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Pacific Fishery Management Council
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Dear Council Members:

The Washington Department of Fish and Wildlife (WDFW) offers the enclosed white paper in supplement to the analyses included in the *Draft Environmental Impact Statement for Proposed Harvest Specifications and Management Measures for the 2011-2012 Pacific Coast Groundfish Fishery and Amendment 16-5 to the Pacific Coast Groundfish Plan to Adopt a Rebuilding Plan for Petrale Sole* (DEIS).

The paper's focus is the Council's rebuilding policies. Our purpose is to describe the connection between those policies and the conservation mandate of the Magnuson-Stevens Act in one place, and in a manner intended to be readily understood by the public. With the many decisions we take up each biennial cycle, and the many detailed analyses we use to inform those decisions, we have perhaps neglected to articulate this basic connection as fully, directly, and clearly as we could. The connection, however, is fundamental.

The connection is also complicated. We revisited this connection and were reminded of its complexity multiple times during development of Amendment 23 and the 2011-12 harvest specifications. The Council's key conservation policies are found in the harvest control rules and biological reference points that we apply under the advisement of the Science and Statistical Committee (SSC). These control rules and biological reference points are based on a large and highly technical body of scientific theory and analysis, as are the stock assessment methods we use to apply them to specific stocks. The science of estimating past, current, and future stock abundance is inherently uncertain and the estimates we rely on to evaluate how well we are meeting our conservation objectives inevitably shift around from stock assessment to stock assessment, further complicating our task.

With the rebuilding groundfish stocks, we are facing circumstances where our past—and in the case of petrale sole, our current—harvest policies led to undesirable outcomes. However, in correcting for these outcomes, our fundamental conservation objectives do not change. We are still managing for the long-term achievement of optimum yield, as mandated by National Standard 1 of the Magnuson-Stevens Act.

In managing for the long-term, we rely on the science of our harvest control rules. The F_{MSY} control rule represents the best scientific estimate of the harvest rate that achieves the Council's optimum yield policy. When rebuilding, we employ harvest control rules that are highly conservative with respect to F_{MSY}. We do so in part because of our legal mandate to rebuild in a time period that is as short as possible. We do so also out of a risk-averse approach to scientific uncertainty. Of note, it is with this same conservative approach that the Council has consistently applied the 40-10 harvest control rule for precautionary zone stocks.

With the rebuilding rockfish, the Council departs substantially from F_{MSY} out of a conservation ethic that calls for a precautionary, highly risk-averse approach to management of these long-lived, erratically productive fish species. It was therefore surprising to us that the recent court finding that our 2009-10 harvest specifications for darkblotched, yelloweye, and cowcod had overemphasized short-term economic needs at the expense of conservation. As the Groundfish Management Team (GMT) suggested to us in one of their June reports, it may be that the rebuilding times for these three stocks do not seem conservation oriented when evaluated against the standard we have set with widow, canary, Pacific ocean perch, and bocaccio. Yet this is a very high standard and one we are able to achieve because of the specific characteristics of these stocks.

The circumstances presented to us by darkblotched, yelloweye, and cowcod are certainly more challenging. Nonetheless, in our view, the rebuilding plans for these stocks are also highly conservation oriented and represent an appropriate exercise of the discretion afforded to the Council by the Magnuson-Stevens Act.

As a maker of the motion setting 2011-12 harvest specifications for several of the rebuilding stocks, we appreciated the GMT's evaluation of the court's ruling and their recommendations for comparing times to rebuild between stocks and considering changes in estimates of status and biology from the past assessment cycles. The team's approach to analyzing petrale sole, in particular, provided us with a straightforward look at the potential long-term costs of accommodating short-term harvesting opportunities. As the team highlighted, those long-term costs appeared negligible in contrast to the yield that would be lost by rebuilding the stock with either a fishing moratorium or a minimal bycatch strategy like we use for rebuilding rockfish.

In June, the team performed the same analysis for yelloweye and concluded that the Council's rebuilding plans were not likely to jeopardize population viability, overemphasize short term economic return, or differ appreciably in how they affect the marine environment. The team's finding gave us further confidence that our approach to rebuilding maintains conservation risk at very low levels.

In particular, with petrale and yelloweye the GMT showed clear instances of where the fastest times to rebuild are not necessarily those that best achieve our long-term conservation objectives. And importantly, by comparing the most productive rebuilding stock with our least productive stock, the GMT illustrated how our harvest control rules account for differences in biology and address tradeoff between short- and long- term yield. Perhaps surprising to many, the GMT's analysis—further supported by Appendix G of the DEIS—indicated that the Council's approach to rebuilding is likely forgoing yield that could be harvested by rebuilding slower with less risk averse harvest rates.

