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June 6, 2022

Mr. Marc Gorelnik
Pacific Fishery Management Council, Chair
7700 NE Ambassador Place, Suite 101
Portland, OR 97220

RE: Agenda Item F.4 Groundfish FMP Amendment Scoping, Stock Definitions

Dear Chair Gorelnik:

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) requires that fishery management plans (FMPs) prevent overfishing, rebuild overfished stocks, and protect, restore, and promote the long-term health of the fishery. The Pacific Fishery Management Council is scoping an amendment to change how to define stocks and stock complexes in the Groundfish FMP. Such an amendment could have significant ramifications for sustainable fishery management and changes should be carefully considered. Any changes to stock definitions should be grounded in the best available science and ultimately enhance the Council's ability to prevent overfishing, rebuild overfished stocks, and minimize risk to vulnerable populations. Any changes that would remove species from active management in the FMP and ultimately weaken conservation and management should be resolutely opposed.

As such, Oceana requests the scope of this FMP amendment focus on those stocks currently managed in stock complexes that are depleted, subject to overfishing, and/or vulnerable to overfishing. We also support consideration of moving tope shark (aka soupfin shark) from ecosystem component species to active management as raised in the scoping questions in the staff materials for this agenda item.[1]

**A. Manage overfished species as individual stocks, separate from stock complexes**

For stocks currently managed within a complex, and where an assessment indicates the stock is overfished or severely depleted below target levels, we recommend removing those species from the stock complex and managing them as individual stocks with individual harvest specifications at an appropriate geographic scale. For example, with

[1] PFMC Agenda Item F.4 Attachment 1, June 2022. At page 15. Available: here

this FMP amendment, the Council should remove quillback and copper rockfish from the nearshore rockfish complexes and manage these as individual stocks consistent with geographic boundaries previously recommended by the Scientific and Statistical Committee.[2] This includes managing quillback stocks at the scale of the recent stock assessments (CA, OR, and WA) and managing copper rockfish as one stock off California and one off the Pacific Northwest.

**B. Manage species subject to overfishing as individual stocks, separate from stock complexes.**

For stocks in complexes, overfishing limits (OFL) are set only for the full complexes, not the individual stocks within them. Yet total mortality for all managed stocks and species is monitored and the OFL contribution of the individual stocks within the complexes is known. To prevent overfishing distinct populations within the overall complex, those species subject to overfishing[3] should be removed from the complex and managed as separate stocks.

According to a recent analysis by the Council's Groundfish Management Team, the OFL contributions for copper rockfish (North of 40° 10'), quillback rockfish (North and South of 40° 10'), vermillion (N and S of 40° 10'), squarespot rockfish (S of 40° 10'), and aurora rockfish (N. of 40° 10') have been repeatedly exceeded in recent years.[4] To prevent overfishing, and for the purpose of enhancing conservation and sustainable management, the Council should consider removing these species from their complexes and managing them as individual stocks at appropriate geographic scales.

**C. Manage species vulnerable to overfishing as individual stocks, separate from stock complexes.**

Relevant to this FMP amendment is a Cope et al. 2011 study, "An approach to defining stock complexes for U.S. West Coast groundfishes using vulnerabilities and ecological distributions" (attached). This study measures the vulnerability of 90 managed Pacific coast groundfish stocks to overfishing, 64 of which are managed in stock complexes. The authors identify five rockfish stocks currently managed within complexes that are of "major concern" to overfishing. These are China, copper, quillback, rougheye and shortraker rockfish. Consistent with the findings of Cope et al. 2011, Oceana recommends

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[2] Agenda Item E.3.a Supplemental SSC Report 1. November 2021, at page 2. Available: here
[3] In this case the OFL contribution of a stock in a stock complex has been repeatedly exceeded.
[4] PFMC Agenda Item E.3.a GMT Report 2 (November 2021). Groundfish Management Team Report on Stock Complexes. Available: here

that the Council consider removing species with very high vulnerability scores from stock complexes and managing them as distinct stocks.

**D. Consider changing the designation of tope shark (soupfin) from Ecosystem Component (EC) species to active management 'in the fishery.'**

Given the clear need for conservation and management, we recommend the Council consider changing the designation of tope shark from an EC species to active management in the fishery. Factors relevant to the conservation and management[5] of tope shark include bycatch in groundfish fisheries and a recently filed petition to list this shark species as endangered or threatened under the U.S. Endangered Species Act. Tope shark are found offshore California, Oregon and Washington from the nearshore to depths of 826 meters. They can live up to 60 years, have a slow maturation rate and are vulnerable to overfishing. Considering persistent global declines, the IUCN now categorizes tope shark as "Critically Endangered" meaning it faces an extremely high risk of extinction in the wild.[6] It is threatened by overfishing, bycatch and habitat degradation. Table 3 of the briefing materials reports tope shark bycatch in West Coast fisheries has increased in recent years, peaking at 23.25 metric tons in 2020.[7] The Council has an obligation to manage species that require conservation and must evaluate whether tope shark meets this threshold.

**E. An FMP amendment is not necessary for NMFS to designate quillback rockfish as overfished.**

NMFS's failure to designate quillback rockfish as overfished is contrary to the MSA, contrary to precedent, and contrary to the agency's procedural directive that stock status determinations be made "as soon as possible after SSC deliberation on the assessment."[8, 9] As explained in the briefing book materials, this proposed FMP amendment stems from the fact that the NMFS decided it would not designate quillback rockfish off California as

[5] 50 C.F.R. §600.305(c)(1) (outlining factors relevant to the determination of whether a species is in need of conservation and management).
[6] Walker, T.I., Rigby, C.L., Pacoureau, N., Ellis, J., Kulka, D.W., Chiaramonte, G.E. & Herman, K. 2020. Galeorhinus galeus. The IUCN Red List of Threatened Species 2020: e.T39352A2907336. Available: https://www.researchgate.net/publication/344905439_Galeorhinus_galeus-Tope_The_IUCN_Red_List_of_Threatened_Species_2020
[7] PFMC Agenda Item F.4 Attachment 1, June 2022. At page 17. Available: here
[8] National Marine Fisheries Service Procedure 01-101-10. Framework for Determining that Stock Status Determinations and Catch Specifications are Based on the Best Scientific Information Available.
[9] Oceana (March 8, 2022). Letter to the PFMC and NMFS. Agenda Item E.3. Stock Definitions. Available: here

overfished despite the recent stock assessment endorsed by the SSC[10] finding that quillback rockfish off California are at 14 percent of their unfished biomass. And despite the SSC's recommendation that quillback be managed at the scale of the assessments for the purpose of status determination.[11]

There are no exceptions under which NMFS may delay notifying the Pacific Council that quillback rockfish are overfished. Such a failure to act on the best available science raises serious concerns that the agency is ignoring clear legal mandates to end overfishing and quickly rebuild this unique rockfish population.

The MSA requirements to prevent and end overfishing and rebuild overfished stocks are fundamental conservation safeguards to ensure short-term economic concerns and political pressures do not outweigh the long-term conservation of fisheries. The Council should implore NMFS to comply with the law. In the meantime, we urge the Council to manage quillback cautiously as if it were designated overfished and take steps to amend the FMP to define quillback and other vulnerable species as distinct stocks and at appropriate geographic scales, consistent with the stocks assessments and best available scientific information.

Sincerely,

Ben Enticknap
Pacific Campaign Manager & Sr. Scientist
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Attached: Cope et al 2011: An Approach to Defining Stock Complexes for U.S. West Coast Groundfishes Using Vulnerabilities and Ecological Distributions, North American Journal of Fisheries Management, 31:4, 589-604

[10] The SSC originally reviewed and endorsed the assessment in June 2021 and then reaffirmed its decision in November 2021 following additional scientific review. See: PFMC SSC, June 2021, Available: here AND. PFMC SSC, November 2021, Available: here

[11] PFMC SSC 2021, *supra note* 1

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**ARTICLE**

# An Approach to Defining Stock Complexes for U.S. West Coast Groundfishes Using Vulnerabilities and Ecological Distributions

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***Abstract***
**The Magnuson–Stevens Fishery Conservation and Management Act (MSA) requires active management of all stocks at risk of overfishing or otherwise in need of conservation and management. In the Pacific Fishery Management Council groundfish fishery management plan, about two-thirds of the more than 90 managed stocks are currently without traditional assessments to help define stock status in relation to management targets. Stock complexes are often employed for management purposes in such situations. The guidelines issued in response to the 2006 MSA amendments defined a complex as a group of stocks with similar geographic distributions, life histories, and vulnerabilities to fisheries. This work uses productivity–susceptibility analysis (PSA) to measure the vulnerabilities of 90 managed groundfish stocks, 64 of which are currently managed within stock complexes. These stock complexes are reevaluated by first using a partitioning cluster analysis to group the stocks by depth and latitude. Vulnerability reference points are then established based on the PSA results to determine vulnerability groups of low, medium, high, and major concern within each ecological group. This method is a simple and flexible approach to incorporating vulnerability measures into stock complex designations while providing information with which to prioritize stock- and complex-specific management.**



Managers of marine resources often confront the challenge of maintaining economically viable yet sustainable levels of removals over long periods of time. This challenge intensifies in marine fisheries where multiple stocks of varying resilience to fishing pressure are caught together (Murawski 1991; Essington et al. 2006). As the number of stocks in need of management increases, the data and resources available typically limit the level of stock analysis available to inform managers (Reuter et al. 2010). One approach to managing multiple stocks in data-limited situations is to form stock complexes (Jiao et al. 2009). Stock complexes are usually determined using some combination of taxonomy, life history, ecology, and relation to fisheries (Shertzer and Williams 2008); thus, common management measures can be assigned to a group of stocks that are both caught together and share similar population responses to removals.

