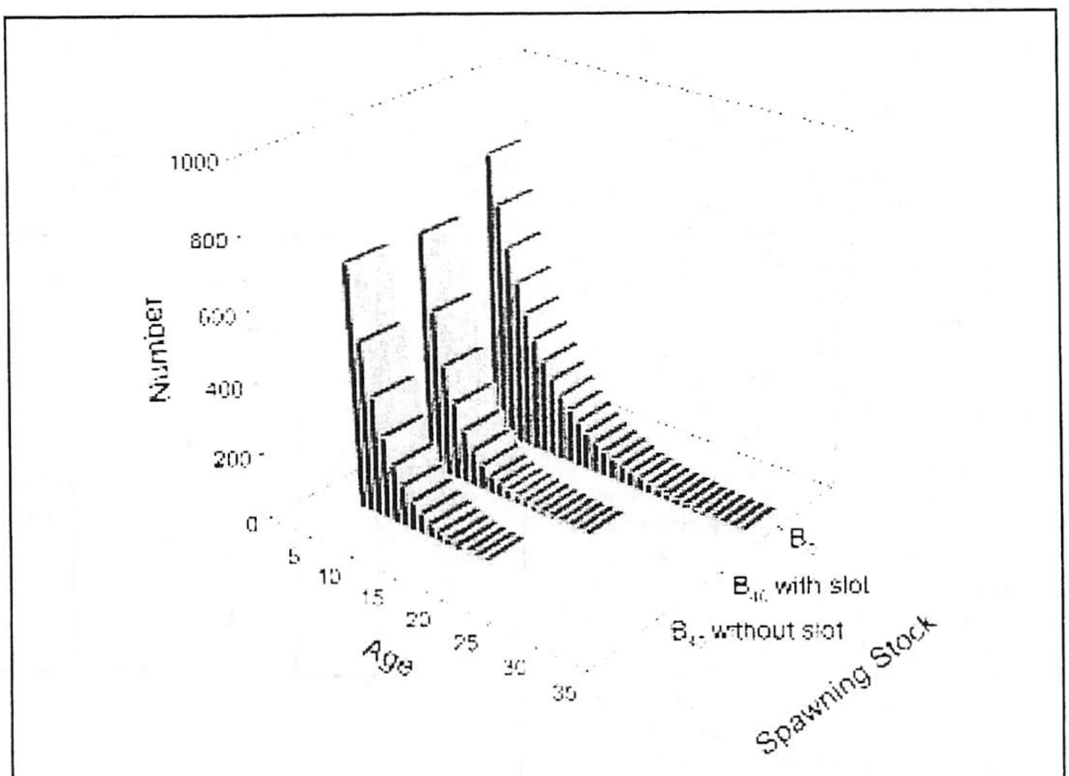


Figure 4. Theoretical effect of a slot limit on the age composition of a population of fish with the same growth and natural mortality characteristics of black rockfish. In this example, the stock is fully vulnerable to fishing between ages 4 and 12 (the slot). Fish older than age 12 are assumed to experience 25% release mortality. Fishing mortality is set at a rate that will result in B_{40} (F = 0.184 with the slot limit; F= 0.165 without the slot limit). The cohort is considered eliminated when less than 0.5% of the initial cohort (at age 4) remains. For comparison, the theoretical age composition of the virgin stock (B_0) is also shown. The unfished stock contains 33 age classes compared to 23 age classes with the slot limit and 19 age classes without the slot limit.

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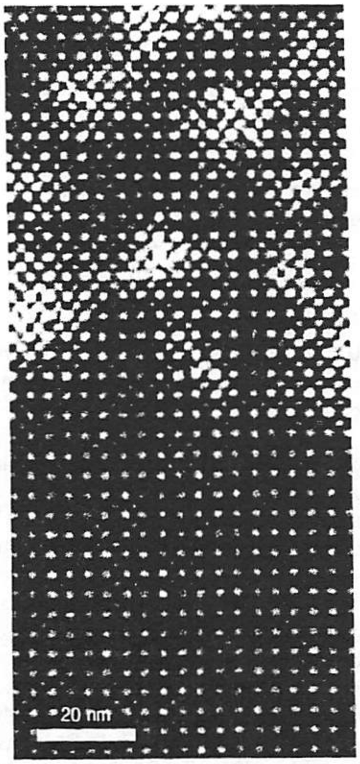

Figure 2 **What a difference a layer makes. The abrupt junction between layers of $SrTiO_3$ (bottom) and $SrTiO_{3-\delta}$ (top) is clear in this image created by Muller *et al.*[3] using a scanning transmission electron microscope. Each bright-orange blob is a cluster of oxygen vacancies.**

defects; simultaneously, the energy loss of the transmitted electrons is measured, revealing the electronic effects of the missing oxygen atoms on the surrounding atoms (that is, changes in their oxidation state). This powerful technique[6] offers outstanding sensitivity in resolving and identifying columns of atoms in crystalline samples, and has been used to image individual impurity atoms in silicon[7].

The team scanned their layered samples in cross-section and spotted regions in which as few as two oxygen atoms were missing. And here came the second breakthrough. The STEM images (such as the one in Fig. 2) show that the oxygen vacancy concentration can change with surprising abruptness — from a layer with no oxygen vacancies to a layer with some constant number of vacancies over a distance of only 0.4 nm (the thickness of a single unit cell of $SrTiO_3$). At 700 °C, oxygen diffuses in minutes over many micrometres[8], which would be expected to completely level out any nanometre-scale steps in the oxygen concentration profile. But it does not. That such sharp doping profiles are achievable is excellent news for the development of devices involving doped $SrTiO_3$ layers, as it has the highest mobility of any known oxide at low temperature[9]. Yet the data do raise the question of why the profiles are so crisp. Are, for example, the oxygen vacancies or the sample microstructure stabilized by an as-yet-unknown mechanism, which may even be applicable to other ionic materials? No doubt Muller and colleagues will set about unravelling this puzzle too.

This work greatly broadens the options available for manipulating the electronic properties of oxides, and probably ionic materials of all sorts, at the nanometre scale. At present, the standard means of doping is to replace one cation with a different cation (that is, an impurity). But the ability to dope films without introducing impurities — thereby avoiding the risk that they might ride on the growing surface or hang around in the deposition chamber and become incorporated at undesired locations — is an enticing advantage of doping with vacancies. As films can grow by the lateral movement of steps as atoms are incorporated, even lateral doping using vacancies might be possible, analogous to the lateral superlattices and one-dimensional wires created using conventional semiconductors[10]. Muller and colleagues show how a view of nothing can turn gems into electronics. ■

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Fisheries science

Why mothers matter

Stephen R. Palumbi

Fish population growth depends on older mothers, which in some species produce more and 'better' offspring than younger fish. When fisheries remove the most productive females, the whole population suffers.

English literature about the ocean is predominantly male. Ernest Hemingway's *The Old Man and the Sea* was about an aggressive fight against the elements and the imponderable deep, with the main protagonist being the masculine *el mar*. But the real state of fisheries depends more on the role of females in the replenishment of fish populations. As Steven Berkeley and colleagues[1] now report in *Ecology*, that role has surprising facets. They find, contrary to popular wisdom, that in the black rockfish, older, larger female fish produce eggs and larvae that are much more likely to survive. From the standpoint of population growth rate and the potential to recover from overfishing, the old saying and country-and-western lyric may apply more often than Hemingway: "If Momma ain't happy, ain't nobody happy."

Larger female fish are vastly more productive than their smaller sisters. A single 61-cm-long red snapper (*Lutjanus campechanus*) has been estimated to produce as many eggs as 212 43-cm-long snappers[2]. This is largely because eggs are produced in proportion to a fish's volume, which is proportional to the cube of its length. The profligate fecundity of larger females has long been cited as a good reason to preserve fish populations in 'no-take' marine reserves. In some cases, larger fish in these reserves may double a species' egg production — even if the reserves encompass only 5% of the marine habitat[3].

Berkeley and co-workers[1] have documented another benefit from larger, older females. They studied rockfish of the genus *Sebastes* (Fig. 1, overleaf), and found that eggs from older females produced larvae that grew faster and were more resistant to starvation than larvae from younger females. The differences were huge: on the same diet, larvae of 12-year-old rockfish grew four times faster than larvae produced by 5-year-old rockfish. At the same time, offspring of older females had more metabolic reserves: larvae took an average of 12 days to starve whereas offspring of 5-year-olds starved in less than half that time.

The central difference lies in a small post-hatching gift each mother gives her offspring, a little oil droplet that serves as a metabolic reserve after the yolk-sac has been absorbed (Fig. 2). Older females provide a larger droplet than younger ones, ensuring a better head start for their larvae as they drift through the oceans, feeding and developing into juvenile fish capable of settling to the sea floor. Larger females, and females in better physical condition, produce better larvae as well, but these effects are slight compared with the effects of age. Such observations are

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particularly surprising in light of long-held views that the optimum reproductive allocation per offspring should be independent of age or parent size[4]. Berkeley and colleagues are not sure why age makes such a difference, but there may be hidden age-related shifts in reproductive effort that will eventually provide an explanation.

These data are also important for attempts to rebuild overfished rockfish populations. Fishers value larger, older fishes — remember Hemingway — and strip away these larger individuals from the reproductive populations. In other fish, such as grouper species that change sex from smaller females to larger males, this tendency to take larger fish has long been known to reduce the number of mature males. Some grouper spawning aggregations have fewer than one male for dozens of females[5], and this imbalance exhausts the fertilization abilities of the few surviving males. The opposite problem is seen in shrimp and crab populations where small males change into larger females[6]. Fishing down the family tree in these cases removes females first, and cuts egg production dramatically[7].

The new data show why heavy fishing pressure on older fish is also a serious problem in species that don't change sex. For example, in coastal Oregon, Berkeley and colleagues[1] document a decline in the average age of female rockfish from 9.5 years to 6.5 years during a period of intensified bottom fishing from 1996 to 1999. Such a culling of the older females reduces the average growth rate of larvae in the population by about 50%, and probably reduces the ability of these larvae to grow and survive to the next stage in their life history. Data on cod and haddock also show that larger females produce larger eggs: presumably these larger eggs produce better larvae[8,9]. The conclusion is that standard fisheries management tools that consider every female to be reproductively equivalent can be far off the mark.

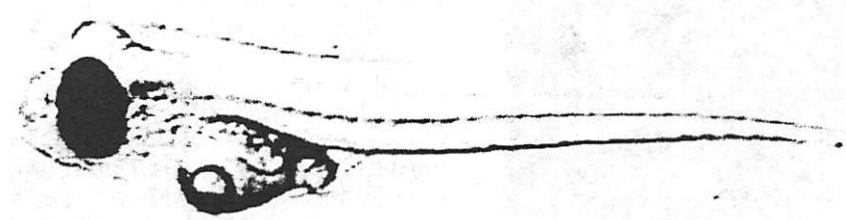

Figure 2 **Post-hatching gift. A larva from a 17-year-old black rockfish (*Sebastes melanops*), showing the large oil droplet used to fuel growth and stave off starvation. Younger mothers produce larvae with smaller droplets that are less likely to survive to the juvenile stage. (Courtesy S. Berkeley.)**

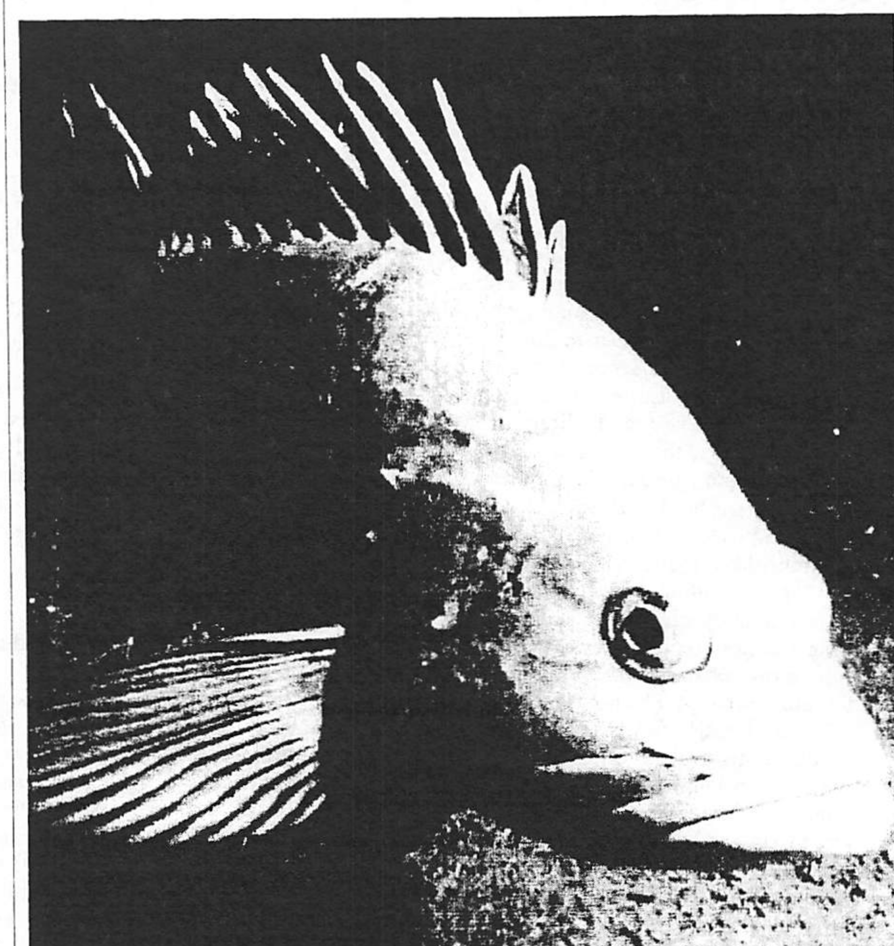

Figure 1 **Yelloweye rockfish (*Sebastes ruberrimus*) from the west coast of North America. Berkeley *et al.*[1] find that older female rockfish produce larvae that have higher rates of growth and survival than those produced by younger mothers. (Courtesy Victoria O'Connell, Alaska Department of Fish and Game.)**

Marine reserves change the landscape of fishing regulations by protecting the entire local populations of fish and invertebrates. The resulting dramatic reduction in mortality has an immediate benefit in producing larger fish in reserves — an effect that has been seen in tropical and temperate settings, along reefs, kelp beds and in estuaries. So protecting larger, older females can be more efficient in producing larger numbers of higher-quality offspring. Not all fisheries suffer from the need for more offspring. But because reproduction is the fuel that keeps all fisheries alive from one generation to the next, enhancing the success of larvae is a key to a sustainable fisheries future.