In closing, the DEIS again contains the many analyses we used in our attempt to minimize bycatch of rebuilding rockfish and equitably distribute management restrictions. We crafted the white paper, structured around the reports the GMT submitted to us in April and June, to help place those analyses within the broader conservation context. We view long-term conservation as the most appropriate metric for considering the weight given to the needs of fishing communities during rebuilding and therefore encourage the GMT to pursue and refine their analysis of the long-term benefits and costs of rebuilding for development of the 2013-14 harvest specifications.

Lastly, I will provide a brief explanation of the white paper at the September meeting during the Council's discussion of the National Marine Fisheries Service's report on groundfish activities.

Sincerely,

Michele K. Culver

Michele K. Culver
Region 6 Director

Enclosure
cc: Phil Anderson
Corey Niles

WASHINGTON DEPARTMENT OF FISH AND WILDLIFE (WDFW) WHITE PAPER ON THE SETTING OF 2011-12 HARVEST SPECIFICATIONS FOR STOCKS MANAGED UNDER A REBUILDING PLAN

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1. Introduction

This white paper describes and discusses the Council's approach to setting 2011-12 annual catch limits (ACLs) and annual catch targets (ACTs) for stocks managed under a rebuilding plan. The intent is to directly address the connection between the Council's approach to setting those ACLs and ACTs and the conservation objectives of the Magnuson-Stevens Fishery Conservation and Management Act (the "MSA").

The Groundfish Management Team (GMT)—the Council's primary technical advisory body for administration of the Groundfish FMP—used a new approach for evaluating this fundamental connection during the 2011-12 harvest specifications process. The GMT first offered the approach to the Council with the analysis of petrale sole rebuilding in April. The team then used the same general framework in

June to advise the Council on the court ruling, *Natural Resources Defense Council v. Locke* (N.D.Ca April 23, 2010) ("*NRDC v. Locke*").

The *NRDC v. Locke* ruling invalidated the Council's 2009-10 harvest specifications for darkblotched, cowcod, and yelloweye as having overemphasized the short-term economic interests of current fishery participants at the expense of long-term conservation. In evaluating this finding, the GMT remarked that the court's rationale appeared to have been based "on certain misperceptions and misunderstandings that [could] and should be addressed" by the Council in setting harvest specifications for 2011-12.[1]

Responding to the court's specific finding that the Council was sacrificing long-term economic return that could be earned if stocks were rebuilt faster, the GMT remarked that its evaluation suggested that the Council's rebuilding plans were "more likely to do the opposite and sacrifice long-term economic return for faster rebuilding."[2]

The remainder of this paper explains how the GMT arrived at these conclusions and provides perspective on the Council's approach for rebuilding stocks not biologically capable of rebuilding within the 10 year timeframe established by section 304(e)(4) of the MSA.

2. Analysis of Petrale Sole Rebuilding

The GMT analysis of petrale sole rebuilding used the best available projections of stock abundance and annual allowable catch over the rebuilding period to provide a direct view of the long-term impact associated with allowing various levels of harvest during the rebuilding period. Table 1 summarizes that analysis.

The team presented the analysis to the Council in April for the setting of preliminary preferred ACLs with minimal accompanying explanation.[3] The team summarized the findings of the analysis in the following manner:

> The rebuilding projections—reflecting the status and biology of the stock—do not show a tradeoff between expected yield in the short-term yield [sic] and yield over the long-term. In fact, the rebuilding analysis projects that the alternative that would be expected to produce the most yield over the rebuilding period is also the alternative that causes the most delay in rebuilding under both [the year-round fishery and winter closure] scenarios.

The team's report also included figures depicting the probability of the stock having rebuilt by year to highlight that the rebuilding analysis did "show some contrast between the alternatives in terms in their probabilities of recovery."

In view of the analysis and findings, the Council added a new alternative that Table 1 represents as Alternative 3. This alternative begins with the Council's standard ABC harvest control rule in 2011 and then transitions to the standard 40-10 harvest control rule with the full transition occurring in 2013. The Council maintained Alternative 3 as the final preferred alternative in June 2010 with one change: the 2011 ACL was set using the standard P-star adjusted ABC control rule used for all Category 1 stocks.

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[1] Agenda Item B.3.b, Supplemental GMT Report 2, June 2010 at p. 1.
[2] Agenda Item B.3.b, Supplemental GMT Report 2, June 2010 at p. 5.
[3] Agenda Item I.4.b, Supplemental GMT Report 3, April 2010

Although brief, the two statements made by the GMT in the context of the rebuilding projections conveyed substantial information to the Council. As described below, their full import arises from the manner in which the Council has established and tracks conservation objectives using biological reference points and harvest control rules.