Amendments made to the Magnuson–Stevens Fishery Conservation and Management Act (MSA) in 2006 require the regional fishery management councils in the United States to develop annual catch limits (ACLs) and accountability measures (AMs; i.e., management controls that either ensure the ACLs are not exceeded or outline procedures if they are exceeded) for each of their managed fisheries. Historically the question of which stocks were in need of management was left to regional interpretation. Fishery management plans (FMPs) established by the eight regional fishery management councils and the National Marine Fisheries Service (NMFS) before the ACL amendments therefore differed in their number of actively managed stocks, with some plans including hundreds of stocks, while others much fewer. For such multistock management plans, the questions became which specific stocks were sufficiently in need of conservation and management to warrant catch limits.

Implementation guidelines issued by NMFS in response to the 2006 MSA amendments addressed this question by advising the councils to set ACLs for stocks "in the fishery" (USOFR 2009, 2010). Stocks "in the fishery" are those for which overfishing (i.e., current catch levels exceed the catch limit) or an overfished status (i.e., current population biomass is below the target biomass) would probably occur in the absence of conservation measures. The guidelines also suggest a second, optional category—"ecosystem component" (EC) stocks, defined as nontarget and nonretained stocks not likely to become overfished or undergo overfishing in the absence of management. These EC stocks are not required to have either ACLs or AMs. The guidelines thus advised the councils to review the FMPs and reclassify all stocks as "in the fishery" or not. For a stock determined not to be "in the fishery," the choice is to designate it as an EC stock, thus retaining it in the FMP without catch limits, or to remove it from the FMP altogether.

For stocks designated "in the fishery," ACLs can be determined for individual stocks or stock complexes. The MSA implementation guidelines define a stock complex as "a group of stocks that are sufficiently similar in geographic distribution, life history, and vulnerability to the fishery such that the impact of management actions on the stocks is similar" (USOFR 2010). The term "vulnerability" in this context refers to a stock's potential to become overfished under current fishery conditions and is defined by the guidelines as a combination of a stock's biological productivity and its susceptibility to impact from the fishery (USOFR 2010). Determining a stock's vulnerability can distinguish both its relationship to a fishery (i.e., Is it "in the fishery"?) and its relationship to other stocks in a fishery (i.e., Do fisheries affect them similarly?).

The Pacific Fishery Management Council's Groundfish FMP lists 90 stocks (see Table 3-1 in www.pcouncil.org/wp-content/uploads/fmpthru19.pdf), 64 of which reside in four major complexes ("Minor rockfish north," "Minor rockfish south," "Other flatfish," "Other fish"), with the "Minor rockfish" categories being separated further into "nearshore," "shelf," and "slope" complexes (Table 1). Most stocks in complexes have not been assessed, thus their status relative to overfishing or being overfished is unknown. Currently, complex designations have relied on taxonomy and distribution (e.g., "slope rockfish") as the main qualifiers. Including stock vulnerability in the factors used to define stock complexes will more fully realize the definition of "stock complex" given in the MSA guidelines while providing managers a tool to enhance organization of effective management measures.

This study conducts a vulnerability analysis on 90 groundfish stocks listed in the groundfish FMP and uses the vulnerability scores to revisit current stock complexes. Vulnerability scores are first used to indicate whether a stock is considered "in the fishery" or not. Vulnerability reference points are then determined in order to group stocks by vulnerability scores. These vulnerability groupings, along with ecological distributions, are then used to reclassify existing stock complexes. These updated stock complexes are compared with the former complexes and subsequent advice on interpreting and applying vulnerability scores to defining stock complexes is offered.

## METHODS

*Vulnerability analysis*.—The productivity–susceptibility analysis (PSA) of Patrick et al. (2009, 2010) was used to quantify vulnerability ($V$) for 90 stocks in the PFMC groundfish FMP (Table 1). The PSA approach defines vulnerability in two dimensions: (1) productivity ($P$), characterized by the life history of each stock, and (2) susceptibility ($S$), characterized by how the stock is likely affected by the fishery in question. This study considers all gears that contribute to the overall susceptibility of each groundfish stock. There are 10 productivity and 12 susceptibility attributes scored on a three-point scale (low, medium, and high; Table 2), with each attribute assigned a weighting value (with a default of 2) relative to its perceived contribution to the overall productivity or susceptibility score. Details on attribute definitions and how each bin was determined are found in Patrick et al. (2009). The overall productivity and susceptibility scores are then calculated as the weighted average across all scored attributes. An $x$–$y$ plot is also produced to visualize the productivity and susceptibility. Vulnerability is defined as the Euclidean distance from the origin in the plot (Patrick et al. 2009).

In addition, the level of confidence in each attribute bin score is obtained by scoring data quality on a five-point scale, with lower scores reflecting increased confidence. This allows weakly scored stocks to be flagged as either needing revised scoring (in the case a more knowledgeable scorer can be found) or indicating information is generally lacking for that stock.

Owing to the large variety of stocks and fisheries worldwide, the PSA was developed as a flexible approach for defining vulnerability. Users may specify bin definitions and values that allow the analysis to capture the most pertinent aspects of productivity and susceptibility among the stocks in question. The definitions for the bins of the first susceptibility attribute ("management strategy") were updated from Patrick et al. (2009) to reflect specific qualities of U.S. west coast groundfish management while maintaining the general objective for that attribute characterized by Patrick et al. (2009) (Table 2). Default bin definitions and values for all other attributes were maintained as in Patrick et al. (2009).

The approach of Patrick et al. (2009) also allows for differential weighting of attributes depending on the specific properties of species groups. We considered three species groups to coordinate attribute weighting for productivity attributes ("Elasmobranchs," "Flatfishes," and "Rockfishes and other fishes") and two for susceptibility attributes ("Assessment" and "No Assessment") (Table 2). Maximum length and fecundity productivity attributes were downweighted by half in two species groups because these attributes are inconsistently indicative of productivity within those species groups. Maximum length becomes inconsistently related to productivity when comparing elasmobranchs and rockfishes outside of their taxonomic families, while fecundity is a misleading measure for rockfishes, which often demonstrate low productivity despite large numbers of inconsistently spawned offspring (Love et al. 2002).

The management strategy susceptibility attribute was upweighted by 50% in all cases because we believe this attribute contributed to true susceptibility more strongly than did other attributes. Two of the susceptibility attributes ("$F$ relative to $M$" and "Relative Spawning Biomass") are derived stock assessment quantities and not available for nonassessed stocks, thus were weighted as zero when a PFMC-approved assessment was not available. Alternatively, one could have scored these two attributes and assigned the data quality a score of 5 (poor information). This approach commonly applies the most risk-averse score (in this case, 3) to the attribute with no information (Hobday et al. 2007). We performed this sensitivity to our scores and it raised each stock's vulnerability score by about 0.1. Such an approach can obscure the interpretation of vulnerability scores (e.g., Is the vulnerability score high because the stocks' vulnerability is high, or because information to score the attributes is lacking?). We therefore chose to decouple vulnerability and data quality by not scoring attributes for which we had no information. Thus, vulnerability scores are our "best estimates" while the data quality score measures the information content in that best estimate.

An iterative approach was used to assign productivity and susceptibility scores for each attribute of the stocks

TABLE 1. Species and assessment weighting groups, minimum (Min) and maximum (Max) latitudinal and depth ranges (used in the cluster analyses), overall scores and results of the productivity–susceptibility analysis (PSA), proposed stock designation, and current and proposed stock complex assignments for each stock in the groundfish fishery management plan. Abbreviations are as follows: $P$ = productivity score; PDQ = productivity data quality score; $S$ = susceptibility; SDQ = susceptibility data quality; $V$ = vulnerability; EC = ecosystem component; and N = neither. Shading indicates different degrees of vulnerability, as follows: white, $V < 1.8$; light gray, $1.8 < V < 2.0$; dark gray, $2.0 < V < 2.2$; and black, $V > 2.2$. Letter designations of species denote retrospective susceptibility scorings based on the year 1998.