And Hemingway's Old Man Santiago may have known the power of females in the sea all along. Younger fishermen thought of the sea as masculine: "But the Old Man always thought of her as feminine and as something that gave or withheld great favours"[10]. Those favours are written in the next generation of the sea's creatures, and these new research results tell us that it is the favours of the mothers that matter most. ■

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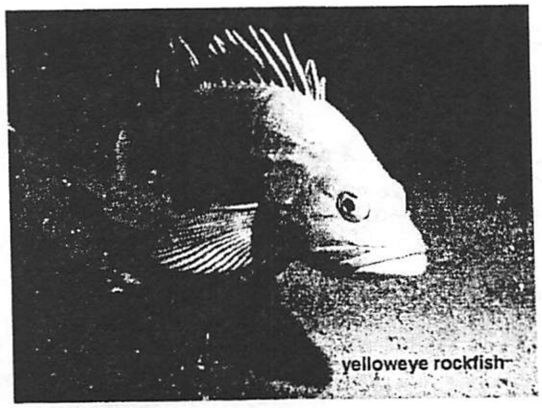
Rockfish Management:
Are We Circling the Wagons Around the Wrong Paradigm?

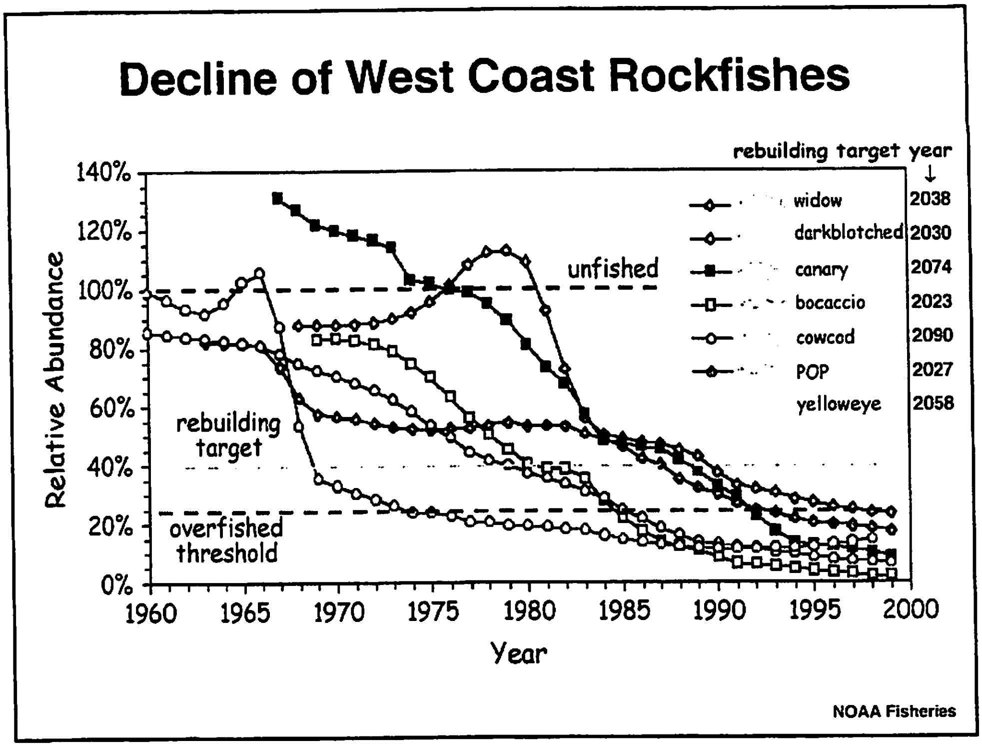


Steven Berkeley, Long Marine Lab, U. C. Santa Cruz
Mark Hixon, Department of Zoology, Oregon State University
Ralph Larson, San Francisco State University
Milton Love, U.C. Santa Barbara

Rockfish species whose status has been assessed:

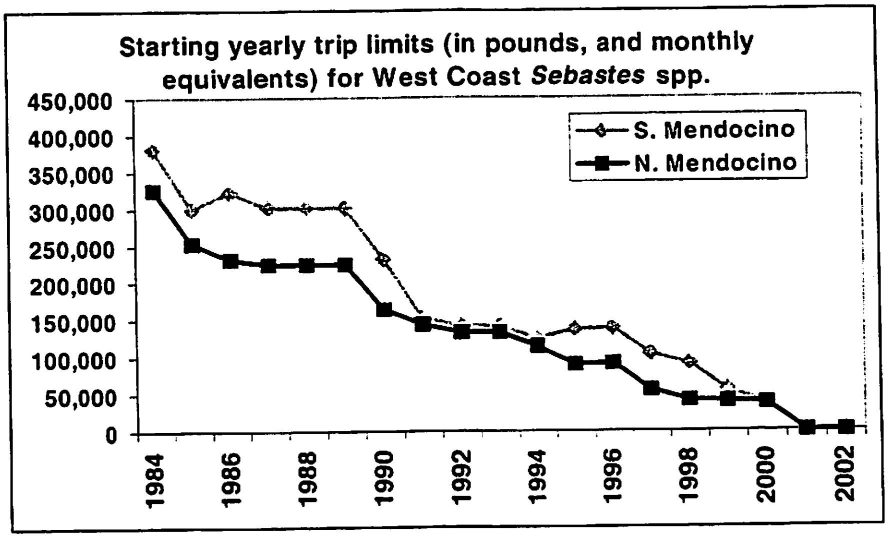
Black	Pacific Ocean Perch
Bocaccio	Shortbelly
Canary	Shortspine Thornyhead
Chilipepper	Splitnose
Cowcod	Widow
Darkblotched	Yelloweye
Longspine Thornyhead	Yellowtail

Red = overfished (7 = 50%)
Blue = not overfished (7 = 50%)
Total rockfish species in FMP = 63 (22% assessed)

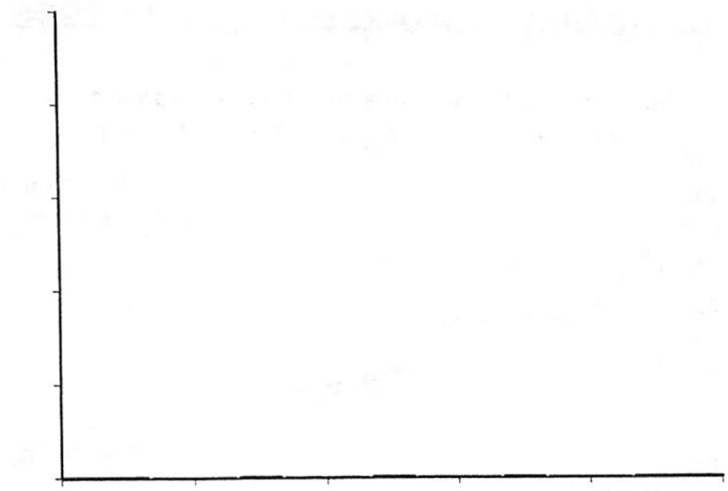


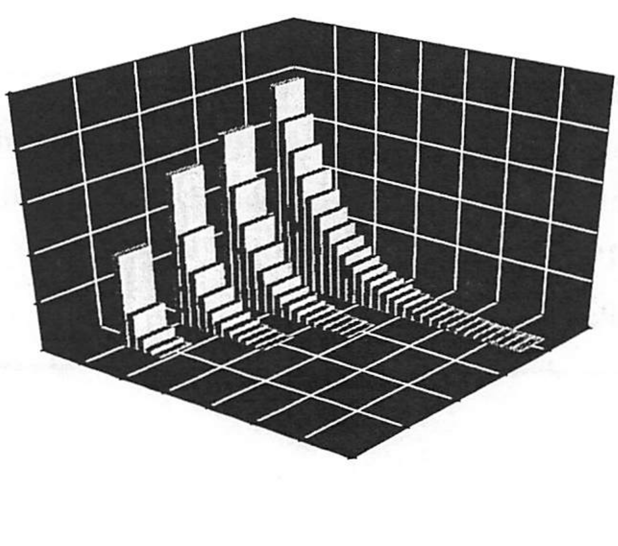
Species	Maximum Age	Age at 50% Maturity
Black	40	6
Bocaccio	50	?
Canary	84	8
Cowcod	55	?
Darkblotched	105	8
Pacific Ocean Perch	100	8
Widow	60	6
Yelloweye	118	19

"Folly, the perverse persistence in a policy demonstrably unworkable" (Smith 1998)



Current management is based on controlling fishing mortality to maintain the spawning biomass at 40% of the level that would exist without fishing.





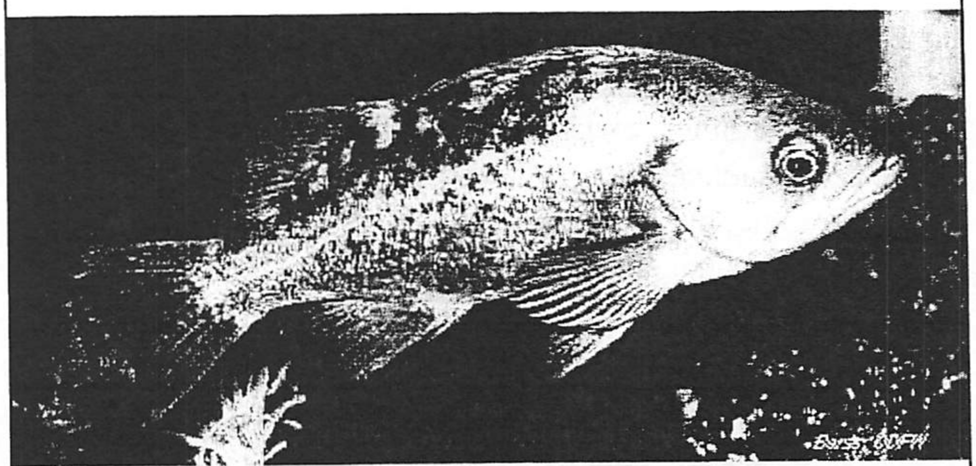
For at least those stocks with highly episodic recruitment, the consequences of age-class truncation may be catastrophic, but this possibility is ignored by conventional fish stock management techniques.

Longhurst, 2002.

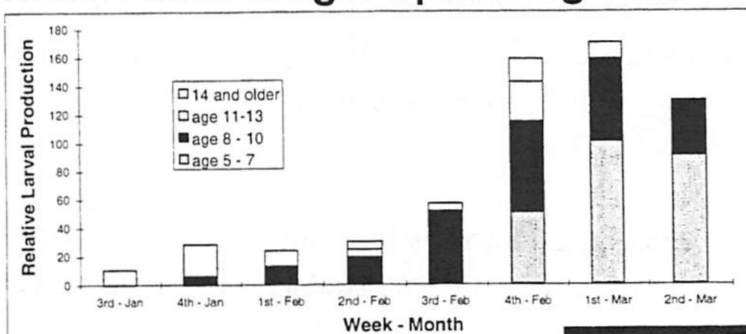
Fundamental Assumptions of Conventional Fisheries Management:

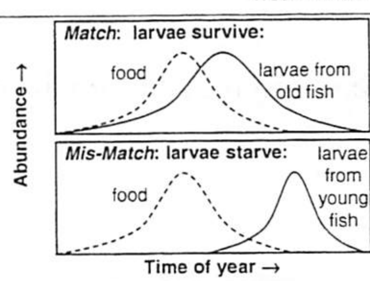
1. Larvae of all females have an equal probability of survival regardless of maternal age, or time or location of spawning.