***Table 1**. Projected rebuilding ACLs (mt) and probability of reaching B_{MSY} by year for the three alternative rebuilding strategies considered by the Council in June 2010 plus the F=0 ("no fishing") and F_{MSY} harvest control rule. The analysis assumes the stock is declared rebuilt the year after the rebuilding analysis projections predict B_{MSY} has been obtained with at least a 50 percent probability (shading indicates this median estimate for each scenario). The ACL at B_{MSY} is assumed to be 2,080 mt.*[4]

No Fishing Strategy	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
ACL	0	0	0	0	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	14,560
P(rebuilt)	0%	0%	25%	75%	100%	100%	100%	100%	100%	100%	100%	--
Alt 1	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	Total
ACL	459	624	791	945	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	17,379
P(rebuilt)	0%	0%	25%	75%	76%	100%	100%	100%	100%	100%	100%	--
Alt 2	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	Total
ACL	776	1,160	1,481	1,720	1,883	*1,981*	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	19,401
P(rebuilt)	0%	0%	0%	25%	25%	56%	67%	74%	79%	84%	87%	--
Preferred - Alt 3	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	Total
ACL	976	1,160	1,432	1,680	1,853	1,963	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	19,464
P(rebuilt)	0%	0%	25%	25%	25%	50%	63%	70%	76%	82%	86%	--
FMSY harvest	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	Total
ACL	1,021	1,279	1,507	1,690	1,824	1,919	1,984	*2,080*	*2,080*	*2,080*	*2,080*	19,544
P(rebuilt)	0%	0%	0%	25%	25%	38%	56%	65%	73%	79%	84%	--

2.1. Considering the Tradeoff in Yield

The GMT's choose the particular method of analysis for petrale sole because long-term yield is a primary conservation objective of fisheries management. The tradeoff between harvesting yield in the short-term and the yield that will be available over the long-term is the central focus of the science and policy of MSY management.[5] The overfishing and overfished concepts are built on concern about this tradeoff, and it is this tradeoff that the Council's biological reference points and harvest control rules are intended to resolve in favor of the long-term. It was thus with this tradeoff in mind that the GMT conceived of and presented the analysis of alternative rebuilding strategies for petrale sole.

With overfished stocks it has been commonly assumed that the tradeoff between short and long-term yield is best served by rebuilding as quickly as possible.[6] Delays may be warranted based on short-term considerations, yet those delays presumably come at a cost to long-term yield. However, this assumption has been shown to not hold true for every circumstance, at least where the optimal rebuilding trajectory

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[4] The estimated ACL at B_{MSY} is derived from Table i, "Yield with *SPR_{MSY}-proxy* at *SB_{SPR}* (mt)" in Agenda Item E.2.a, Attachment 1: Entire Report "Draft Status of the U.S. Petrale Sole Resource in 2008," September 2009.

[5] Walters and Martell (2004) ("Easily the single most difficult and pervasive trade-off issue in fisheries management is between catching fish now versus leaving them in the water to produce surplus for harvesting in the future.") .

[6] *See* Holland, D. S. (2010):

> As is well known (e.g. Clark 1990), when prices and marginal cost are constant so that the profit function is linear, the optimal rebuilding approach is the fastest possible, often referred to as the bang-bang solution. Harvest is set at zero until the fish stock has risen to the optimal level. . .

factors in economic considerations like changes in prices, the marginal cost of harvesting, and the discount rate.[7]

The analysis reproduced in Table 1 clearly showed the Council and GMT that the assumption does not hold for petrale, even without consideration of economic factors other than expected yield. As explained further below, rebuilding under the quickest time possible does produce larger yields in future years than the slower to rebuild alternatives. Yet the benefit of those larger yields is only incremental to what is harvestable under the slower to rebuild alternatives. And with petrale, those incremental benefits are not large enough to make up for the yield lost by banning harvest during rebuilding. Based on the metric of cumulative yield, the shortest rebuilding period performs the worst of all the alternatives. It was this fact that the GMT was highlighting to the Council with the statement that the slowest to rebuild alternatives were expected to produce more yield over the long-term than the quicker to rebuild alternatives.