| | Weighting group | | Preferred latitude | | Preferred depth (m) | | PSA | | | | | Stock | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Species | Assessment? | Min | Max | Min | Max | $P$ | PDQ | $S$ | SDQ | $V$ | Designation | Current complex | Proposed complex |
| 1. Arrowtooth flounder *Atheresthes stomias* | Rockfishes | Yes | 42.8 | 55 | 50 | 500 | 1.95 | 1.90 | 1.60 | 2.96 | 1.21 | In the fishery | | |
| 2. Aurora rockfish *Sebastes aurora* | Rockfishes | No | 32.5 | 46.3 | 300 | 500 | 1.33 | 2.11 | 2.29 | 1.19 | 2.10 | In the fishery | Slope rockfish | Slope rockfish |
| 3. Bank rockfish *Sebastes rufus* | Rockfishes | Yes | 27.5 | 39.5 | 100 | 270 | 1.25 | 2.00 | 2.00 | 2.00 | 2.02 | In the fishery | Slope rockfish | Shelf rockfish, deep |
| 4. Big skate *Raja binoculata* | Elasmobranchs | No | 34.5 | 46 | 50 | 200 | 1.37 | 2.68 | 2.14 | 2.57 | 1.99 | In the fishery | Other fish | Elasmobranchs, shallow |
| 5. Big skate *Sebastes melanops* | Rockfishes | Yes | 38 | 54 | 0 | 55 | 1.33 | 2.00 | 2.00 | 1.44 | 1.94 | In the fishery | | |
| 6. Black-and-yellow rockfish *Sebastes chrysomelas* | Rockfishes | No | 34.5 | 39.5 | 1 | 18 | 1.89 | 1.89 | 2.29 | 1.33 | 1.70 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 7. Blackgill rockfish *Sebastes melanostomus* | Rockfishes | Yes | 36.7 | 42 | 250 | 600 | 1.22 | 1.78 | 2.08 | 1.40 | 2.08 | In the fishery | Slope rockfish | Slope rockfish |
| 8. Blue rockfish *Sebastes mystinus* | Rockfishes | Yes | 33 | 46.5 | 25 | 90 | 1.39 | 1.89 | 2.20 | 1.52 | 2.01 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 9. Bocaccio *Sebastes paucispinis* | Rockfishes | Yes | 32.5 | 42 | 100 | 250 | 1.28 | 2.11 | 1.88 | 1.56 | 1.93 | In the fishery | | |
| 10. Bronzespotted rockfish *Sebastes gilli* | Rockfishes | No | 31 | 37 | 200 | 290 | 1.22 | 1.94 | 2.16 | 1.92 | 2.12 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 11. Brown rockfish *Sebastes auriculatus* | Rockfishes | No | 23 | 38 | 1 | 120 | 1.61 | 2.33 | 2.43 | 1.48 | 1.99 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 12. Butter sole *Isopsetta isolepis* | Flatfishes | No | 34.3 | 55 | 2 | 150 | 2.45 | 2.80 | 2.05 | 3.52 | 1.18 | In the fishery | Other flatfish | Flatfishes, shallow |
| 13. Cabezon *Scorpaenichthys marmoratus* | Other fishes | Yes | 34 | 46 | 0 | 25 | 1.72 | 1.89 | 2.08 | 1.42 | 1.68 | In the fishery | Other fish | Other fishes, shallow |
| 14. Calico rockfish *Sebastes dallii* | Rockfishes | No | 28 | 37.6 | 60 | 120 | 1.75 | 2.44 | 1.76 | 2.05 | 1.46 | EC? | Nearshore rockfish | Shelf rockfish, shallow |
| 15. California scorpionfish *Scorpaena gutatta* | Rockfishes | Yes | 22.9 | 34.4 | 2 | 50 | 1.83 | 2.00 | 1.80 | 1.44 | 1.41 | In the fishery | | |
| 16. California skate *Raja inornata* | Elasmobranchs | No | 32.5 | 39 | 18 | 671 | 1.21 | 3.21 | 2.14 | 2.57 | 2.12 | In the fishery | Other fish | Elasmobranchs, deep |
| 17. Canary rockfish *Sebastes pinniger* | Rockfishes | Yes | 34.5 | 54 | 50 | 250 | 1.28 | 1.78 | 2.04 | 1.56 | 2.01 | Iin the fishery | | |

TABLE 1. Continued.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18. Chameleon rockfish *Sebastes phillipsi* | Rockfishes | No | 33.6 | 34.5 | 174 | 274 | 1.39 | 2.61 | 2.24 | 2.81 | 2.03 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 19. Chilipepper *Sebastes goodei* | Rockfishes | Yes | 32.5 | 39.3 | 50 | 250 | 1.83 | 1.78 | 1.68 | 1.36 | 1.35 | In the fishery | | |
| 20. China rockfish *Sebastes nebulosus* | Rockfishes | No | 36 | 59.5 | 18 | 92 | 1.33 | 2.22 | 2.48 | 1.48 | 2.23 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 21. Copper rockfish *Sebastes caurinus* | Rockfishes | No | 32 | 34.5 | 0 | 90 | 1.36 | 2.11 | 2.57 | 1.48 | 2.27 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 22. Cowcod *Sebastes levis* | Rockfishes | Yes | 32.5 | 34.5 | 150 | 244 | 1.06 | 1.44 | 1.88 | 1.88 | 2.13 | In the fishery | | |
| 23. Curlfin sole *Pleuronichthys decurrens* | Flatfishes | No | 31 | 55 | 7 | 90 | 2.45 | 3.80 | 2.10 | 3.52 | 1.23 | In the fishery | Other flatfish | Flatfishes, shallow |
| 24. Darkblotched rockfish *Sebastes crameri* | Rockfishes | Yes | 34.5 | 54.3 | 140 | 210 | 1.39 | 1.67 | 2.04 | 1.24 | 1.92 | In the fishery | | |
| 25. Dover sole *Microstomus pacificus* | Flatfishes | Yes | 34 | 48 | 200 | 500 | 1.80 | 1.90 | 1.96 | 2.56 | 1.54 | In the fishery | | |
| 26. Dusky rockfish *Sebastes ciliatus* | Rockfishes | No | 54 | 60 | 100 | 300 | 1.28 | 2.33 | 0.00 | 0.00 | 1.99 | | Shelf rockfish | Revisit FMP inclusion |
| 27. Dwarf-red rockfish *Sebastes rufinanus* | Rockfishes | No | 32.5 | 34.4 | 58 | 167 | 1.83 | 3.17 | 0.00 | 0.00 | 1.54 | | Shelf rockfish | Revisit FMP inclusion |
| 28. English sole *Parophrys vetulus* | Flatfishes | Yes | 32.5 | 60 | 0 | 250 | 2.25 | 2.10 | 1.92 | 2.64 | 1.19 | In the fishery | | |
| 29. Pacific flatnose *Antimora microlepis* | Other fishes | No | 23 | 55 | 500 | 950 | 1.72 | 3.89 | 1.75 | 2.38 | 1.48 | In the fishery | Other fish | Other fishes, deep |
| 30. Flag rockfish *Sebastes rubrivinctus* | Rockfishes | No | 30 | 37.8 | 60 | 200 | 1.33 | 2.61 | 2.05 | 1.48 | 1.97 | In the fishery | Shelf rockfish | Shelf rockfish, shallow |
| 31. Flathead sole *Hippoglossoides elassodon* | Flatfishes | No | 36.5 | 65 | 0 | 366 | 2.30 | 2.40 | 2.05 | 2.86 | 1.26 | In the fishery | Other flatfish | Flatfishes, deep |
| 32. Freckled rockfish *Sebastes lentignosus* | Rockfishes | No | 27.2 | 34 | 44 | 180 | 1.78 | 3.17 | 1.76 | 1.67 | 1.44 | EC? | Shelf rockfish | Shelf rockfish, shallow |
| 33. Gopher rockfish *Sebastes carnatus* | Rockfishes | Yes | 32.5 | 39.5 | 12 | 37 | 1.56 | 2.22 | 2.00 | 1.64 | 1.76 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 34. Grass rockfish *Sebastes rastrelliger* | Rockfishes | No | 30 | 43 | 0 | 15 | 1.61 | 2.67 | 2.29 | 1.48 | 1.89 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 35. Greenblotched rockfish *Sebastes rosenblatti* | Rockfishes | No | 28 | 38 | 61 | 396 | 1.28 | 1.78 | 2.24 | 1.71 | 2.12 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 36. Greenspotted rockfish *Sebastes chlorostictus* | Rockfishes | No | 28 | 36.7 | 90 | 179 | 1.39 | 2.44 | 2.14 | 1.90 | 1.98 | In the fishery | Shelf rockfish | Shelf rockfish, shallow |
| 37. Greenstriped rockfish *Sebastes elongatus* | Rockfishes | Yes | 31 | 54 | 100 | 250 | 1.28 | 1.56 | 1.76 | 2.00 | 1.88 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 38. Halfbanded rockfish *Sebastes semicinctus* | Rockfishes | No | 27.7 | 38 | 60 | 150 | 2.00 | 1.89 | 1.76 | 2.00 | 1.26 | EC? | Shelf rockfish | |

(*Continued on next page*)

TABLE 1. Continued.