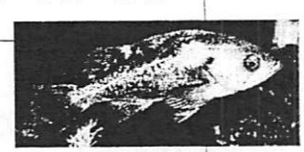
2. Stocks are well-mixed, so it makes no difference where fish are caught, only how many.



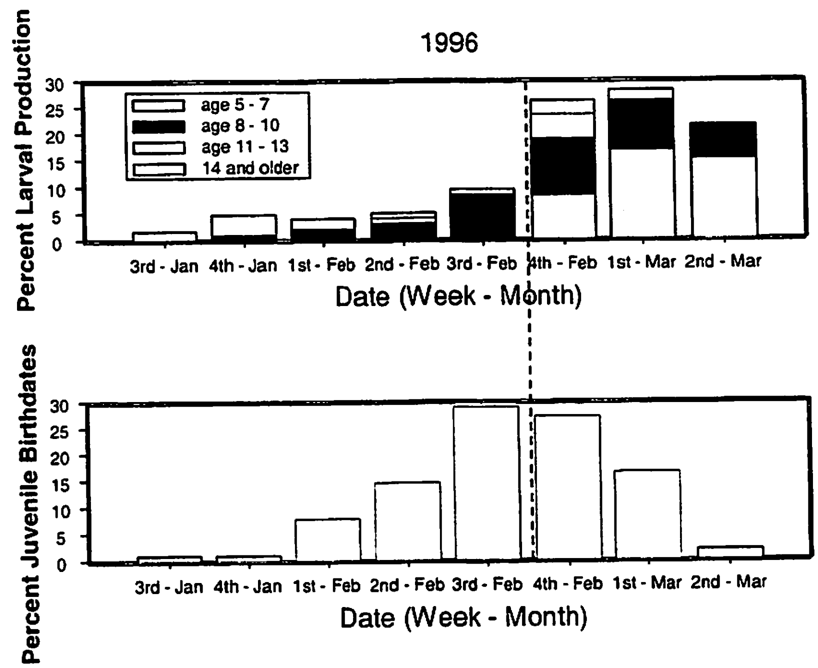
Old fish have longer spawning seasons:



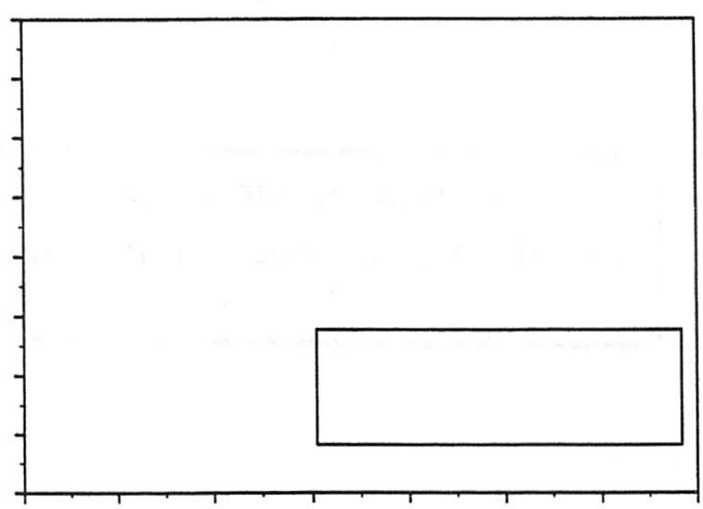


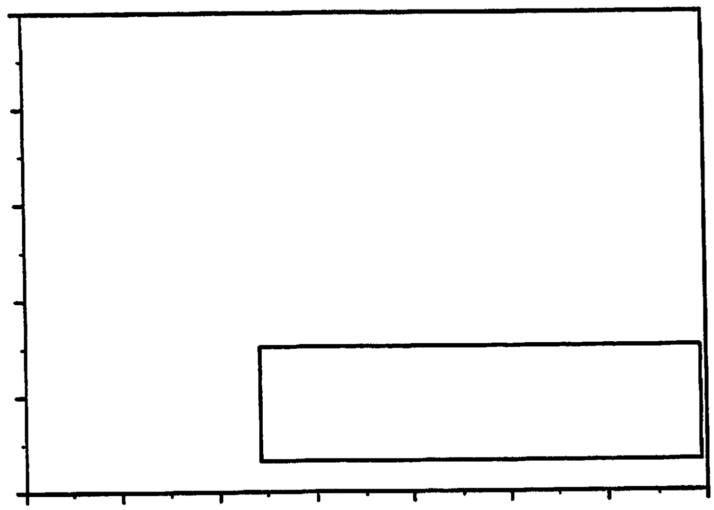


Bobko & Berkeley (2004)



What about larval quality?
Do older fish produce more competent larvae?





So, all spawning biomass is not equivalent. Maternal age affects the time of larval production and the length of the spawning season.

And all larvae are not equivalent. Larvae of older females are more competent and almost certainly more likely to survive.

Assumption of conventional fisheries biology:

Stocks are well-mixed.

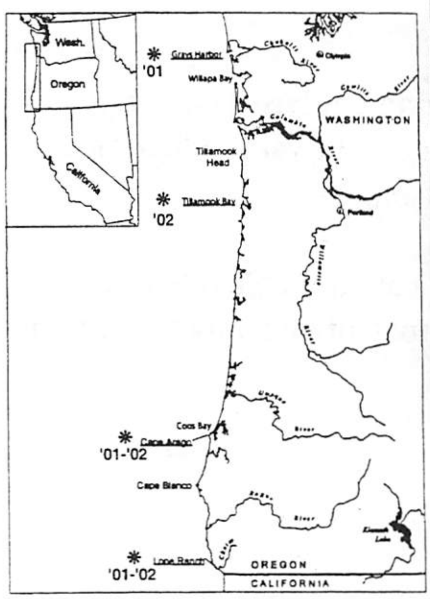
New data:

Stocks are actually comprised of multiple, reproductively distinct units.

Multiple stocks per rockfish species

4 population subdivisions off Oregon and southern Washington:

identified from chemical signatures in daily growth rings of otoliths



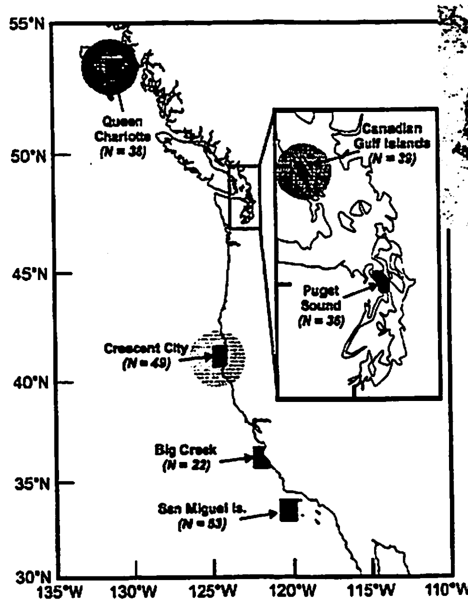
otolith (ear stone) rings

Miller & Shanks (2004)

Multiple stocks per rockfish species

3 population subdivisions between Puget Sound and Pacific Coast, with a genetic gradient along the open coast:

identified from microsatellite DNA at 6 loci

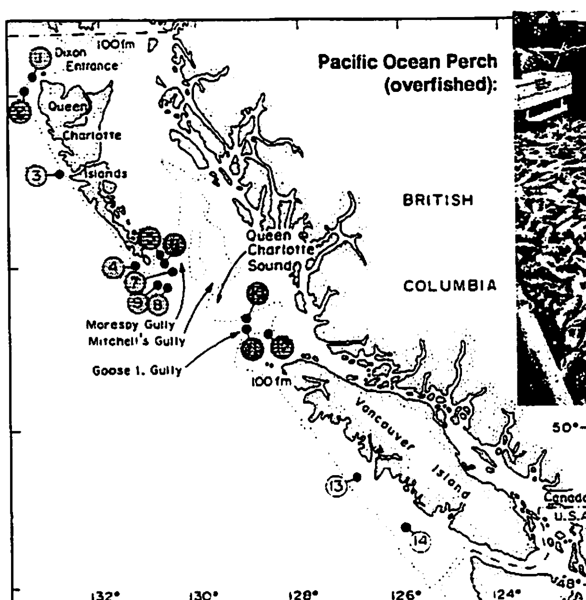


Buonaccorsi et al. (2002)

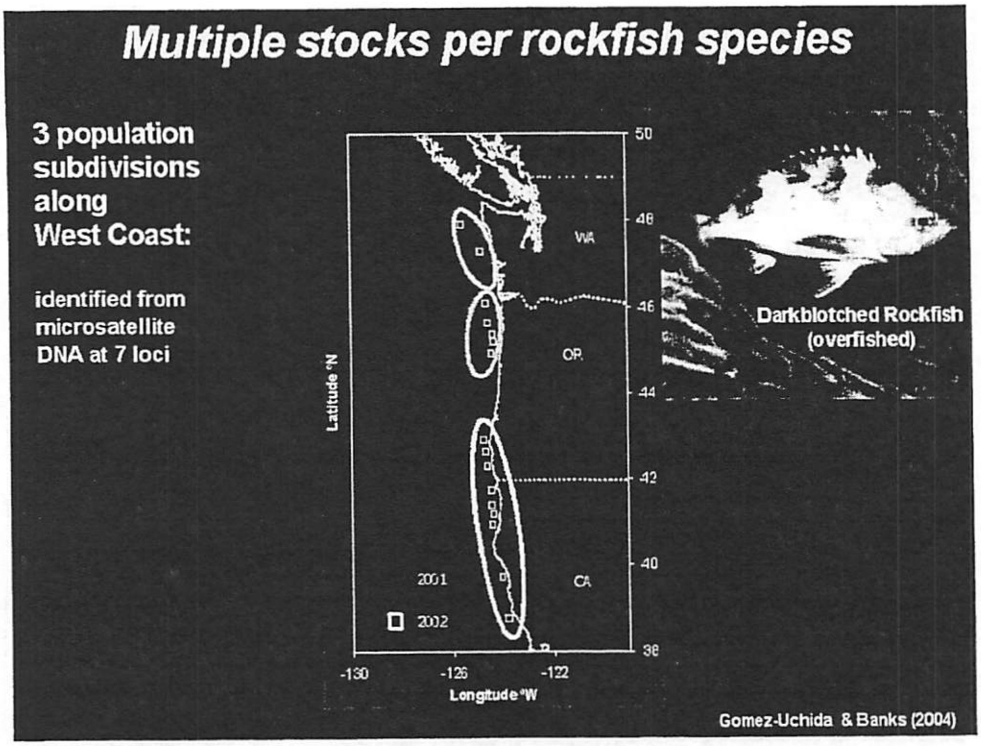
Multiple stocks per rockfish species

3 population subdivisions off British Columbia:

identified from microsatellite DNA at 5 loci



Withler et al. (2001)



But, it may be more complicated than that. Recruitment may come from restricted temporal and spatial oceanographic windows which vary from one year to the next (i.e. the sweepstakes-chance matching hypothesis, Hedgecock, 1994).

Shortbelly rockfish
Genetic Diversity Within Samples (Nei's H statistic: Diagonal)
Genetic Differentiation Between Samples (Nei's G: Off-Diagonal)

Larson, R. J, C. Orrego and R.W. Julian, 1995. (* $p<0.10$; ** $p < 0.05$)

N_e estimates for cohort pairs

Cohorts	F_k	S	N_e	95% CI
1995-1996	0.0028	48-82	2,073	1,456-2,798
1996-1997	-0.0002	82-123	∞	-
1997-1998	0.0012	123-67	4,807	3,367-6,500
1998-1999	-0.0015	67-627	∞	-
1999-2000	0.0001	627-140	101,728	73,470-134,513
Mean	0.0005		12,345	8,692-16,416

$N = 16.7 \times 10^6$ (spawning population)[1]; $N_e/N \approx 10^{-3}$

1. Mean estimate (1964-2003) from Rogers et al. (2000) Status of the darkblotched resource in 2000. PFMC (www.pcouncil.org)

Gomez-Uchida & Banks (2004)

Fundamental Assumptions of Conventional Fisheries Management:

1. Larvae of all females have an equal probability of survival regardless of maternal age, or time or location of spawning.

2. Stocks are well-mixed, so it makes no difference where fish are caught, only how many.

So, what do we know that suggests a new management approach may be needed?

For at least some species, we know:

1. Older fish spawn earlier than younger fish.
2. Larvae of older females are more likely to survive.
3. Stocks are much more complex than previously thought so local depletions might not be replenished from other areas.
4. Recruitment may come from distinct time/area windows that vary from year to year.

So, what do we do about these findings? Can conventional management approaches accommodate this new information and if not, what tools are most appropriate?

Looking only at how different fishing strategies affect age structure which in turn affects larval survival:

1. B_{40}
2. Slot limit w/25% release mortality
3. 20% marine reserve
4. Reduced fishing mortality rate

Mgmt Strategy	Spawning Age Classes	% Virgin SSB	% Yield Relative to B_{40}	% of Virgin Age 12+ SSB
B_0	29	100	0	100
B_{40} (F=0.177)	15	40	100	12.5
Slot (w/25% rel. mort)	19	40	94	18.3
20% MR (F outside = 0.316)	29	40	96	22.3
F adj to MR on table (F=0.124)	17	50	85	22.3
20% MR off table (F outside = 0.177)	29	52	80	30.0
F adj to MR off table (F=0.0982)	19	56	75	30.0

Management Strategy	Effective Larval Output (% of B_{40})
B_0	314
B_{40}	100
Slot (w/25% release mort.)	103
20% MR on table	107
F adj to 20% MR on table	132
20% MR off table	143
F adj to MR SSB off table	154

Mgmt Strategy	Recruitment (% of B_{40})	Yield (% of B_{40})
B_{40} (F=0.177)	100	100
Slot w/25% release mort.	103	97
20% MR on table	107	103
F adj to 20% MR on table (F=0.1635)	107	103
20% MR off table	143	115
F adj to 20% MR off table (F=0.110)	143	115

Conclusions:

	Fishing Mortality	Marine Reserves	Slot Limit
Time of spawning	Maybe	Yes	Probably not
Age structure	Maybe	Yes	Probably not
Stock spatial complexity	No	Yes (if networked)	No
Hedgecock effect	No	Yes (if networked)	No

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FEBRUARY 2005

Analysis of Localized Depletion for Bering Sea/ Aleutian Islands Rockfish

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Introduction

The Statistical and Scientific Committee (SSC) of the North Pacific Fishery Management Council requested in their December, 2003, meeting:

a. A listing of species of rockfish which are most likely to be subject to local depletions either because of life-history characteristics or fishing practices;

b. The availability of data for those species which could be used to evaluate the occurrence of local depletion; and

c. The quality of data that would be needed to detect local depletion with reasonable certainty.

Localized depletion is defined here as the reduction of population size over a relatively small spatial area as a result of intensive fishing. Localized depletion is a potential conservation issue for rockfish because several species have been observed to be patchily distributed and stock structure could occur at relatively small spatial scales; thus local depletions could affect local spawning populations to a greater degree than the overall population. For example, three genetically distinct stocks of Pacific ocean perch have been observed off the coast of British Columbia (Wither et al. 2001). Other species of rockfish, such as rougheye and shortraker rockfish, have adult phases that appear strongly associated with rugged benthic habitats and appear relatively sedentary as adults. Genetic studies for rougheye and shortraker rockfish indicates that genetic stock structure occurs at broad spatial scales that are consistent with areas used for management in Alaskan waters, although what might be considered as appropriate management units may have a smaller spatial scale than the genetic population structure. Apart from genetic information for some species, much is unknown about the spatial structuring of rockfish populations within the Aleutian Islands. Because the population structure of Aleutian Islands rockfish could potentially be complex, most rockfish species in this area may be susceptible to localized depletions, including Pacific ocean perch, northern rockfish, shortraker rockfish, and rougheye rockfish.

Localized depletion is dependant upon fishing intensity of sufficient strength to reduce the population size, and it is important to note that a target rockfish fishery in the Aleutian Islands exists only for Pacific ocean perch. Typically, analyses of localized depletion use the catch-per-unit-effort (CPUE) from directed fishing as an index of abundance, but in the absence of directed fishing one would not necessarily expect the changes in CPUE to directly reflect changes in abundance. For example, the catch of northern rockfish in the Aleutian Islands is obtained predominately in the Atka mackerel fishery, and declines in CPUE of northern rockfish fishery could either reflect declines of northern rockfish biomass or the increased use of areas where northern rockfish bycatch is minimized. One could potentially use a survey to detect localized depletion of bycatch species, but the sampling intensity of trawl surveys in the Aleutians is not sufficient to detect population declines within small areas. For these reasons, Pacific ocean perch are the only species in the Aleutian Islands that are expected to have data available for an analysis of localized depletion. There are localized areas where high catches of some other rockfish species have occurred, such as rougheye rockfish in the Seguam area, but the lack of a target fishery and the relatively few hauls where rougheye are the most dominant rockfish in the catch impedes a quantitative approach to estimation of depletion.

The Leslie model (as described by Ricker 1975) has generally been used to assess local depletion, and has been applied to cases where intensive fishing has been applied to relatively sedentary species in well-defined areas. The Leslie model assumes that (1) the population is closed to immigration and emigration; (2) the catchability of the fishing gear remains constant, and (3) changes in CPUE are directly related to abundance. These assumptions are met if directed fishing occurs within a well-defined area of study within a relatively short time. The purpose of this manuscript is to assess the extent to which localized depletion has occurred for Pacific ocean perch in the Aleutian Islands.

Methods

Data selection

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Trawl hauls from the POP fishery sampled for species composition by the North Pacific Groundfish Observer Program were used to identify potential areas of study (Figure 1). A targeting algorithm was used to assign hauls to target species, with POP hauls being defined as those hauls in which rockfish was the largest component of the catch and POP were largest component of the rockfish catch. The resulting maps indicate that three areas appeared to have consistent POP targeting over a number of recent years: (1) the Buldir Reef area; (2) northwest of Buldir Island; and (3) northeast of Atka Island.

The POP fishery in the Aleutian Islands is conducted by vessels larger than 125 feet and thus has observer coverage on 100% of the days fished, with the total catch, depth, location, and hours fished recorded for each haul. A random selection of hauls is sampled for species composition. Unsampled hauls were assigned to the POP targeted fishery if they occurred on the same vessel, cruise, date, area, and depth in which sampled POP hauls were observed. The POP catch for unsampled hauls was estimated by applying the proportion of POP in the total catch of the sampled hauls to the total catch for the unsampled haul.

The POP fishery has occurred during a relatively brief time in recent years, typically beginning in late June or early July and extending for only a few weeks to no later than late July. The number of hauls and estimated POP catch from hauls targeting POP during the POP fishery from 2000-2004 in each of the three study areas is shown in Table 1, separated by hauls sampled for species composition and unsampled hauls where POP catch was estimated. The Buldir Reef area in 2003 and 2004 shows 33 and 34 POP hauls that contributed 28% and 31% of the total POP catch in the western Aleutians, repsectively; approximately three-fourths of the hauls were sampled for species composition. In contrast, in 2002 8 POP hauls were observed and no POP hauls were observed in 2000 and 2001. The number of POP hauls in the northwest Buldir area from 2002 to 2004 ranged from 14 to 32, contributing 14% to 27% of the total POP catch in the western Aleutians; the proportion of hauls sampled for species composition was greater than 75% during these years. In contrast, in 2000 and 2001 eight and three POP hauls were observed, respectively. In the northeast Atka area, the number of POP hauls from 2000 to 2004 ranged from 15 to 36, contributing from 24% to 38% of the POP catch in the eastern Aleutians during this time. The proportion of these hauls sampled for species composition ranged from 52% in 2001 to 94% in 2004.

Data from 2003-2004 in the Buldir Reef area, 2002-2004 in the northwest Buldir area , and 2000-2004 in the northeast Atka Island area were selected for analysis of depletion using the Leslie model. Years 2000 to 2002 in the Buldir Reef area were not used because of small sample sizes, as were years 2000 and 2001 in the northwest Buldir area. Although some years in the northeast Atka area showed relatively small sample sizes (i.e., less than 20), all years from 2000 to 2004 were included in the interest of producing a time series of depletion estimates by year. Similarly, data from the northwest Buldir area in 2004 was included for analysis to despite a sample size of 14 to examine the most recent data for this area. Within year and area, the catch per unit effort for each day was computed as the total POP caught (tons) divided by the total hours fished. The number of vessels ranged from 2 to 5 per year and area, and no fishing power correction was applied between vessels.

The Leslie method assesses population depletion by a fishery via a linear decline in the CPUE as a function of cumulative fish catch since the start of the fishery:

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$$\frac{C_t}{f_t} = qB_0 - qK_t$$

where C_t and f_t are the total catch and effort, respectively, for a daily time period t, B_0 is the initial biomass prior to the start of the fishery, q is the catchability coefficient defining the proportion of B_0 that is taken with one hour of trawling, and K_t is the cumulative catch taken prior to period t plus one half the catch during period t. For cases where estimates of q were significantly less than zero, confidence bounds of B_0 were determined from equations 2.6 and 2.7 in DeLury (1951).

Results

Buldir Reef

The point estimate of catchability for Buldir Reef in 2003 was negative, giving the counter-intuitive result that CPUE increased with cumulative catch (Table 2, Figure 2). In 2004, the estimated catchability was 0.0061. The estimated 95% confidence bounds indicate that neither the 2003 or 2004 estimates of catchability were significantly different from zero.

Northwest Buldir

The point estimates of catchability on the northwest Buldir area increased from 0.0034 in 2002 to 0.0149 in 2003 and 0.0189 in 2004 (Table 2). For the analysis of the 2002 data, the CPUE on final day of the fishery was substantially larger that any other day (Figure 3), and this day was excluded in order to obtain a positive estimate of catchability. The 95% confidence limits on these point estimates indicate that catchability was not significantly different from zero in 2002, but was significantly differently from zero in 2003 and 2004. The point estimate of initial biomass in 2003 was 2056 t, with 95% confidence limits of 1477 t to 6809 t. Note that the estimates of catchability and B_0 for 2003 are sensitive to the CPUE on the initial day of the fishery, which more than twice that observed for any other day. The mean CPUE for this day is based upon three hauls and reflects a single very large haul with an unusually high CPUE. If this day is removed from the analysis, the estimated q drops from 0.0149 to 0.006 and is no longer significant from zero. The 2004 point estimate of initial biomass was 1287 t, with 95% confidence limits of 825 t to 2940 t.

Northeast Atka

The point estimates catchability in the northeast Atka area ranged from -0.0125 to 0.0252 during 2000-2004, and the 95% confidence bounds indicate that none of these point estimates are significantly different form zero (Table 3, Figure 4).

Discussion

The underlying principle of Leslie depletion estimates is that intensive fishing occurs such that that CPUE is markedly reduced over the length of the fishing season, allowing one to make reasonable estimates of catchability, initial population size, and exploitation rate. Of the 10 area-year combinations analyzed here, two produced the counter-intuitive result of increasing CPUE during the fishery, and a third would have produced this result had the CPUE fro12he final day of fishing not been removed from the analysis. Of the remaining 8 analyses, 6 produced estimates of catchability that were not significantly different from zero. For these area-year combinations, the available data do not indicate significant declines in CPUE that would suggest localized depletion.

The two area-year combinations where estimates of catchability were significant were northwest Buldir in 2003 and 2004. As mentioned above, the estimates of catchability for 2003 are sensitive to the initial day of fishing, which in turn is influenced by one haul with an unusually high CPUE. If localized depletion occurred within these years, it does not seem to have carried over between years. For example, after the first day of the fishery in 2003 the subsequent four days showed daily CPUE of approximately 15 t/hr before declining to 10 and 5 t/hr in the final two days. If localized depletion were to carry across to subsequent years, one would expect the CPUE in 2004 to be consistent with estimates observed near the end of the 2003 fishery. However, examination of the 2004 data indicates that the initial CPUE was near 25 t/hr, and the CPUE observed on subsequent days was approximately 15 t/hr, consistent with most of the days in 2003 before the end of the fishery. It appears that any population decline during the 2003 fishery has been replenished by population movement and/or recruitment before the 2004 fishery.

One of the features of the POP fishery is that it is limited to only a few days each year in any given area, and the total number of hauls from which a daily CPUE can be computed may be limited to three or less for some area-day combinations. As seen in the 2003 northwest Buldir data, these low sample sizes can potentially have a large influence on the results. Ideally, one would combine time periods such that more hauls were included in each time interval, but that generally was not possible with the data available. It should be recognized that the numerous cases where catchability was not significantly from zero likely reflects the limited data associated with fisheries of short duration and limited numbers of hauls. Also, the appropriate size of study area should be sufficiently small to consider the population as a single homogenous unit within that area. Although the study areas chosen for this analysis are small relative to the entire Aleutian Islands management area, it is possible that these areas are large enough to reflect a non-uniform distribution of POP. For example, the high CPUEs often observed in the initial day of a fishery may have occurred on distinctly different fishing grounds within the study area than the remaining hauls.

Definitions of localized depletion are dependent on the spatial and temporal scale appropriate for the species of interest. For example, previous work on localized depletion of Atka mackerel was motivated by the importance of Atka mackerel in the diet in Stellar sea lions (Fritz 1999). In that study, the areas of interest showed localized depletion within a year but between years the population showed no overall decline. The localized depletion over the coarse of several weeks was viewed as sufficiently long to affect Stellar sea lion feeding. The appropriate spatial and temporal scale at which localized depletion becomes important for rockfish is a subject for future research. The extent to which localized fishing becomes problematic for rockfish is dependent upon the ability of rockfish to replenish fished areas such that any potential local spawning populations are not eliminated. Considerations regarding localized depletion for rockfish should reflect the spatial scale characterizing fish movement within a year and the location and spatial extent of spawning populations and this information is largely unknown for rockfish.