| | Weighting group | | Preferred latitude | | Preferred depth (m) | | PSA | | | | | Stock | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Species | Assessment? | Min | Max | Min | Max | *P* | PDQ | *S* | SDQ | *V* | Designation | Current complex | Proposed complex |
| 39. Harlequin rockfish *Sebastes variegatus* | Rockfishes | No | 49 | 60 | 100 | 350 | 1.31 | 2.83 | 1.95 | 3.00 | 1.94 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 40. Honeycomb rockfish *Sebastes umbrosus* | Rockfishes | No | 27 | 34.5 | 45 | 60 | 1.36 | 2.50 | 2.10 | 2.76 | 1.97 | In the fishery | Shelf rockfish | Nearshore rockfish |
| 41. Kelp greenling *Hexagrammos decagrammus* | Other fishes | Yes | 34.5 | 55 | 0 | 20 | 1.83 | 2.11 | 2.04 | 1.52 | 1.56 | In the fishery | Other fish | Other fishes, shallow |
| 42. Kelp rockfish *Sebastes atrovirens* | Rockfishes | No | 32 | 38 | 18 | 24 | 1.83 | 2.11 | 2.12 | 1.48 | 1.62 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 43. Leopard shark *Triakis semifasciata* | Elasmobranchs | No | 32.5 | 42 | 0 | 4 | 1.26 | 1.89 | 2.00 | 2.57 | 2.00 | In the fishery | Other fish | Elasmobranchs, shallow |
| 44. Lingcod *Ophiodon elongatus* | Other fishes | Yes | 34.5 | 58 | 100 | 150 | 1.75 | 2.22 | 1.92 | 1.96 | 1.55 | In the fishery | | |
| 45. Longnose skate *Raja rhina* | Elasmobranchs | Yes | 46 | 53.5 | 100 | 150 | 1.53 | 1.95 | 1.80 | 2.64 | 1.68 | In the fishery | | |
| 46. Longspine thornyhead *Sebastolobus altivelis* | Rockfishes | Yes | 33 | 55 | 500 | 1300 | 1.47 | 1.67 | 1.16 | 2.40 | 1.54 | In the fishery | | |
| 47. Mexican rockfish *Sebastes macdonaldi* | Rockfishes | No | 22.5 | 36.3 | 100 | 256 | 1.50 | 3.17 | 2.00 | 2.95 | 1.80 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 48. Olive rockfish *Sebastes serranoides* | Rockfishes | No | 34.3 | 39 | 0 | 75 | 1.69 | 2.22 | 2.33 | 1.48 | 1.87 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 49. Pacific cod *Gadus macrocephalus* | Other fishes | No | 40 | 65 | 50 | 300 | 2.11 | 2.11 | 2.00 | 1.57 | 1.34 | In the fishery | | |
| 50. Pacific ocean perch *Sebastes alutus* | Rockfishes | Yes | 42 | 55 | 100 | 450 | 1.44 | 2.50 | 1.67 | 2.43 | 1.69 | In the fishery | | |
| 51. Pacific grenadier *Coryphaenoides acrolepis* | Other fishes | No | 38 | 55 | 1500 | 2825 | 1.44 | 2.50 | 1.95 | 1.95 | 1.82 | In the fishery | Other fish | Other fishes, deep |
| 52. Pacific sanddab *Citharichthys sordidus* | Flatfishes | No | 22.8 | 55 | 50 | 150 | 2.40 | 3.80 | 2.10 | 2.76 | 1.25 | In the fishery | Other flatfish | Flatfishes, shallow |
| 53. Pacific hake *Merluccius productus* | Other fishes | Yes | 24.5 | 50 | 50 | 500 | 2.00 | 2.22 | 2.36 | 2.04 | 1.69 | In the fishery | | |
| 54. Petrale sole *Eopsetta jordani* | Flatfishes | Yes | 38 | 49 | 50 | 300 | 1.70 | 1.50 | 2.44 | 1.80 | 1.94 | In the fishery | | |
| 55. Pink rockfish *Sebastes eos* | Rockfishes | No | 27.8 | 35 | 80 | 366 | 1.33 | 2.72 | 2.14 | 3.10 | 2.02 | In the fishery | Shelf rockfish | Shelf rockfish, deep |

TABLE 1. Continued.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 56. Pinkrose rockfish *Sebastes simulator* | Rockfishes | No | 28.9 | 34.4 | 150 | 320 | 1.31 | 2.72 | 1.67 | 2.48 | 1.82 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 57. Pygmy rockfish *Sebastes wilsoni* | Rockfishes | No | 32.5 | 60 | 60 | 150 | 1.78 | 2.67 | 1.71 | 2.48 | 1.42 | EC? | Shelf rockfish | Shelf rockfish, shallow |
| 58. Quillback rockfish *Sebastes maliger* | Rockfishes | No | 34.5 | 60 | 44 | 66 | 1.31 | 2.06 | 2.43 | 1.48 | 2.22 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 59. Spotted ratfish *Hydrolagus colliei* | Elasmobranchs | No | 28.5 | 58 | 100 | 150 | 1.63 | 2.89 | 2.05 | 2.71 | 1.72 | In the fishery | Other fish | Elasmobranchs, shallow |
| 60. Redbanded rockfish *Sebastes babcocki* | Rockfishes | No | 34.5 | 60 | 150 | 450 | 1.28 | 2.39 | 2.05 | 2.48 | 2.02 | In the fishery | Slope rockfish | Slope rockfish |
| 61. Redstripe rockfish *Sebastes proriger* | Rockfishes | No | 42 | 60 | 150 | 275 | 1.31 | 2.50 | 2.33 | 2.57 | 2.16 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 62. Rex sole *Glyptocephalus zachirus* | Flatfishes | No | 28 | 62 | 50 | 450 | 2.05 | 2.70 | 1.86 | 3.67 | 1.28 | In the fishery | Other flatfish | Flatfishes, deep |
| 63. Rock greenling *Hexagrammos lagocephalus* | Other fishes | No | 34 | 64.6 | 0 | 80 | 1.78 | 2.67 | 2.29 | 1.48 | 1.77 | In the fishery | | |
| 64. Rock sole *Lepidopsetta bilineata* | Flatfishes | No | 32 | 55 | 0 | 300 | 1.95 | 3.00 | 1.95 | 3.86 | 1.42 | In the fishery | Other flatfish | Flatfishes, deep |
| 65. Rosethorn rockfish *Sebastes helvomaculatus* | Rockfishes | No | 34.5 | 60 | 100 | 300 | 1.19 | 1.94 | 2.05 | 2.86 | 2.09 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 66. Rosy rockfish *Sebastes rosaceus* | Rockfishes | No | 31 | 40 | 40 | 150 | 1.61 | 3.11 | 2.29 | 3.52 | 1.89 | In the fishery | Shelf rockfish | Shelf rockfish, shallow |
| 67. Rougheye rockfish *Sebastes aleutianus* | Rockfishes | No | 42 | 60 | 150 | 450 | 1.17 | 1.78 | 2.33 | 3.19 | 2.27 | In the fishery | Slope rockfish | Slope rockfish |
| 68. Sablefish *Anoplopoma fimbria* | Other fishes | Yes | 28 | 55 | 200 | 1200 | 1.61 | 1.78 | 1.88 | 1.88 | 1.64 | In the fishery | | |
| 69. Sand sole *Psettichthys melanostictus* | Flatfishes | No | 33.5 | 55 | 0 | 73 | 2.35 | 2.80 | 2.05 | 3.95 | 1.23 | In the fishery | Other flatfish | Flatfishes, shallow |
| 70. Sharpchin rockfish *Sebastes zacentrus* | Rockfishes | No | 36.5 | 60 | 100 | 350 | 1.36 | 1.94 | 2.24 | 3.71 | 2.05 | In the fishery | Slope rockfish | Shelf rockfish, deep |
| 71. Shortbelly rockfish *Sebastes jordani* | Rockfishes | Yes | 34.5 | 48.5 | 150 | 200 | 1.94 | 1.89 | 1.40 | 1.12 | 1.13 | EC | | |
| 72. Shortraker rockfish *Sebastes borealis* | Rockfishes | No | 48.5 | 58.5 | 100 | 600 | 1.22 | 2.17 | 2.38 | 2.90 | 2.25 | In the fishery | Slope rockfish | Slope rockfish |
| 73. Shortspine thornyhead *Sebastolobus alascanus* | Rockfishes | Yes | 32 | 50 | 100 | 850 | 1.33 | 2.22 | 1.68 | 2.00 | 1.80 | In the fishery | | |
| 74. Silvergray rockfish *Sebastes brevispinis* | Rockfishes | No | 42 | 60 | 100 | 300 | 1.22 | 1.78 | 1.95 | 2.19 | 2.02 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 75. Tope *Galeorhinus galeus*[a] | Elasmobranchs | No | 32.5 | 38 | 2 | 471 | 1.11 | 1.42 | 1.71 | 3.33 | 2.02 | In the fishery | Other fish | Elasmobranchs, deep |

(*Continued on next page*)

TABLE 1. Continued.