Re12ences

Fritz, L.W. 1999. Do trawl fisheries off Alaska create localized depeltions fo Atka mackerel (*Pleurogrammus monopteygius*)?. Unpublished document, Alaska Fisheries Science Center, Seattle, WA.

Delury, D.B. 1951. On the planning of experiments for the estimation of fish populations. J. Fish. Res. Board Canada 8:281-307.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Canada 191. 382 pp.

Withler, R.E., T.D. Beacham, A.D. Schultze, L.J. Richards, and K.M. Miller. 2001. Co-existing populations of Pacific ocean perch, *Sebastes alutus*, in Queen Charlotte Sound, British Columbia. Mar. Biol. 139:1-12.

Table 1. Observed POP catch (t) from sampled hauls and estimated from unsampled hauls in three study areas as compared to the total catch estimate for the appropriate management area (i.e., the eastern or western Aleutian Islands).

Area	Year	POP catch (t) Sampled hauls	Unsampled hauls	Total	Total catch estimate for management area	Percent of catch in study area
Buldir Reef	2002	379 (7)	27 (1)	405 (8)	5039	8
	2003	1397 (25)	273 (8)	1671 (33)	6027	28
	2004	1349 (25)	339 (9)	1688 (34)	5485	31
NW Buldir	2000	329 (6)	85 (2)	414 (8)	4808	9
	2001	236 (3)	0 (0)	236 (3)	3590	7
	2002	960 (18)	256 (6)	1216 (24)	5039	24
	2003	1597 (30)	13 (2)	1609 (32)	6027	27
	2004	700 (13)	54 (1)	755 (14)	5485	14
NE Atka	2000	472 (10)	157 (5)	629 (15)	2086	30
	2001	289 (11)	266 (10)	556 (21)	2340	24
	2002	521 (12)	183 (5)	704 (17)	2570	27
	2003	1022 (27)	196 (9)	1218 (36)	3767	32
	2004	863 (16)	91 (1)	954 (17)	2536	38

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Table 2. Total POP hauls and days in the POP fishery for each of the three study areas, with estimates of catchability (q) and initial biomass (B_0). Confidence intervals for B_0 were computed only when the estimate of catchability was significantly different from zero. The alternative analysis for the northwest Buldir area in 2003 was produced by removing the initial day, which showed an unusually high CPUE.

Area	Year	Hauls	Total Days	q	95% CI lower	upper	B_0 (t)	95% CI lower	upper
Buldir Reef	2003	33	6	-0.0007	-0.0102	0.0088			
	2004	34	6	0.0061	-0.0012	0.0134	2916		
Northwest Buldir	2002	22	7	0.0034	-0.0058	0.0126	4784		
	2003	32	7	0.0149	0.0028	0.0271	2056	1477	6809
	2003	29	6	0.0061	-0.0043	0.0166	2917		
	2004	14	5	0.0189	0.0061	0.0317	1287	825	2940
Northeast Atka	2000	15	4	0.0252	-0.1277	0.1782	904		
	2001	21	6	-0.0125	-0.0524	0.0274			
	2002	17	6	0.0076	-0.0026	0.0178	2478		
	2003	36	7	0.0088	-0.0039	0.0214	1944		
	2004	17	5	0.0232	-0.0039	0.0503	1409		

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Figure 1. POP catch from observed hauls targeting POP in the Aleutian Islands from 2000-2004.

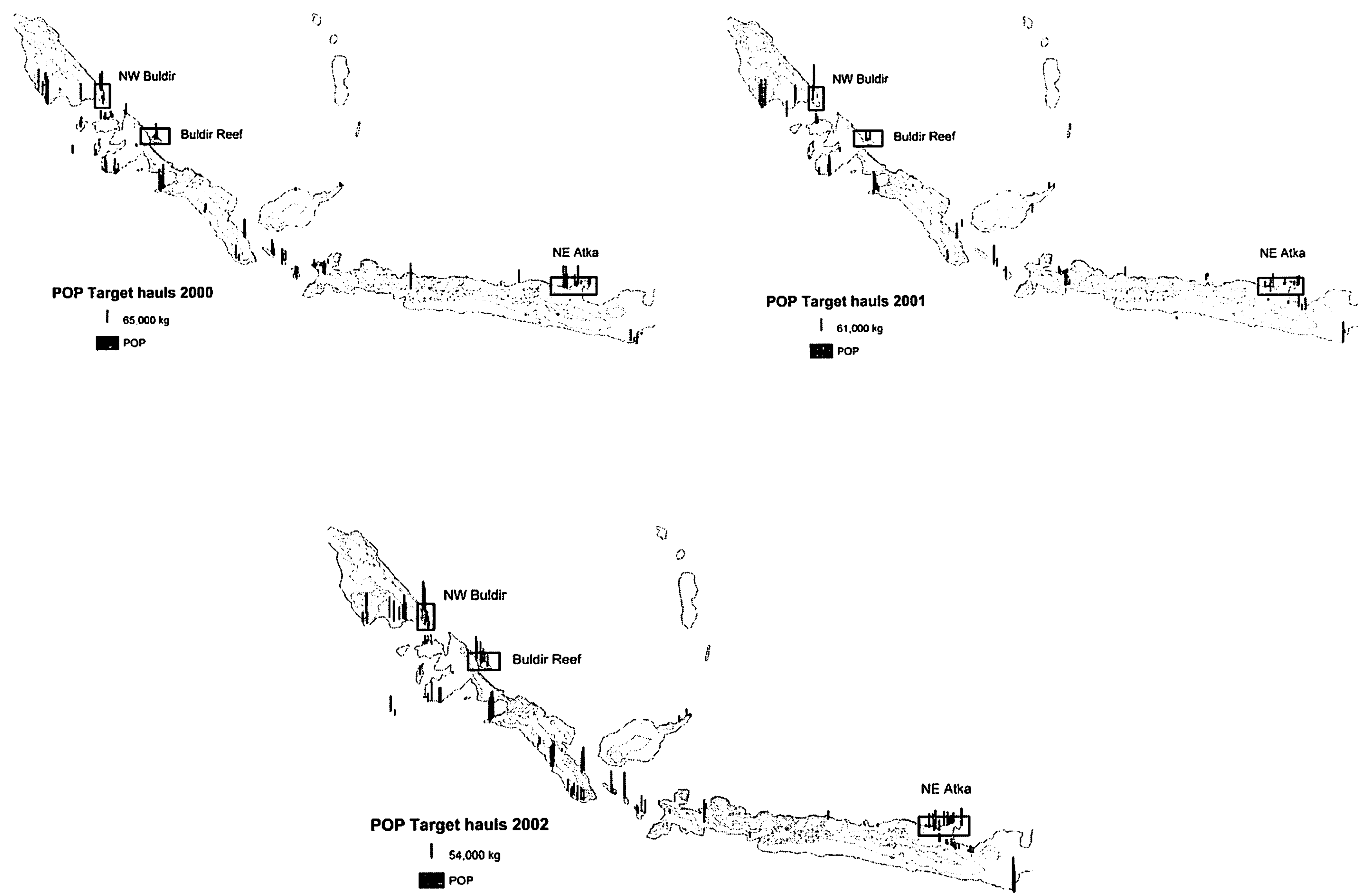

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Figure 1, continued. POP catch from observed hauls targeting POP in the Aleutian Islands from 2000-2004.

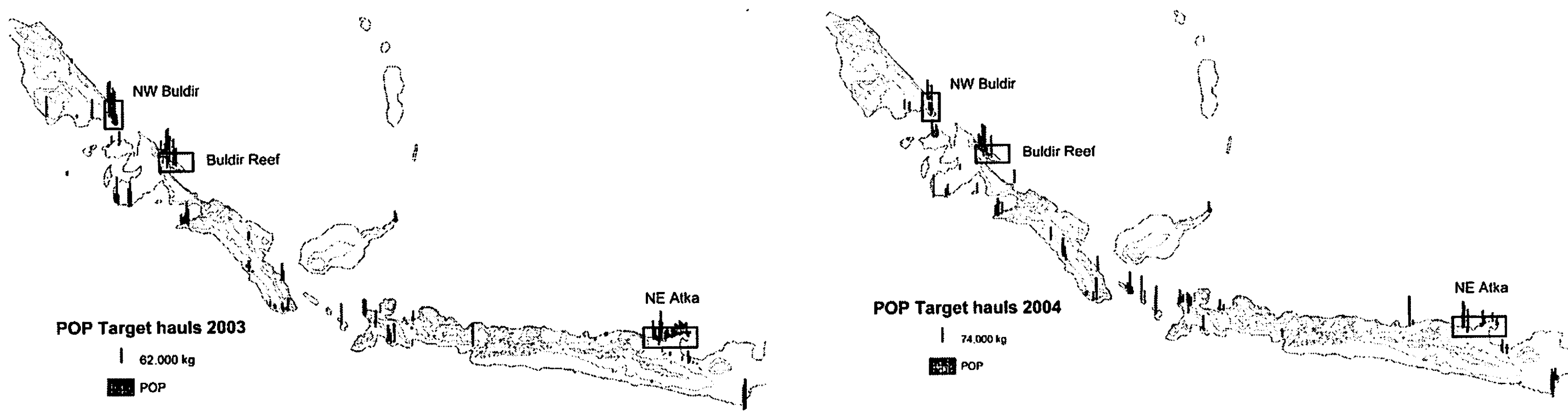


Figure 2. Daily estimates of POP CPUE (t/hr) in the Buldir reef area in 2003 and 2004 as a function of cumulative catch. The negative of the slope of the regression line is the estimate of catchability. The data labels show the number of hauls from which the average daily CPUE was computed.

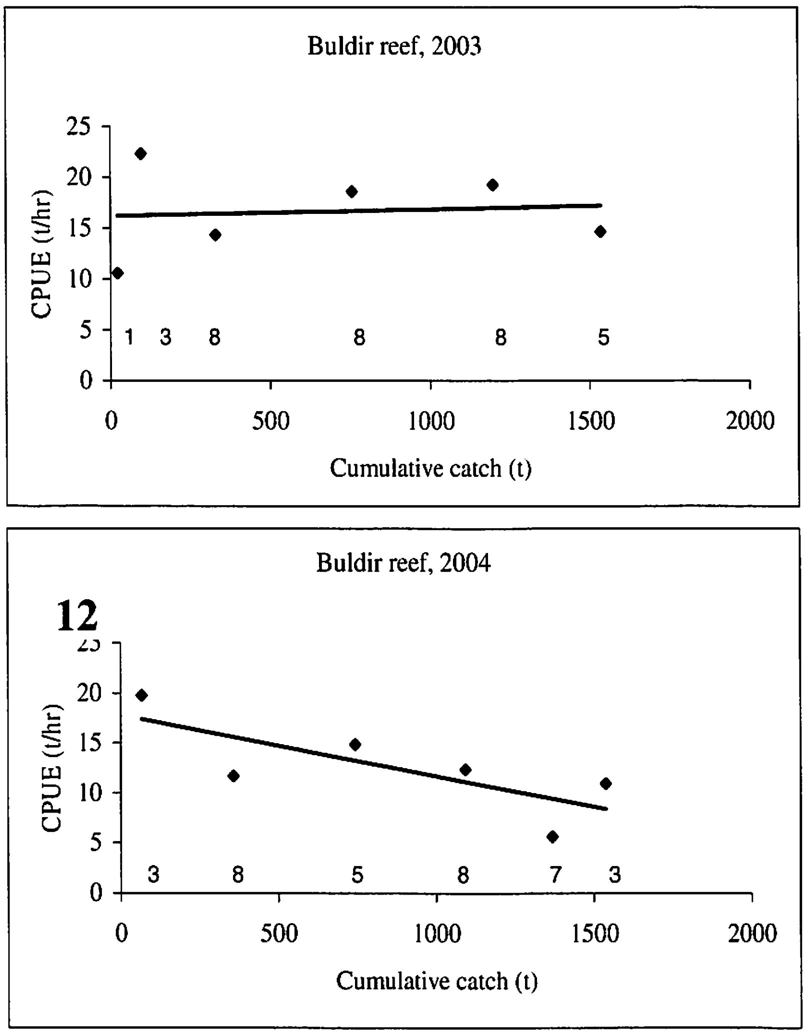


Figure 2. Daily estimates of POP CPUE (t/hr) in the northwest Buldir area from 2002 to 2004 as a function of cumulative catch. The negative of the slope of the regression line is the estimate of catchability. For 2002, the regression excludes the last data point. For 2003, the dotted regression line excludes the first data point whereas the solid line includes all points. The data labels show the number of hauls from which the average daily CPUE was computed.