| | Weighting group | | Preferred latitude | | Preferred depth (m) | | PSA | | | | | Stock | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Species | Assessment? | Min | Max | Min | Max | *P* | PDQ | *S* | SDQ | *V* | Designation | Current complex | Proposed complex |
| 76. Speckled rockfish *Sebastes ovalis* | Rockfishes | No | 32 | 38 | 76 | 152 | 1.33 | 2.22 | 2.29 | 2.52 | 2.10 | In the fishery | Shelf rockfish | Shelf rockfish, shallow |
| 77. Spiny dogfish *Squalus acanthias* | Elasmobranchs | No | 30 | 55 | 0 | 350 | 1.11 | 1.00 | 1.98 | 3.24 | 2.13 | In the fishery | | Elasmobranchs, deep |
| 78. Splitnose rockfish *Sebastes diploproa* | Rockfishes | No | 32.5 | 54.3 | 150 | 450 | 1.28 | 1.78 | 1.60 | 2.00 | 1.82 | In the fishery | Slope rockfish | Slope rockfish |
| 79. Squarespot rockfish *Sebastes hopkinsi* | Rockfishes | No | 30 | 38 | 36 | 150 | 1.61 | 2.94 | 2.24 | 2.29 | 1.86 | In the fishery | Shelf rockfish | Shelf rockfish, shallow |
| 80. Starry flounder *Platichthys stellatus* | Flatfishes | Yes | 33.7 | 70 | 0 | 150 | 2.15 | 2.60 | 1.60 | 2.64 | 1.04 | In the fishery | | |
| 81. Starry rockfish *Sebastes constellatus* | Rockfishes | No | 23 | 36.5 | 60 | 150 | 1.25 | 2.11 | 2.14 | 2.38 | 2.09 | In the fishery | Shelf rockfish | Shelf rockfish, shallow |
| 82. Stripetail rockfish *Sebastes saxicola* | Rockfishes | No | 33 | 49 | 10 | 350 | 1.39 | 2.56 | 1.81 | 2.48 | 1.80 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 83. Swordspine rockfish *Sebastes ensifer* | Rockfishes | No | 31 | 32.5 | 60 | 200 | 1.33 | 2.33 | 2.00 | 2.19 | 1.94 | In the fishery | Shelf rockfish | Shelf rockfish, shallow |
| 84. Tiger rockfish *Sebastes nigrocinctus* | Rockfishes | No | 41 | 55 | 55 | 274 | 1.25 | 2.50 | 2.10 | 2.19 | 2.06 | In the fishery | Shelf rockfish | Shelf rockfish, deep |
| 85. Treefish *Sebastes serriceps* | Rockfishes | No | 28 | 34.5 | 3 | 60 | 1.67 | 2.33 | 2.10 | 2.05 | 1.73 | In the fishery | Nearshore rockfish | Nearshore rockfish |
| 86. Vermilion rockfish *Sebastes miniatus* | Rockfishes | Yes | 28 | 43 | 50 | 150 | 1.22 | 1.67 | 2.02 | 2.24 | 2.05 | In the fishery | Shelf rockfish | Shelf rockfish, shallow |
| 87. Widow rockfish *Sebastes entomelas* | Rockfishes | Yes | 38 | 54 | 100 | 350 | 1.31 | 1.44 | 2.16 | 2.08 | 2.05 | In the fishery | | |
| 88. Yelloweye rockfish *Sebastes ruberrimus* | Rockfishes | Yes | 38 | 54 | 91 | 180 | 1.22 | 1.44 | 1.92 | 2.00 | 2.00 | In the fishery | | |
| 89. Yellowmouth rockfish *Sebastes reedi* | Rockfishes | No | 42 | 58.5 | 275 | 366 | 1.61 | 1.89 | 2.38 | 2.33 | 1.96 | In the fishery | Slope rockfish | Slope rockfish |
| 90. Yellowtail rockfish *Sebastes flavidus* | Rockfishes | Yes | 42 | 48 | 90 | 180 | 1.33 | 1.78 | 1.88 | 2.00 | 1.88 | In the fishery | | |
| A. Bocaccio | Rockfishes | Yes | 32.5 | 42 | 100 | 250 | 1.28 | 2.11 | 2.72 | 1.56 | 2.43 | | | |
| B. Canary rockfish | Rockfishes | Yes | 34.5 | 54 | 50 | 250 | 1.28 | 1.78 | 2.84 | 1.56 | 2.52 | | | |
| C. Cowcod | Rockfishes | Yes | 32.5 | 34.5 | 150 | 244 | 1.06 | 1.44 | 2.68 | 2.36 | 2.57 | | | |
| D. Darkblotched rockfish | Rockfishes | Yes | 34.5 | 54.3 | 140 | 210 | 1.39 | 1.67 | 2.76 | 1.24 | 2.39 | | | |
| E. Pacific ocean perch | Rockfishes | Yes | 32.8 | 55 | 100 | 450 | 1.39 | 2.06 | 2.32 | 2.04 | 2.08 | | | |
| F. Yelloweye rockfish | Rockfishes | Yes | 38 | 54 | 91 | 180 | 1.22 | 1.44 | 2.80 | 2.00 | 2.53 | | | |

[a]Formerly known as soupfin shark *G. Zyopterus*.

considered. Each of the authors received a set of unique stocks to score. The major sources used to inform scoring were available from stock-specific stock assessments, Cailliet et al. (2000), Love et al. (2002), the Pacific Shark Research Center (Moss Landing Marine Laboratories) elasmobranch life history matrix (http://psrc.mlml.calstate.edu/recommended-reading-list/life history-data-matrix/ [October 2009]), and FishBase (www.fishbase.org [August 2009]). Given the range of scorer experience, all scorers were encouraged to score every productivity and susceptibility attribute that was scoreable (regardless of confidence in that score), but to record the data quality to reflect their belief in their score. Attribute values that straddled two bins were given an intermediate bin score. Once all stocks were scored, all scores were evaluated by the entire scoring team to (1) ensure a consistent (i.e., agreed upon by all scorers) scoring approach prevailed (especially among the more subjective susceptibility attributes), (2) rectify any perceived discrepancies, and (3) indentify stocks with poor data quality scores for further scoring consideration. Two scorers (J. M. Cope and E. J. Dick) again reviewed the resultant productivity scores, while another (J. DeVore) reviewed the resultant susceptibility scores, making any updates or corrections to scores as needed. The scoring team subsequently reviewed and finalized the PSA scores. All scoring was done using the Productivity–Susceptibility Analysis (version 1.4) module of the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/PSA.html [February 2010]).

Vulnerability scores are then applied to help identify stocks having significant interactions with fisheries (and are therefore “in the fishery”) or are EC stocks. Stocks are considered candidates as an EC stock if (1) an appreciable portion of their population is within the management area, (2) they have low vulnerability scores (defined below), and c) they are neither targeted nor retained in a fishery. These three criteria (ecological presence, low vulnerability, and nontargeted–retained in fisheries) were applied to all stocks.

*Identifying stock complexes*.—Stock complex assignments for all stocks currently in stock complexes (Table 1) were reevaluated using grouping analysis in the following manner: (1) clustering stocks based on ecological distribution (e.g., depth and latitude), (2) grouping within ecological distributional clusters based on vulnerability scores, and (3) evaluating the final groups in terms of fishery interactions (i.e., separating groups further by associations in particular fisheries, if needed). All rockfish currently in complexes were analyzed together. Stocks in the Other flatfish and Other fish complexes were analyzed separately.

Ecological distributions for each stock were defined using the Pacific Coast Ocean Observing System (www.webapps.nwfsc.noaa.gov/pacoos/faces/FishData.jsp [February 2010]) to identify minimum and maximum depth and latitudinal distributions (four total variables; Table 1). For each cluster analysis, a k-medoids partitioning analysis based on Euclidean distances was used. The number of clusters best supported by the data were identified using silhouette and Hubert’s gamma cluster validity diagnostics (see Cope and Punt 2009 for methods). It was reasoned that stocks should first be clustered based on ecological distributions so as to maintain spatial relations, then grouped by vulnerability scores. Attempts to cluster all variables at once (minimum and maximum depths and latitudes and vulnerability scores) generated some groups of stocks with common vulnerabilities, but that lacked spatial coherence. Clustering depth and latitude simultaneously also resulted in stocks with similar latitudinal ranges, but did not occur in similar depths. Given the current complexes are based primarily on depth co-occurrences, the following multistep grouping approach was implemented: cluster all stocks first by depth, then by latitude, and finally group by vulnerability reference points (see below). This approach allowed resultant groupings to be transparent and interpretable by depth, latitude, and vulnerability. An additional grouping level based on fishery interactions (i.e., grouping fish by the fisheries they are predominantly found in) was considered, but did not alter the results based on the above grouping analysis. All cluster analysis was performed in R 2.11.0 (R Development Core Team 2010).

To both help with general interpretation of vulnerability scores ($V$) and identification of vulnerability groupings for stock complexes, vulnerability reference points were defined. Patrick et al. (2009, 2010) noted that $V$ greater than 1.8 was often associated with stocks undergoing overfishing or in an overfished state. A more detailed analysis of their results indicated that $V = 2.0$ was more generally associated with stocks currently considered overfished. Given that stocks currently overfished are often in rebuilding phases with substantial reductions in the current susceptibility to overfishing achieved through management response, susceptibility scores based on current conditions may thus underestimate the absolute value of vulnerability indicative of becoming overfished. To gain better resolution in the relationship between vulnerability and being in an overfished state, the susceptibilities of six PFMC groundfish stocks currently designated “overfished” were rescored to reflect conditions under a major population decline (defined as reference year 1998 and found at the end of Table 1). All of the updated scoring was made to susceptibility attributes 1–6 (Table 2). In addition to this retrospective consideration, comparisons were also made with the results of Dick and MacCall (2010) who estimated the probability of overfishing occurring among several data-limited stocks using the depletion-based stock reduction analysis (DB-SRA). Stocks with $V$ greater than 2.2 demonstrated about a 50% chance of current catch exceeding the DB-SRA based estimate of the overfishing limit (OFL). Combining these two sources of information (the retrospective PSA and comparisons with DB-SRA), a minimum vulnerability of 2.2 was used to indicate stocks with high probabilities of being overfished or in the midst of overfishing (see Figure 1). The following guidance for interpreting vulnerability scores via vulnerability reference points

TABLE 2. Productivity and susceptibility attributes with bin definitions and score weightings for different species groups and those with and without Pacific Fishery Management Council–approved assessments. Default weights for all attributes are 2. Full descriptions of all attributes and the determination of binning values can be found in Patrick et al. (2009).

| | Bins | | | Weight (0 to 4) | | |
|---|---|---|---|---|---|---|
| Productivity attributes | High (3) | Moderate (2) | Low (1) | Elasmobranchs | Flatfishes | Rockfishes and other fishes |
| $r$ | $\geq$0.5 | 0.5 to 0.16 | $\leq$0.16 | 2 | 2 | 2 |
| Maximum age | $\leq$10 years | 10 to 30 years | $\geq$30 years | 2 | 2 | 2 |
| Maximum size | $\leq$60 cm | 60 to 150 cm | $\geq$150 cm | 1 | 2 | 1 |
| von Bertalanffy growth coefficient ($k$) | $\geq$0.25 | 0.15 to 0.25 | $\leq$0.15 | 2 | 2 | 2 |
| Estimated natural mortality ($M$) | $\geq$0.40 | 0.20 to 0.40 | $\leq$0.20 | 2 | 2 | 2 |
| Measured fecundity | $\geq 10^4$ | $10^2$ to $10^3$ | $\leq 10^2$ | 2 | 2 | 1 |
| Breeding strategy | 0 | Between 1 and 3 | $\geq$4 | 2 | 2 | 2 |
| Recruitment pattern | Highly frequent recruitment success ($\geq$8 per decade) | Moderately frequent recruitment success (>1 and <8 per decade) | Infrequent recruitment success ($\leq$1 per decade) | 2 | 2 | 2 |
| Age at maturity | $\leq$2 years | 2 to 4 years | $\geq$4 years | 2 | 2 | 2 |
| Mean trophic level | $\leq$2.5 | 2.5 to 3.5 | $\geq$3.5 | 2 | 2 | 2 |
| | Bins | | | Weight (0 to 4) | | |
| Susceptibility attributes | Low (1) | Moderate (2) | High (3) | Assessment | | No assessment |
| Management strategy | Proactive management; sort requirements; individual specification; discard monitoring; biological data; representative fishery-independent indices | Reactive management; decent catch records; some assessment data; weak spatial knowledge; weakly informed indices | High catch uncertainty; low assessment data; no sorting; inadequate discard monitoring; low confidence in control rule | 3 | | 3 |
| Areal overlap | $\leq$25% of stock occurs in the area fished | Between 25% and 50% of the stock occurs in the area fished | $\geq$50% of stock occurs in the area fished | 2 | | 2 |
| Geographic concentration | Stock is distributed in $\geq$50% of its total range | Stock is distributed in 25% to 50% of its total range | Stock is distributed in $\leq$25% of its total range | 2 | | 2 |
| Vertical overlap | <25% of stock occurs in the depths fished | Between 25% and 50% of the stock occurs in the depths fished | $\geq$50% of stock occurs in the depths fished | 2 | | 2 |
| $F$ relative to $M$ | $\leq$0.5 | 0.5 to 1.0 | $\geq$1 | 2 | | 0 |
| Relative spawning biomass | $B$ is $\geq$40% of $B_0$ (or maximum observed from time series of biomass estimates) | $B$ is between 25% and 40% of $B_0$ (or maximum observed from time series of biomass estimates) | $B$ is $\leq$25% of $B_0$ (or maximum observed from time series of biomass estimates) | 2 | | 0 |

TABLE 2. Continued.

| Susceptibility attributes | Bins | | | Weight (0 to 4) | |
|---|---|---|---|---|---|
| | Low (1) | Moderate (2) | High (3) | Assessment | No assessment |
| Seasonal migrations | Seasonal migrations decrease overlap with the fishery | Seasonal migrations do not substantially affect the overlap with the fishery | Seasonal migrations increase overlap with the fishery | 2 | 2 |
| Schooling–aggregation and other behavioral responses | Behavioral responses decrease the catchability of the gear | Behavioral responses do not substantially affect the catchability of the gear | Behavioral responses (e.g., schooling) increase the catchability of the gear | 2 | 2 |
| Morphology affecting capture | Species shows low selectivity to the fishing gear | Species shows moderate selectivity to the fishing gear | Species shows high selectivity to the fishing gear | 2 | 2 |
| Survival after capture and release | Survival probability $\geq$67% | 33% < survival probability <67% | Survival probability $\leq$33% | 2 | 2 |
| Desirability–value of the fishery | Stock is not highly valued or desired by the fishery | Stock is moderately valued or desired by the fishery | Stock is highly valued or desired by the fishery | 2 | 2 |
| Fishery impact to EFH or habitat in general for non-targets | Adverse effects absent, minimal, or temporary | Adverse effects more than minimal or temporary but are mitigated | Adverse effects more than minimal or temporary and are not mitigated | 2 | 2 |

is offered given the above insight: $V \geq 2.2$ indicates stocks of major concern; $2.0 \leq V < 2.2$ indicates stocks of high concern; $1.8 \leq V < 2.0$ indicates stocks of medium concern; and $V < 1.8$ indicates stocks of low concern.

## RESULTS

Five stocks are found in the area of major concern ($V \geq 2.2$) and another 23 of the 90 stocks are in the area of high concern ($2.0 \leq V < 2.2$; Table 1; Figure 1). These stocks were exclusively rockfishes (*Sebastes* spp.) and elasmobranchs. Another 28 stocks are of medium concern ($1.8 \leq V < 2.0$). Patrick et al. (2010) provided additional guidance that stocks with susceptibility scores greater than 2.3 should also be of concern, regardless of the vulnerability score. There were 11 stocks with such susceptibilities, and all but one stock (Pacific hake) is included in our categories of medium to high concern. The median rockfish productivity score ($N = 59$) was 1.33 (with the lowest value possible being 1), meaning that relatively low susceptibility scores of 1.67 and 2.10 would cause 50% of the rockfish to have $V$ of 1.8 or greater and $V$ of 2.0 or greater, respectively, demonstrating the innate vulnerability of these stocks to being overfished based solely on life history traits. Flatfishes tended to have the lowest vulnerabilities (Table 1; Figure 1).

Productivity and susceptibility data quality scores (Table 1; Figure 2) are generally well informed (i.e., most data quality scores reside in the bottom left quadratic) for most stocks. The susceptibility scoring is relatively less reliable than the productivity scoring. Flatfishes, although the least vulnerable group, were also the relatively least-informed group, with 6 of the 12 flatfish stocks having at least one of the vulnerability components (productivity and susceptibility) poorly informed. Of the seven elasmobranch stocks in the FMP, three had poorly informed vulnerability components. Only 7 of the 59 rockfishes had either poorly informed productivity or susceptibility attributes.

### Applying PSA to the Needs of the MSA

Most of the stocks (88 of 90) occur significantly within the waters managed by the FMP, but only a minority of the stocks (35 of 90) in the FMP have low vulnerability scores (Table 1). Most (30 of 35) are affiliated with or are targeted by a fishery, so 85 of 90 stock are considered "in the fishery." There are five stocks that fit the EC criteria of ecological presence, low vulnerability, and nontargeting–retainment in fisheries (see "Proposed Stock Designation" column in Table 1). Shortbelly rockfish commonly occur in FMP-managed waters, but have low vulnerability ($V = 1.13$) and no target or retention fishery. This stock's extremely low vulnerability makes it a strong EC candidate. The remaining EC candidate stocks—calico, freckled, halfbanded, and pygmy rockfishes—have relatively higher

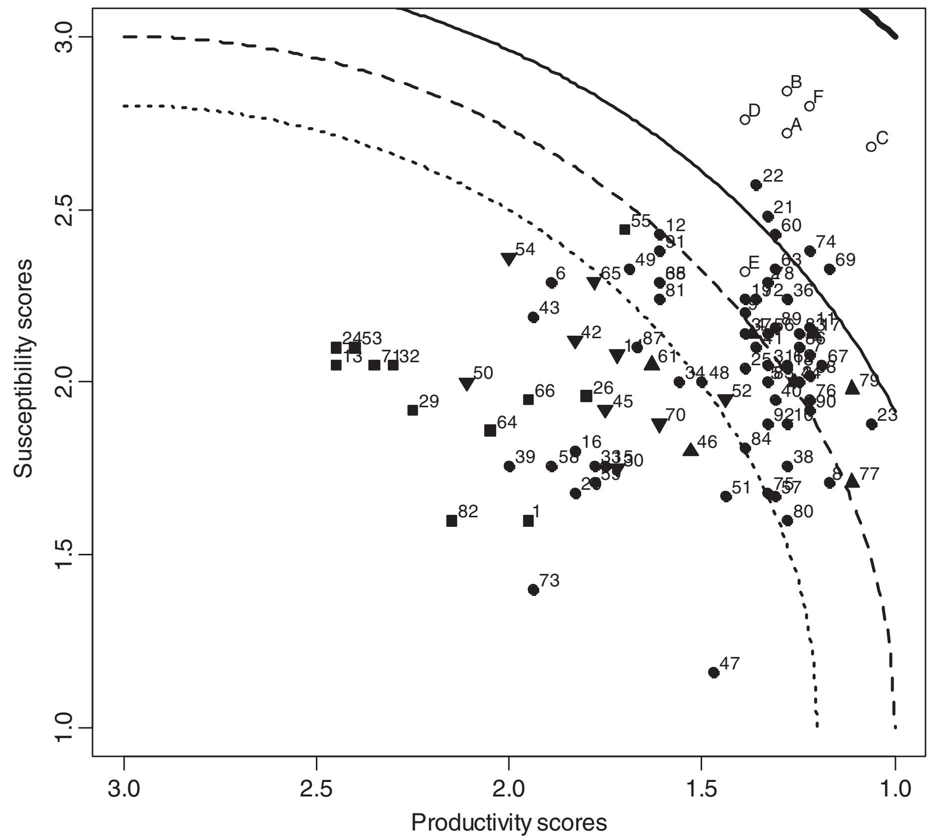


FIGURE 1. Productivity–susceptibility analysis (PSA) plot for species in the West Coast groundfish fishery management plan. Contours delineate areas of relative vulnerability ($V$, i.e., distance from the origin), with stocks of the highest vulnerability above the solid line ($V = 2.2$), those of high vulnerability above the dashed line ($V = 2.0$), those of medium vulnerability above the dotted line ($V = 1.8$), and those of the lowest vulnerability below the dotted line. The maximum theoretical vulnerability ($V = 2.8$) is indicated by the thickest solid line (top right corner). Solid symbols are based on current PSA scores. Open symbols are based on PSA scores circa 1998 for the rebuilding species only ("Retrospective"). Point labels refer to the species identifiers in Table 1. Note that the productivity axis is in descending value in order to make the top right quadrant of the plot the area of greatest vulnerability (i.e., the lowest productivity and highest susceptibility).



susceptibilities owing to minor interactions with recreational fisheries, but still generally fit the EC criteria. Susceptibilities for all EC candidate stocks were less than 1.8, which may be a useful preliminary criterion to characterize EC stocks from other stocks that have low vulnerabilities owing to high productivities.