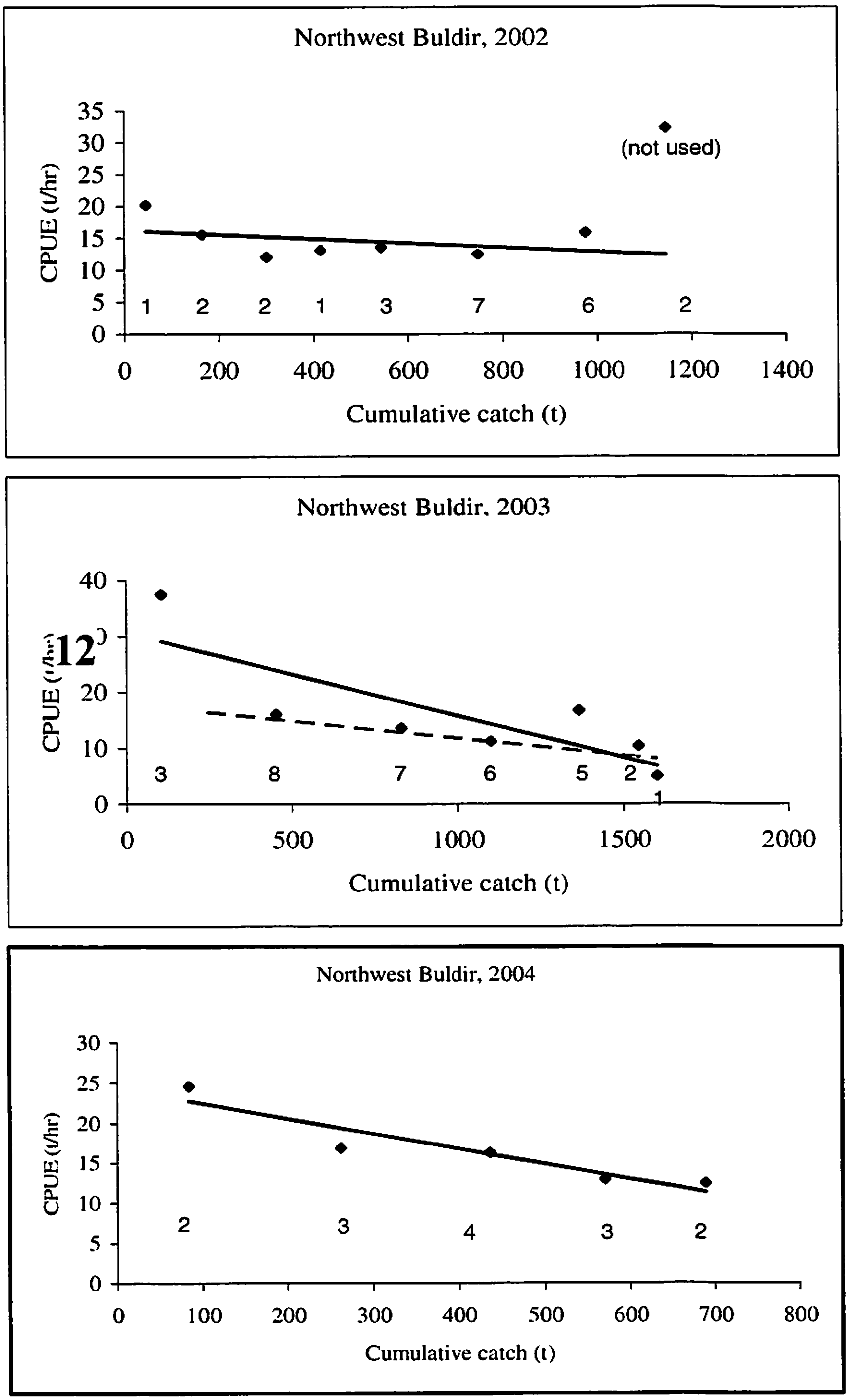
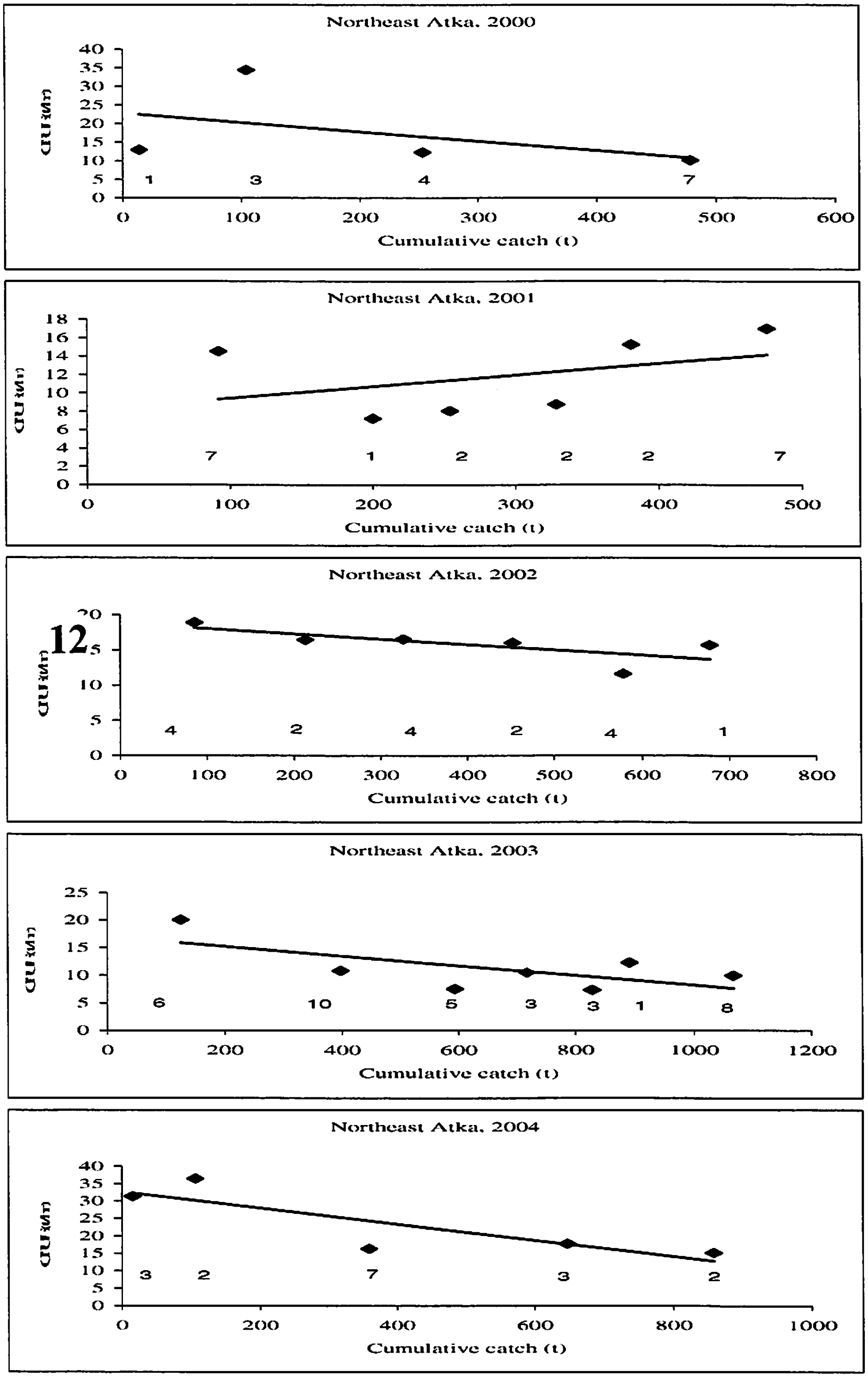


Figure 3. Daily estimates of POP CPUE (t/hr) in the northeast Atka area from 2000 to 2004 as a function of cumulative catch. The negative of the slope of the regression line is the estimate of catchability. The data labels show the number of hauls from which the average daily CPUE was computed.



BREAK OTHER SPECIES CATEGORY INTO SQUID, SHARKS, SKATES, SCULPINS, AND OCTOPI
Discussion Paper
February 1, 2005

In December 2004, the Council requested that staff develop a discussion paper of a proposal from the Groundfish Plan Teams and Science and Statistical Committee to amend the Gulf of Alaska and Bering Sea/Aleutian Islands Groundfish Fishery Management Plans. The amendments would provide additional precautionary management of five groups of non-target species that are managed in the "other species" category. The Plan Teams, SSC, ad hoc committee, and Non-Target Species Committee have been continuing development of recommendations for improving management of all non-target species, which began with a proposal by the State of Alaska in 1998. This proposed plan amendment is the third step in a series of recommendations under consideration by the Council at the February meeting by the teams, SSC, and two committees for improving management of non-target species. Step I would revise the GOA Groundfish FMP to set the GOA "other species" TAC $\leq$ 5 percent of the sum of all Groundfish TACs in time for the 2006 specification cycle; this would allow for setting the category on bycatch status at the beginning of the year. Step 2 would set an overfishing level and allowable biological catch for the GOA "other species" category for the first time in the 2007 specification cycle (due to staff constraints), as is done in the BSAI. Because analytical and stock assessment needs, the Step 3 plan amendment would not be ready for implementation until the 2007 specification cycle. At its February meeting, the Council will review the paper and decide whether to initiate the plan amendments and set a timeline for action.

PROPOSED ACTION: Eliminate the "other species" category and set separate specifications for squid, sharks, skates, sculpins, and octopi in the Gulf of Alaska and Bering Sea/Aleutian Islands (except squid which are already broken out).

PROBLEM STATEMENT/OBJECTIVE: The two groundfish FMPs require that specifications be set for the "other species" category; however, the "other species" category does not offer sufficient protection from overfishing of the component groups because the overfishing level, allowable biological catch, and total allowable catch for the category is set equal to the sum of the estimates for the individual groups. Therefore, any one (or more) groups are vulnerable to overfishing because they are managed under specifications that are set for the category, which is set equal to the sum of five (in the GOA) or four (in the BSAI) groups.

BACKGROUND: For several years, the BSAI Groundfish Plan Team and SSC have recommended that the Council initiate a FMP amendment to set group-specific (squid, sharks, skates, sculpins, and octopi) OFLs and ABCs rather than complex-wide ("other species") specifications. The SSC and Plan Team recommended that the "other species" category be placed on bycatch-only status until implementation of an industry proposed and Council-approved data collection program that minimally provides accurate data on location of catch, total fishery removals by species, and opportunities for biological sampling of the catch for age, length, weight, and sex. Bycatch-only status (meaning retention of other species is only allowed as a percentage of target species on board) is recommended to prevent directed fishing on all species groups in this category until stock assessment information improves. The assessment authors wholeheartedly concur with SSC recommendations for data collection programs and setting of group-specific ABCs and OFLs. The entire assessment was reformatted in 2004 to better accommodate group-specific management. The section for each group recommended potential data collection programs, including increased retention for the purpose of collecting biological data at delivery points without additional burdens to at-sea observers.

Catches of "other species" have been very small compared to those of target species, but they appear to be increasing. There are data limitations in terms of life history for all creatures in the other species complex; we lack information on age and growth, reproductive biology, habitat requirements, and in some cases, species descriptions. Considerable further investigation is necessary to be sure that all components of "other species" are not adversely affected by groundfish fisheries. Furthermore, if target fisheries develop for any component of the other species group (as they have for skates in the Gulf of Alaska in 2003), effective management will be extremely difficult with the current limited information. The development of a skate fishery in 2003 in the central GOA and concerns about potential overfishing of several skate species prompted the Council to initiate a GOA plan amendment to separate GOA skates from the category in 2004. Similar concerns regarding a developing spiny dogfish (shark) fishery in the GOA are occurring in 2005. Interest has been reported for developing a target fishery for octopus species in the BSAI, and also for sculpin species in the GOA.

Until 2004, the BSAI "other species" TAC has never been exceeded in the BSAI or the GOA with the current composition of the category. As of October 23, 2004, the BSAI non-CDQ TAC of 23,124 mt was exceeded, so the category was put on prohibited status (meaning no further retention is allowed, but catch and discard can continue up to the OFL of 81,150 mt). In addition, the CDQ reserve of 2,040 mt was also exceeded as of November 4. While it was exceeded, the TAC was reduced from the amount of harvest allowed under the ABC to keep the total catch of groundfish in compliance with the BSAI OY cap, so it is likely there were no biological threats to the groups. However, if interest continues in developing fisheries within this category, the lower aggregate TAC may restrict retention and utilization of the more valuable components of the "other species" category (i.e., skates and octopus).

The 2004 BSAI "other species" assessment and 1998 draft assessment for GOA "other species" identified the fisheries and gear types that catches each species in each area and possible group level specifications (Attachment).Current data suggests that the only catches that approached group level specifications was GOA octopus in1999; it should be noted that octopus are poorly covered by the biennial GOA trawl survey.

ANALYSIS: An EA/RIR/IRFA for a joint BSAI/GOA plan amendment is required.