The two remaining stocks—dusky and dwarf-red rockfish—did not fit either the "in the fishery" or any of the EC criteria. These stocks are not found in significant numbers within the area covered by the groundfish FMP, not susceptible to the fisheries, and thus not in danger of overfishing or being overfished. And despite having moderate (dusky rockfish) to low (dwarf-red rockfish) overall vulnerability (owing exclusively to low productivity scores), considering these stocks as either "in the fishery" or EC overstates their ecological presence in the system. Thus, the lack of both ecological and fishery relevance in the waters managed by the PFMC support potential revision of their inclusion in the groundfish FMP.

## Defining Stock Complexes

In general, the ecological grouping analysis supported four rockfish complexes based mainly on depth categories, with two latitudinal groupings also apparent (Table 3). The Flatfishes, Elasmobranchs, and Other fishes complexes were defined by two depth categories (Table 4). Stocks in each of the ecological complexes were also grouped into one of four vulnerability categories (Tables 3, 4). Several notable changes to the current complex designations are apparent. The biggest differences are the inclusions of shallow- and deep-shelf rockfish complexes instead of one Shelf rockfish complex (Table 3) and an Elasmobranchs complex separated from the original Other fish complex (Table 4). The remaining stocks in the Other fish category demonstrate two disparate depth distributions, necessitating two additional complexes. The Flatfishes complex contains the same stocks as in Other flatfish, but with an added descriptor based on ecological distribution. Additional differences include four rockfishes (bank, calico, honeycomb, and sharpchin rockfish) that changed complexes (Table 1).

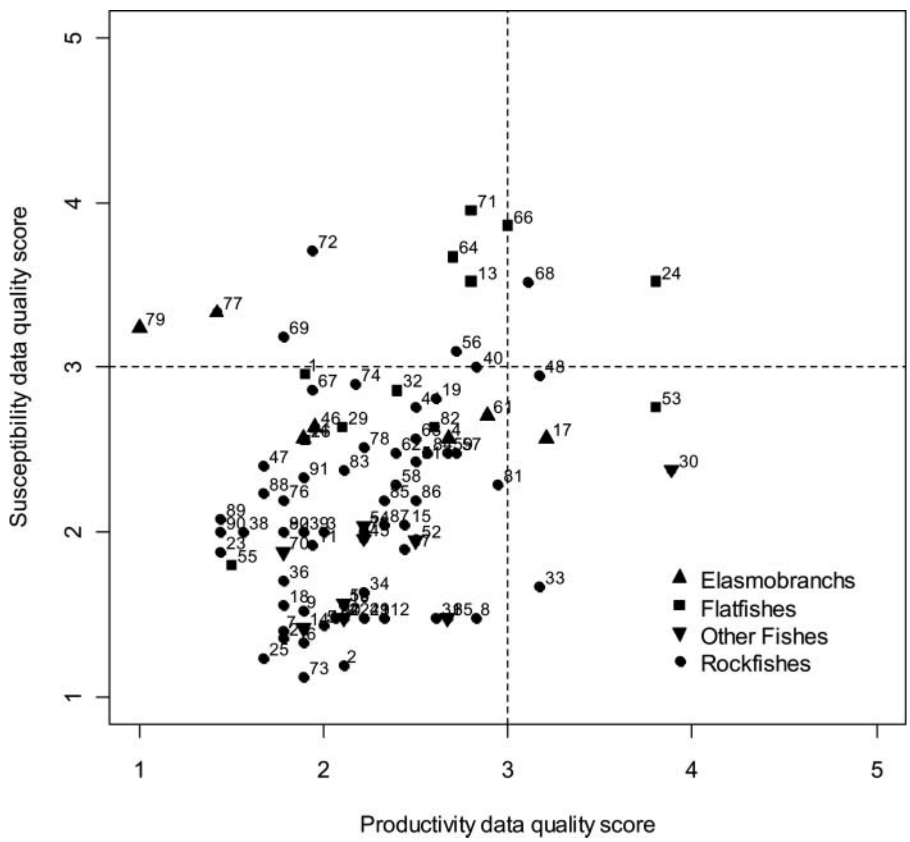


FIGURE 2. Data quality plots for the productivity and susceptibility scores in the productivity–susceptibility analysis for the stocks in the West Coast groundfish FMP. Higher scores indicate poorer data quality (e.g., a score of 5 on either axis means the overall data quality is poorest). Scores at the upper right corner therefore indicate the least-informed stocks. The vertical and horizontal lines provide a general guide to relative data quality, with values above 3 on either axis considered poorly informed scores.



Most of the members of the rockfish complexes show medium to high vulnerabilities, but most are below $V = 2.2$. Five rockfish stocks had $V$ greater than 2.2, with three stocks in the nearshore rockfish (China, copper, and quillback rockfish) and two in the slope (rougheye and shortraker rockfish), all of which are long-lived, deep-dwelling rockfishes. In general, there is no striking relationship of vulnerability with latitudinal distribution, though deep-dwelling stocks tend to exhibit relatively higher vulnerabilities (Table 3). The Flatfishes complex is composed exclusively of flatfishes with low vulnerabilities, while the newly proposed Elasmobranchs complex contains stocks with mostly medium to high vulnerabilities. The deep elasmobranchs complex demonstrates the greatest vulnerability of the non–rockfish complexes.

## DISCUSSION

The PSA provided an accessible approach to two needs brought forth by the reauthorized MSA (2006). First, in conjunction with fleet-targeting behavior, vulnerability scores were able to shed light on which stocks should be considered "in the fishery" or an EC stock, thus identifying the stocks for which ACLs and AMs are required. Secondly, for those stocks without council-approved stock assessments, stock complexes were established based on ecological distributions and vulnerabilities, incorporating both spatial considerations and population response to shared fishery interactions. The results are proposed stock complexes that offer managers focused attention on stocks that co-occur and exhibit similar responses to current fishing conditions.

One of the strengths of the PSA approach is the ease of scoring stocks with limited information. Despite the majority of the stocks in the groundfish FMP lacking fine biological resolution on many life history attributes, scoring a PSA requires only a general understanding of the attributes because bins are used rather than precise estimates. The generally high quality scores given to the information used to score each attribute even in data-limited situations attests to the practicality and usefulness of the PSA approach.

Scoring of the susceptibility attributes proved the most difficult, especially the attributes addressing areal and spatial overlap with the fishery, as well as geographic concentration of the stock, because such measures are inherently more difficult to estimate

TABLE 3. Proposed rockfish complexes informed by ecological distribution, productivity–susceptibility analysis score, and fisheries. Gray cells indicate "northern" stocks, white cells "southern" stocks.

| | Depth category | | | |
|---|---|---|---|---|
| Vulnerability ($V$) | Nearshore | Shelf-shallow | Shelf-deep | Slope |
| Major ($V \geq 2.2$) | China rockfish (2.23) | | | Rougheye rockfish (2.27) |
| | Quillback rockfish (2.22) | | | Shortraker rockfish (2.25) |
| | Copper rockfish (2.27) | | | |
| High ($2.0 \leq V < 2.2$) | Blue rockfish (2.01) | Speckled rockfish (2.1) | Redstripe rockfish (2.16) | Redbanded rockfish (2.02) |
| | | Starry rockfish (2.09) | Rosethorn rockfish (2.09) | Aurora rockfish (2.1) |
| | | Vermilion rockfish (2.05) | Sharpchin rockfish (2.05) | Blackgill rockfish (2.08) |
| | | | Silvergrey rockfish (2.02) | |
| | | | Tiger rockfish (2.06) | |
| | | | Bank rockfish (2.02) | |
| | | | Bronzespotted rockfish (2.12) | |
| | | | Chameleon rockfish (2.03) | |
| | | | Pink rockfish (2.02) | |
| Medium ($1.8 \leq V < 2.0$) | Brown rockfish (1.99) | Yellowtail rockfish (1.88) | Greenstriped rockfish (1.88) | Splitnose rockfish (1.82) |
| | Grass rockfish (1.89) | Flag rockfish (1.97) | Harlequin rockfish (1.94) | Yellowmouth rockfish (1.96) |
| | Honeycomb rockfish (1.97) | Greenspotted rockfish (1.98) | Stripetail rockfish (1.80) | |
| | Olive rockfish (1.87) | Rosy rockfish (1.89) | Greenblotched rockfish (1.92) | |
| | | Squarespot rockfish (1.86) | Mexican rockfish (1.80) | |
| | | Swordspine rockfish (1.94) | Pinkrose rockfish (1.82) | |
| Low ($V < 1.8$) | Black-and-yellow rockfish (1.7) | Pygmy rockfish (1.42) | | |
| | Gopher rockfish (1.76) | Calico rockfish (1.46) | | |
| | Kelp rockfish (1.59) | Freckled rockfish (1.44) | | |
| | Treefish rockfish (1.73) | Halfbanded rockfish (1.26) | | |

(Table 2). Maintaining a consistency in scoring these attributes when there are multiple scorers proved challenging and should be a focus when applying the PSA. Having all scorers clarify how each bin definition is treated during the first scoring iteration encouraged consistency. Data quality scoring was particularly useful in identifying such troublesome attributes in need of further consideration. Additional guidance to quantitatively scoring the areal and spatial overlap attributes is found in Patrick et al. (2009).