RANGE OF ALTERNATIVES:

1. No action
2. Eliminate the "other species" category and set separate specifications for squid, sharks, skates, sculpins, and octopi in the Gulf of Alaska and Bering Sea/Aleutian Islands

The Council may wish to absorb Step 2 (described above and in more detail in GOA "other species" discussion paper under Agenda Item D-2 (Staff Tasking)) into this proposed joint amendment to conserve staff resources and speed implementation of Step 3 for 2007, since it will not be possible to implemented Step 2 (set an OFL and ABC based on the sum of group-level OFLs and ABCs) for the 2006 specification cycle.

ESTIMATE OF STAFF RESOURCES: Likely no more than 16 weeks of total interagency staff time for analytical and regulatory writing and review. Anticipated staff includes project leader/analyst (Jane DiCosimo), Sarah Gaichas (AFSC analyst), Melanie Brown (regional coordinator), economist to be named.

TIMELINE TO IMPLEMENTATION: Initial review/final action in February/April 2006 for implementation in time for 2007 specification cycle. Staff recommends scheduling the analysis for determining GOA groundfish OFL and ABC estimates until after the 2005 summer trawl survey.

Attachment to Other Species Discussion Paper

Table 16- 2. Estimated total (retained and discarded) catches of other species (mt) in the eastern Bering Sea and Aleutian Islands by groundfish fisheries, 1977-2002. JV=Joint ventures between domestic catcher boats and foreign processors. Estimated catches of other species from 1977-98 include smelts.

	Eastern Bering Sea				Aleutian Islands				Grand
Year	Foreign	JV	Domestic	Total	Foreign	JV	Domestic	Total	Total
1977	35,902			35,902	16,170			16,170	52,072
1978	61,537			61,537	12,436			12,436	73,973
1979	38,767			38,767	12,934			12,934	51,701
1980	33,955	678		34,633	13,028			13,028	47,661
1981	32,363	3,138	100	35,651	7,028	246		7,274	42,925
1982	17,480	720		18,200	4,781	386		5,167	23,367
1983	11,062	1,139	3,264	15,465	3,193	439	43	3,675	19,140
1984	7,349	1,159		8,508	184	1,486		1,670	10,178
1985	6,243	4,365	895	11,503	40	1,978	32	2,050	13,553
1986	4,043	6,115	313	10,471	1	1,442	66	1,509	11,980
1987	2,673	4,977	919	8,569		1,144	11	1,155	9,724
1988		11,559	647	12,206		281	156	437	12,643
1989		4,695	298	4,993		1	107	108	5,101
1990			16,115	16,115			4,693	4,693	20,808
1991			16,261	16,261			938	938	17,199
1992			29,994	29,994			3,081	3,081	33,075
1993			20,574	20,574			3,277	3,277	23,851
1994			23,456	23,456			1,099	1,099	24,555
1995			20,923	20,923			1,290	1,290	22,213
1996			19,733	19,733			1,706	1,706	21,440
1997			23,656	23,656			1,520	1,520	25,176
1998			23,077	23,077			2,455	2,455	25,531
1999			18,884	18,884			1,678	1,678	20,562
2000			23,098	23,098			3,010	3,010	26,108
2001			23,148	23,148			4,029	4,029	27,178
2002			26,639	26,639			1,980	1,980	28,619
2003									28,703
2004*									26,298

*2004 open access catch reported through October 23, 2004 plus CDQ catch reported through November 4, 2004.

Data Sources: Foreign and JV catches-U.S. Foreign Fisheries Observer Program, Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA, BIN C15700, Bld.4, 7600 Sand Point Way NE, Seattle, WA 98115. Domestic catches before 1989 (retained only; do not include discards): Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, Portland, OR 97201. Domestic catches since 1989: NMFS Regional Office BLEND and CAS databases, Juneau, AK 99801.

Table 16- 3. Estimated total catch (t) of BSAI non-target species groups by FMP category, 1997-2002. Source: NORPAC observer database and year-end estimates of target species catch from the NMFS Regional Office BLEND database (see text for estimation methods). ***Note that this estimation method is different from the one used in Table 16-2, so Other species totals reported here do not match Table 16-2 totals for 1997-2002 exactly.

Group	1997	1998	1999	2000	2001	2002	6 year avg	cv	avg % of category
squid	1,573.40	1,255.80	501.76	412.93	1,810.37	1,742.13	1,216.07	0.51	
skates	17,747.37	19,317.86	14,079.84	18,876.53	20,570.46	21,278.69	18,645.12	0.14	70.76%
sculpin	7,477.84	6,285.46	5,470.00	7,086.45	7,669.76	7,176.18	6,860.95	0.12	26.04%
dogfish	4.09	6.38	4.95	8.88	17.33	7.27	8.15	0.59	0.03%
salmonshk	6.82	18.04	29.96	23.30	24.45	33.90	22.75	0.42	0.09%
sleepershk	304.07	336.00	318.68	490.43	687.27	433.17	428.27	0.34	1.63%
shark	52.77	136.08	176.40	67.61	34.97	44.40	85.37	0.67	0.32%
octopus	248.37	189.68	326.08	418.15	227.28	374.45	297.33	0.30	1.13%
Total Other Species	25,841.33	26,289.50	20,405.92	26,971.35	29,231.51	29,348.07	26,347.95	0.12	
smelts	29.76	36.57	45.30	51.68	80.12	18.64	43.68	0.49	88.32%
gunnel		0.02	0.04	0.00	0.01	0.02	0.02	0.68	0.04%
sticheidae	0.40	0.24	0.03	0.11	0.41	0.09	0.21	0.77	0.43%
sandfish	1.11	0.40	3.29	20.29	1.85	1.68	4.77	1.61	9.64%
lanternfish	0.42	0.40	0.02	0.11	0.29	2.75	0.67	1.55	1.35%
sandlance	0.10		0.02	0.00	0.14	0.28	0.11	1.03	0.22%
Total Forage Species	31.79	37.64	48.70	72.19	82.81	23.46	49.45	0.47	
grenadier	5,851.55	6,589.04	7,388.23	7,320.94	3,753.93	4,698.09	5,933.63	0.25	28.05%
otherfish	1,569.15	1,362.69	1,327.28	1,458.20	1,459.89	1,189.60	1,394.47	0.09	6.59%
crabs	303.78	185.92	108.86	142.69	144.18	134.15	169.93	0.41	0.80%
starfish	6,191.00	3,287.17	3,051.47	3,174.02	4,221.00	3,742.66	3,944.55	0.30	18.64%
jellyfish	8,849.21	7,147.51	7,153.25	10,491.25	3,861.50	1,897.49	6,566.70	0.48	31.04%
invertunid	1,608.58	638.35	140.08	1,121.43	923.35	784.41	869.37	0.56	4.11%
seapen/whip	2.61	2.40	4.96	4.96	8.16	13.60	6.12	0.69	0.03%
sponge	530.12	500.83	321.84	164.91	245.36	330.26	348.89	0.41	1.65%
anemone	182.96	113.73	171.52	347.24	209.24	229.16	208.97	0.37	0.99%
tunicate	1,793.67	728.06	372.01	1,055.72	1,525.29	1,273.77	1,124.75	0.46	5.32%
benthinv	672.70	531.37	226.43	365.96	556.36	371.70	454.09	0.36	2.15%
snails					0.00	0.60	0.30	1.41	0.00%
echinoderm	44.88	24.27	30.32	42.37	43.42	32.76	36.34	0.23	0.17%
coral	38.89	27.67	52.49	43.12	183.29	79.23	70.78	0.82	0.33%
shrimp	2.73	1.71	1.23	3.70	2.41	3.03	2.47	0.36	0.01%
birds	28.69	43.49	24.39	27.04	17.44	8.19	24.87	0.48	0.12%
Total Non-Specified	27,670.52	21,184.21	20,374.36	25,763.55	17,154.83	14,788.70	21,156.23	0.23	
Total Non-Targets	55,117.04	48,767.14	41,330.75	53,220.02	48,279.51	45,902.36	48,769.69	0.10	

We recommended group specific ABCs and OFLs (based on the 10 year average EBS shelf survey biomass by group plus the 10 year average EBS slope survey biomass by group plus the 10 year average AI survey by group, all times the natural mortality rates listed below times 0.75 for ABC and 1 for OFL), and **placing all groups on "bycatch-only" status until information improves**:

	Sharks	Skates	Sculpins	Octopi
Avg Biomass	17,711	477,993	206,148	6,321
M (see text)	0.09	0.10	0.19	0.50
BSAI ABC	**1,195**	**35,849**	**29,376**	**2,371**
BSAI OFL	**1,594**	**47,799**	**39,168**	**3,161**
recent avg catch	545	18,645	6,861	297

These ABCs and OFLs would permit the levels of bycatch historically observed (1997-2002 average) while increasing protection for the species groups.

Most recent ABC and OFL estimates from the GOA were done for the 1999 SAFE appendix, would obviously have to be redone for assessment in 2006, but can serve as a baseline, note that octopus and sculpin Ms = Fofls would change based on analysis presented in 2004 BSAI assessment:

This is the first assessment of Gulf of Alaska Other species. The purpose of this chapter is to highlight some of the available data for these species and develop some approaches toward evaluating the harvest levels and resource abundances. Input data included catch estimates by species groups from 1990-98, and GOA triennial trawl survey biomass estimates for each species group. The proposed assessment model is a simple state-space model described in Appendix E. Although changing the procedure for establishing TAC of other species requires a amendment to the GOA FMP, we proposed separate ABC and OFL levels for each species groups within other species to ensure that less productive groups are not overharvested. These individual ABCs sum to slightly less than the recent aggregate TACs in the range of 14,000 t, but observed catches in each of the categories have never exceeded these proposed ABCs in the domestic fishery, with the eception of octopus catches in 1992 and 1997. We believe that cephalopod biomass is substantially underestimated by the bottom trawl survey, resulting in overly conservative estimates of ABC and OFL for these species groups, but we have no other data on which to base recommendations.

		Sharks	**Skates**	**Sculpins**	**Octopi**	**Squid**	**Total**
Tier 5	**M**	0.09	0.10	0.15	0.30	0.40	
Model estimated 1999 biomass		34,214	72,164	30,259	550	2,134	
F=0.75M ABC		2,309	5,412	3,404	124	640	11,890
F=M OFL		3,079	7,216	4,539	165	854	15,853

Estimated total catch (t) of GOA non-target species groups by FMP category, 1997-2002. Source: NORPAC observer database and year-end estimates of target species catch from the NMFS Regional Office BLEND database (see BSAI other species SAFE for estimation methods).

Group	1997	1998	1999	2000	2001	2002	6 year avg	cv	avg % of category
sculpin	906.58	540.83	544.39	943.01	601.28	925.65	743.62	0.27	15.16%
skates	3,119.83	4,476.19	2,000.41	3,238.44	1,828.40	6,483.86	3,524.52	0.49	71.85%
shark	123.48	1,379.86	33.00	73.64	76.98	25.91	285.48	1.88	5.82%
salmonshk	123.77	70.96	131.58	37.82	32.78	58.17	75.85	0.56	1.55%
dogfish	657.47	864.85	313.57	397.60	493.97	117.04	474.08	0.55	9.66%
sleepershk	135.87	74.02	557.66	608.19	249.00	225.56	308.38	0.72	6.29%
octopus	232.19	112.00	166.34	175.95	88.17	298.27	178.82	0.43	3.65%
squid	97.49	59.22	40.69	18.62	90.78	42.72	58.25	0.53	1.19%
Total Other Species	4,490.10	7,037.10	3,243.23	4,550.26	2,860.08	7,251.53	4,905.38	0.38	
smelts	23.06	122.74	26.09	123.78	534.85	156.41	164.49	1.15	98.06%
gunnel	0.11	0.03	0.03		0.00		0.04	1.08	0.03%
sandfish	3.68	2.16	0.53	0.32	1.24	1.70	1.60	0.77	0.96%
sticheidae	0.29	0.03	3.53	0.49	4.66	0.13	1.52	1.33	0.91%
lanternfish	0.00	0.00	0.00		0.03	0.00	0.01	2.04	0.00%
sandlance	0.02	0.01	0.06	0.35	0.04	0.04	0.09	1.50	0.05%
Total Forage Species	27.15	124.97	30.24	124.94	540.82	158.28	167.75	1.14	
grenadier	12,029.38	14,683.06	11,387.68	11,610.01	9,684.62	10,479.16	11,645.65	0.15	76.38%
otherfish	575.92	8,400.26	819.00	979.34	696.56	2,173.02	2,274.02	1.34	14.91%
crabs	15.42	25.13	10.85	12.43	4.24	4.30	12.06	0.65	0.08%
starfish	987.15	1,244.53	1,510.44	894.20	469.22	518.51	937.34	0.43	6.15%
jellyfish	36.05	166.60	107.16	37.87	235.16	159.72	123.76	0.64	0.81%
invertunid	8.15	42.86	1.33	15.18	6.42	12.83	14.46	1.02	0.09%
seapen/whip	0.62	2.92	2.69	0.90	0.30	0.35	1.30	0.92	0.01%
sponge	3.61	3.65	12.90	4.30	3.97	5.07	5.58	0.65	0.04%
anemone	17.57	15.68	17.41	16.17	15.86	20.51	17.20	0.10	0.11%
tunicate	1.57	1.16	0.03	3.55	2.62	3.88	2.14	0.69	0.01%
benthinv	24.56	31.25	25.24	10.35	12.53	5.59	18.25	0.55	0.12%
echinoderm	22.55	32.39	8.45	7.02	8.12	8.60	14.52	0.72	0.10%
coral	4.06	7.92	1.16	10.24	5.20	16.32	7.48	0.71	0.05%
shrimp	3.74	2.33	0.62	1.39	3.04	6.01	2.85	0.67	0.02%
birds	2.00	5.64	6.40	3.27	2.99	0.94	3.54	0.59	0.02%
Total Non-Specified	13,759.50	24,790.36	13,941.60	13,731.14	11,691.68	13,573.09	15,247.91	0.31	
Total Non-Targets	15,854.01	26,847.60	15,981.35	15,750.12	13,783.50	15,617.85	15,306.25	0.31	

AGENDA D-1(c)
FEBRUARY 2005
Supplemental

PROWLER FISHERIES

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Stephanie Madsen, Chair
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Re: D-1 GOA and BSAI Other Species Breakout: Improvement of Biomass Estimates of Components is Necessary Prior to Breakout.