The analysis confirmed an already well-documented supposition that the life histories of many rockfishes and elasmobranchs increase the probability of their being overfished (Musick et al. 2000; Parker et al. 2000; Berkeley et al. 2004). In particular, three of the nearshore rockfishes (China, copper, and quillback

TABLE 4. Proposed stock complexes of noninformed species by ecological distribution, productivity–susceptibility analysis score, and fisheries. Shading in depth category indicates different levels of vulnerability, as follows: black = major, dark gray = high, light gray = medium, and white = low.

| | Depth category | |
|---|---|---|
| Complex | Shallow | Deep |
| Flatfishes | | |
| | | |
| | | |
| | Butter sole (1.18) | Flathead sole (1.26) |
| | Curlfin sole (1.23) | Rex sole (1.28) |
| | Pacific sanddab (1.25) | Rock sole (1.42) |
| | Sand sole (1.23) | |
| Elasmobranchs | | |
| | Leopard shark (2.00) | California skate (2.12) |
| | | Soupfin shark (2.02) |
| | | Spiny dogfish (2.13) |
| | Big skate (1.99) | |
| | Ratfish (1.57) | |
| Other fishes | | |
| | | |
| | | Pacific grenadier (1.82) |
| | Cabezon (1.48) | Finescale codling (1.48) |
| | Kelp greenling (1.59) | |

rockfish) are identified as being of high concern to be overfished (O'Farrell and Botsford 2006; Field et al. 2010), as are several of the slope stocks. Similar conclusions were arrived at by Dick and MacCall (2010), who found that most of the same stocks considered of highest vulnerability in this study are also the most likely to have undergone overfishing from recent catch levels. Although the results from the PSA are not meant to be a substitute for a proper stock assessment, it appears the information contained in applying the proposed vulnerability references can draw attention to stocks in need of increased management attention despite data limitations.

The stock complexes provided in this analysis are desirable in many ways. The need for allowing flexibility in fisheries management is a preferred trait (Hanna 1999; Smith et al. 1999). Grouping in a step-wise fashion (by depth, then latitude, then vulnerability scores) rather than using all variables at once, then presenting the final stock complexes with each level of detail explicit (depth, latitudinal, and vulnerability groups) would allow managers to assemble the complexes in a manner most useful to their needs. For example, using the information contained in Table 3 for rockfish complexes, managers could decide whether management needs warrant the collapsing of some of the depth or latitudinal categories, while maintaining the vulnerability groupings. They may also decide the vulnerability differences warrant distinct complexes, rather than just subcomplex distinction. The trade-off between too much detail (e.g., too many complexes) and enough to maintain management flexibility and applicability needs consideration. While the stock complexes suggested in this analysis add a layer in the form of vulnerability groupings, it is a resolution encouraged by the MSA and accessible to ways of assigning ACLs (Shertzer et al. 2008; Prager and Shertzer 2010).

The vulnerability reference points and contours introduced in this study provide guidance on how to interpret the vulnerability scores. Using the retrospective susceptibility scores to help define these reference points demonstrates a main attribute of interpreting vulnerabilities; management has the greatest influence in altering susceptibility when trying to reduce a stock's vulnerability. Productivity scores (Figure 1, horizontal axis) are usually static in the short term, thus are unlikely to change unless improvements in the data quality alter scoring. Most reduction in vulnerability via management will thus be realized on the susceptibility axis (Figure 1, vertical axis). Scoring should be updated on a regular basis to reflect any changes in susceptibility or increased knowledge of productivity attributes.

## Additional Applications of PSA to Groundfish Management

Beyond the two objectives previously outlined, vulnerability scores can help rapidly identify stocks of interest for either scientific emphasis or management attention. Data quality scores can identify stocks in need of basic biological or fisheries data, helping to prioritize data collection. Productivity and susceptibility scores may lend additional information to the setting of catch levels in data-limited situations (Prager and Shertzer 2010) or prioritizing stock-assessment resources. Additionally, the PSA could be used to identify other species not already contained in the FMP, but vulnerable to being overfished. Just as two species were suggested for possible removal from the FMP, other species with high vulnerability scores could be appropriate additions to the FMP. Given the possibility of emergent and developing fisheries (Perry et al. 1999), identification of such species is an ongoing relevant consideration.

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## REFERENCES

Berkeley, S. A., M. A. Hixon, R. J. Larson, and M. S. Love. 2004. Fisheries sustainability via protection of age structure and spatial distribution of fish populations. Fisheries 29(8):23–32.

Cailliet, G. M., E. J. Burton, J. M. Cope, and L. A. Kerr. 2000. Biological characteristics of nearshore fishes of California: a review of existing knowledge and proposed additional studies for the Pacific Ocean interjurisdictional fisheries management plan coordination and development. Available: www.dfg.ca.gov/marine/lifehistories/index.asp. (September 2010).

Cope, J. M., and A. E. Punt. 2009. Drawing the lines: resolving fishery management units with simple fisheries data. Canadian Journal of Fisheries and Aquatic Sciences 66:1256–1273.

Dick, E. J., and A. D. MacCall. 2010. Estimates of sustainable yield for 50 data-poor stocks in the Pacific coast groundfish fishery management plan. NOAA Technical Memorandum NMFS-SWFSC-460.

Essington, T. E., A. H. Beaudreau, and J. Wiedenmann. 2006. Fishing through marine food webs. Proceedings of the National Academy of Sciences of the USA 103:3171–3175.

Field, J., J. Cope, and M. Key. 2010. A descriptive example of applying vulnerability evaluation criteria to California nearshore finfish species. Pages 229–240 *in* R. Starr, C. Culver, C. Pomeroy, S. McMillan, T. Barnes, and D. Aseltine-Neilsen, editors. Managing data-poor fisheries: case studies, models and solutions 1. University of California–San Diego, California Sea Grant Program, La Jolla.

Hanna, S. S. 1999. Strengthening governance of ocean fishery resources. Ecological Economics 31:275–286.

Hobday, A. J., A. Smith, H. Webb, R. Daley, S. Wayte, C. Bulman, J. Dowdney, A. Williams, M. Sporcic, J. Dambacher, M. Fuller, and T. Walker. 2007. Ecological risk assessment for the effects of fishing: methodology. Australian Fisheries Management Authority, Report R04/1072, Canberra. Available: www.afma.gov.au/environment/eco_based/eras/docs/methodology.pdf. (June 2011).

Jiao, Y., C. Hayes, and E. Cortes. 2009. Hierarchical Bayesian approach for population dynamics modeling of fish complexes without species-specific data. ICES Journal of Marine Science 66:367–377.

Love, M. S., M. Yoklavich, and L. Thorsteinson. 2002. Rockfishes of the Northeast Pacific. University of California Press, Berkeley.

MSA (Magnuson-Stevens Fishery Conversation and Management Act). 2006. Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, U.S. Code, volume 16, sections 1801–1891d.

Murawski, S. A. 1991. Can we manage our multispecies fisheries? Fisheries 16(5):5–13.

Musick, J. A., G. Burgess, G. Cailliet, M. Camhi, and S. Fordham. 2000. Management of sharks and their relatives (*Elasmobranchii*). Fisheries 25(3):9–13.

O'Farrell, M. R., and L. W. Botsford. 2006. Estimating the status of nearshore rockfish (*Sebastes* spp.) populations with length frequency data. Ecological Applications 16:977–986.

Parker, S. J., S. A. Berkeley, J. T. Golden, D. R. Gunderson, J. Heifetz, M. A. Hixon, R. Larson, B. M. Leaman, M. S. Love, J. A. Musick, V. M. O'Connell, S. Ralston, H. J. Weeks, and M. M. Yoklavich. 2000. Management of pacific rockfish. Fisheries 23(3):22–25.

Patrick, W. S., P. Spencer, J. Link, J. Cope, J. Field, D. Kobayashi, P. Lawson, T. Gedamke, E. Cortes, O. Ormseth, K. Bigelow, and W. Overholtz. 2010. Using productivity and susceptibility indices to assess the vulnerability of United States fish stocks to overfishing. U.S. National Marine Fisheries Service Fishery Bulletin 108:305–322.

Patrick, W. S., P. Spencer, O. Ormseth, J. Cope, J. Field, D. Kobayashi, T. Gedamke, E. Cortés, K. Bigelow, W. Overholtz, J. Link, and P. Lawson. 2009. Using productivity and susceptibility indices to determine the vulnerability of a stock: case studies from six U.S. fisheries. NOAA Technical Memorandum NMFS-F/SPO-101.

Perry, R. I., C. J. Walters, and J. A. Boutillier. 1999. A framework for providing scientific advice for the management of new and developing invertebrate fisheries. Reviews in Fish Biology and Fisheries 9:125–150.

Prager, M. H., and K. W. Shertzer. 2010. Deriving acceptable biological catch from the overfishing limit: implications for assessment models. North American Journal of Fisheries Management 30:289–294.

R Development Core Team. 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available: www.R-project.org. (September 2010).

Reuter, R. F., M. E. Conners, J. Dicosimo, S. Gaichas, O. Ormseth, and T. T. Tenbrink. 2010. Managing non-target, data-poor species using catch limits: lessons from the Alaskan groundfish fishery. Fisheries Management and Ecology 17:323–335.

Shertzer, K. W., M. H. Prager, and E. H. Williams. 2008. A probability-based approach to setting annual catch levels. U.S. National Marine Fisheries Service Fishery Bulletin 106:225–232.

Shertzer, K. W., and E. H. Williams. 2008. Fish assemblages and indicator species: reef fishes off the southeastern United States. U.S. National Marine Fisheries Service Fishery Bulletin 106:257–269.

Smith, A. D. M., K. J. Sainsbury, and R. A. Stevens. 1999. Implementing effective fisheries-management systems-management strategy evaluation and the Australian partnership approach. ICES Journal of Marine Science 56: 967.

USOFR (U.S. Office of the Federal Register). 2009. Magnuson-Stevens Act provisions; annual catch limits; national standard guidelines, Final Rule. Federal Register 74:11(16 January 2009):3178–3213.

USOFR (U.S. Office of the Federal Register). 2010. National standard 1—optimum yield. Code of Federal Regulations, Title 50, Part 600, Subpart D. U.S. Government Printing Office, Washington, D.C.