Dear Madam Chair,

The specific action plan (as indicated by the agenda) for the breakout of "other species" in the GOA and BSAI does not appear to be available to the public. Therefore, I have to assume that the breakout plan is derived from the Non-Target Committee report and alternatives.

Included in the numerous alternatives in the Non-Target Committee report, are actions to eliminate the "o. species" assemblage and break out into separate shark, skate, octopus, and sculpin categories for both the GOA and BSAI (with skates having been broken out already in the GOA). Also in the alternatives are identified needs for policies based on scientific criteria to determine when sufficient data is available to move species between target and non-target as well as between core stocks and stock assemblages.

What appears to missing is a policy based on scientific criteria to determine when there is sufficient data and sufficient need to break out stock assemblages into species groups. Specifically, there needs to be a component to improve stock assessment **prior** to breaking out the "o. species" assemblage particularly for sharks and octopus. Given the biomass estimates that are currently available, it is likely that the resulting Tier 5 ABCs or the default Tier 6 ABCs will be constraining and disruptive to fisheries (**see tables**). In almost all cases, past catches would have exceeded the proposed Tier 6 ABCs. For sharks, past catches have exceeded many of the recent proposed Tier 5 ABCs.

For example in the BSAI (though this would also apply in the GOA), if stock assessment for sharks and octopus is not improved and the "o.species" assemblage is broken out the results may be as follows:

1.) Skates, sculpins, sharks and octopus all go into separate Tier 5 ABCs. The ABCs for sharks and octopus will prove to be constraining on fisheries and disruptive since the ABCs will widely varying year to year.
2.) Skates and sculpins go into separate Tier 5 ABCs. Sharks and octopus go into separate Tier 6 ABCs. Since Tier 6 is 75% of catch, it is highly likely that this would immediately become restraining on the fisheries.
3.) Skates and sculpins go into separate Tier 5 ABCs. Sharks and octopus remain in "o. species" as either a Tier 5 or Tier 6. As above, the effect on fisheries would be constraining and disruptive.

There does not appear to an urgent conservation need to fast track the break out of "o. species" based on biomass trends or trends in incidental catches. Due to the confines of TAC and the OY cap in the BSAI, "o. species" will remain on bycatch status with no directed fishing. In the GOA, skates have been broken out already to manage the directed fishery and there currently is no directed fishing on the other components of "o. species".

The impetus for the breakout seems to be based on the limited knowledge of life history parameters of the individual species such as the reproductive rates, growth rates, natural mortality rates, stock structures, and longevity. While these factors support a precautionary approach, there are no identified serious conservation issues.

Therefore an incremental approach to fill the data needs seems to be in order. In particular, improved biomass estimates would seem to be at the top of the list, i.e. how much is out there? The current trawl surveys should be evaluated for their ability to provide a biomass estimate for sharks and octopi. In the Appendix to the 2004 SAFE (*Sharks in the GOA, EBS, and AI*), the author states (p. 12), "*...the catchability of sharks in bottom trawl gear is unknown. Bottom trawl survey biomass estimates for shark species should be considered a relative index of abundance at best.*"

Prior to the breakout of "o. species", the Council should consider recommending that further research be conducted to provide an improved biomass estimate and an improved survey. A biomass estimate is a necessary requirement for a Tier 5 ABC. The current trawl surveys are relative indicators of biomass but it is arguable that the current surveys provide a biomass estimate.

Gerry Merrigan
Prowler Fisheries

Supporting Information

Previously Suggested BSAI Tier 5 and Tier 6 ABCs (2002-05) for Individual Species Components of BSAI"O. Species", in mt (from SAFE documents)

SPECIES	2005 ABC, TIER 5	2005 & 2004 ABC, TIER 6	2004 ABC, TIER 5	2003 ABC, TIER 5, "A"	2003 ABC, TIER 5, "B"	2003 ABC, TIER 5, "C"	2002 ABC, TIER 5, "A"	2002 ABC, TIER 5, "B"	2002 ABC, TIER 5, "C"
Sharks	1195	434	1980	468	1975	2196	167	257	256
Skates	35,849	13,821	36,284	26,647	36,150	35,170	25,272	32,366	26,596
Sculpins	29,376	5,744	23,836	27,560	23,986	21,990	28,566	25,516	19,615
Octopus	2371	278	1120	1543	961	1076	1847	1033	630

Method "A" = biomass average of all years.
Method "B" = biomass average for last ten years (90's).
Method "C" = most recent biomass average.

BSAI "Other Species: Estimated Catch (mt) by Species Components, 1997-2002 (from Table 16-3, Nov. 10, 2004 SAFE, catch estimation is from a derived method as described in SAFE text p. 3-4.)

Catches that have been greater than proposed Tier 5 ABC or Tier 6 ABCs are in **bold** (note: ABCs and catches are for different years, no catch data is estimated post 2002).

SPECIES	2002	2001	2000	1999	1998	1997
Sharks	**518**	**764**	**590**	**530**	**496**	**368**
Skates	**21,279**	**20,571**	**18,877**	**14,079**	**19,318**	**17,747**
Sculpins	**7,176**	**7,670**	**7,087**	5,470	**6,286**	**7,478**
Octopus	**375**	227	**418**	**326**	190	**248**

Biomass Estimates: The current biomass estimates for sharks, skates, sculpins, and octopus come from trawl surveys. While the trawl surveys may give a reasonable time series of biomass estimates for skates and sculpins, these same surveys do not appear to provide reasonable estimates for biomass estimates of sharks (particularly large sharks) and octopus (due to the preferred rocky habitat). As a result, the biomass estimates for sharks and octopus are highly variable (**see attached**) and result in widely varying proposed Tier 5 ABCs in past years. Some of the proposed Tier 5 ABCs would have been constraining on the fisheries in past years (as well as the proposed Tier 6 ABCs as well).

Since sharks are long-lived animals, it does not make sense that biomass estimates should vary considerably year to year (as in the 2002 and 2004 EBS slope surveys). Nor does it seem logical that all sharks would occasionally completely disappear as indicated by the biomass estimates of zero for numerous years (EBS shelf surveys in 1975, 1982, 1984, 1986, 1989, 1990, 1991, 1993, 2001, and in the AI in 1983 and 1986).

Biomass Trends and Incidental Catch: Overall, the biomass trends appear to be stable or increasing for most of the species groups in the "o. species" assemblage in both the GOA and BSAI. In the BSAI in 2004, skates are at the highest biomass level since 1991 and sculpins are at the highest biomass level since 1997. In the GOA, skate populations have tripled from 1984 to 2003. The estimates for sharks and octopus are problematic as noted above. However, the summary to a shark appendix to the 2004 SAFE (*Sharks in the GOA, EBS, and AI*) states (p. 11),

"There is no evidence to suggest that overfishing is occurring for any shark species in the GOA and BSAI. There are currently no directed commercial fisheries for shark species in

federally or state managed waters of the GOA and BSAI...Incidental catches of shark species in the GOA and BSAI fisheries have been very small compared to catch rates of target species. Preliminary comparisons of incidental catch estimates with available biomass estimates suggest that current levels of incidental catches are low relative to available biomass for spiny dogfish and Pacific sleeper sharks in the GOA and for Pacific sleeper sharks in the BSAI. There is also an increasing trend [1984-2003] *in bottom trawl survey biomass estimates (used here as an index of relative abundance) for Pacific sleeper sharks and perhaps for spiny dogfish in the GOA. An independent analysis of NMFS AFSC bottom trawl surveys in the GOA also found that Pacific sleeper shark abundance has significantly increased in the CGOA during 1984 – 1996 (Mueter and Norcross 2002). Salmon sharks are rarely captured in the GOA or BSAI in either the fishery or the bottom trawl surveys. However, a recent demographic analysis suggests that salmon shark populations in the eastern and western North Pacific are stable at this time (Goldman 2002-b). Spiny dogfish are rarely captured in the BSAI in either the fishery or the bottom trawl surveys. Other shark species are rarely captured and incidental catches are not likely to play a significant role in their stock structure because catches were small and generally occurred near the edge of their ranges."*

Additionally, the report notes (p. 9) that *"In the 2002 and 2004 EBS slope bottom trawl surveys, a substantial biomass of Pacific sleeper sharks was reported."*

BIOMASS ESTIMATES O. SPECIES

Table 16- 4. Estimated biomass (t) of BSAI other species from various AFSC surveys.

EBS shelf survey biomass estimates

Year	Sharks	Skates	Sculpins	Octopi
→ 1975	0	24,349	111,160	6,129
1976				
1977				
1978				
1979	692	58,147	284,228	30,815
1980				
1981				
→ 1982	0	164,084	340,877	12,442
1983	379	161,041	292,025	3,280
1984	0	186,980	252,259	2,488
1985	47	149,576	182,469	2,582
→ 1986	0	251,321	303,671	480
1987	223	346,691	195,501	7,834
1988	4,058	409,076	233,169	9,846
→ 1989	0	410,119	215,666	4,979
→ 1990	0	534,556	219,020	11,564
→ 1991	0	448,458	272,653	7,990
1992	2,564	390,466	239,947	5,326
→ 1993	0	375,040	215,922	1,355
1994	5,012	414,235	260,994	2,183
1995	1,005	391,768	218,693	2,779
1996	2,804	423,913	187,817	1,746
1997	37	393,716	215,766	211
1998	2,378	354,188	197,675	1,225
1999	2,079	370,543	146,185	832
2000	1,487	325,292	161,350	2,041
→ 2001	0	419,678	143,555	5,407
2002	5,602	410,573	176,728	2,435
2003	734	386,339	199,351	8,264
2004	3,121	427,713	210,509	4,902

EBS slope survey biomass estimates

Year	Sharks	Skates	Sculpins	Octopi
1979	0	3,056	4,555	729
1981	1	2,743	5,372	234
1982	23	2,723	3,261	180
1985	314	3,329	2,316	152
1988	1,967	3,271	4,944	138
1991	2,635	4,031	2,449	61
2000	*pilot survey, no official biomass estimate*			
2002	25,445	69,275	6,409	979
2004	2,260	33,182	5,488	1,957

LARGE VARIABILITY IN BIOMASS ESTIMATES RESULTS IN LARGE VARIABILITY IN ABC.

AI trawl survey estimates

Year	Sharks	Skates	Sculpins	Octopi
1980	800	10,123	33,624	757
→ 1983	0	16,259	24,570	440
→ 1986	0	19,491	32,211	781
1991	2,927	14,987	15,904	1,148
1994	421	24,964	17,192	1,728
1997	2,497	28,902	13,680	1,219
2000	2,663	29,206	13,037	775
2002	1,557	34,412	14,248	1,384
2004	1,017	53,047	16,781	4,099

→ = ZEROES IN ASSESSMENT = NO SHARKS ENCOUNTERED IN SURVEY

Public Testimony Sign-Up Sheet

and

Handouts Received During the Meeting on this Agenda Item

Public Testimony Sign Up Sheet
Agenda Item ~~Bering Sea Salmon Bycatch~~
D-1 (a, b, c) Non-target species, rockfish, other species breakout

	NAME (PLEASE PRINT)	AFFILIATION
1	Donna Parker	Arctic Storm
2	Ben Enticknap	AMCC
3	Jon Warrenchuk	Oceana
4	Julie Bonney	AGDB
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NOTE to persons providing oral or written testimony to the Council: Section 307(1)(I) of the Magnuson-Stevens Fishery Conservation and Management Act prohibits any person " to knowingly and willfully submit to a Council, the Secretary, or the Governor of a State false information (including, but not limited to, false information regarding the capacity and extent to which a United State fish processor, on an annual basis, will process a portion of the optimum yield of a fishery that will be harvested by fishing vessels of the United States) regarding any matter that the Council, Secretary, or Governor is considering in the course of carrying out this Act.