With no expected long-term cost associated with rebuilding under the standard F_{MSY} harvest control rule, petrale rebuilding posed interesting circumstances. As Hilborn and Stokes (2010) had pointed out in article published during the team's development of the April 2010 petrale analysis, rebuilding petrale at anything but the standard F_{MSY} harvest control rule raised a potential incongruity with the major rationale for rebuilding. If the primary objective of rebuilding is to correct for the yield being lost by the stock not being at its target biomass level, it would then appear incongruous to rebuild in manner that was expected to forgo more yield from the stock. With long-term yield as the major metric of conservation performance, the benefit of rebuilding more quickly becomes questionable.

The GMT's emphasis on the probabilities of rebuilding highlighted the primary countervailing objective the Council could use to address this facial incongruity. Projections of the annual yield that would be available for harvest during rebuilding are based on the median estimates from the rebuilding analysis. Median estimates, i.e. the 50th percentile or "even odds", are typically provided to the Council as the best available, risk-neutral scientific estimate. Tolerance for risk is therefore a typical factor considered by the Council when setting harvest specifications. Preference for less risk—i.e., for a higher probability that stock will rebuild over the relevant time period—is another policy basis with the Council considers risk-neutral estimates of long-term yield.

And it was essentially a preference for the more risk-averse 40-10 harvest control rule that the Council chose Alternative 3 as its final preferred alternative. As shown in Table 1, Alternative 3, is expected to produce slightly less yield (less than 1%) over the ten year rebuilding period than the F_{MSY} rebuilding scenario and yet to perform slightly better with the annual probability of having rebuilt as the metric.

2.2. Considering Long-term Economic Return

The other important contrast in petrale rebuilding is between the Council's preferred Alternative 3 and Alternative 1. Alternative 1 is basically indistinguishable from the quickest to rebuild—the no fishing scenario —in terms of expected times to rebuild. Significantly, Alternative 1 was proposed based on the

[7] Id. *See also.,* Larkin, S. L. et al. (2006):

> Our analysis demonstrates that extending the rebuilding timeframe (as allowed under the New Zealand Act) could increase the net present value of commercial harvests from small to very significant levels depending on input and output prices, technology, productivity of the stock, and the discount rate.

same rebuilding philosophy used for rockfish: providing a minimal harvest for incidental bycatch or petrale by vessels targeting of non-rebuilding groundfish stocks.

Implementing Alternative 1 would involve cost to the non-whiting fleet. That cost would arise from the lost revenue from lower harvest and sale of petrale and from the additional constraints and lowered harvest of other stocks needed to keep petrale harvests within in the ACL. This second component of cost can be substantial. Yet as is demonstrated by the integrated holistic analysis used to consider rockfish rebuilding, it is indirect and difficult to predict and measure. With the GMT's analysis of petrale, it was unnecessary to quantify these indirect costs. The first component of cost provided information enough and was easily considered by comparing Alternative 1 to the other alternatives, again, using the projections summarized in Table 1. The result of the comparison was clear: based on the metric of yield, the costs of quicker rebuilding are not accompanied by offsetting long-term benefits.

Table 2 focuses in on the comparison between Alternative 1 and Alternative 3. Based on the risk-neutral projections, Alternative 1 holds the fishery to minimal bycatch for the four years it takes the stock to rebuild. During those four years, Alternative 3 provides the fishery with, on average, 607 mt more yield per year. Alternative 1 rebuilds two years quicker, and in those two years, provides the fishery with 227 mt and 117 mt more yield than would Alternative 3. This incremental benefit is not enough to offset the better performance of Alternative 1 in the first four years and Alternative 3 produces an expected 2,085 mt more yield to the fishery over the rebuilding period. Although unnecessary to the weighing of benefit and costs, this 2,085 mt would translate to over $5 million based on an average ex vessel price per pound of $1.14 per lb.

More sophisticated analysis that factor in indirect costs, net present value, etc. were unnecessary to reach the conclusion that Alternative 1 was inferior to the slower rebuild alternatives based on overall yield provided to the fishery. The fact that petrale was the third most economically important stock to the non-whiting trawl fleet prior to overfished status is largely immaterial to the question of long-term economic return. Alternative 3 would appear superior to Alternative 1 if petrale were the least valuable stock in the fishery. No realistic economic assumption can make Alternative 1 equivalent to Alternative 3 in terms of long-term economic value to fishing communities. A preference for Alternative 1 would therefore have to be based on considerations other than long-term yield and economic considerations.

Table 2. *Projected rebuilding ACLs (mt) from Table 1 for the Council's final preferred rebuilding alternative (Alternative 3) and Alternative 1, with the annual and cumulative difference between the two expressed in both terms of harvestable yield and ex-vessel value ($1,000s). Dollar values are based on an ex-vessel price of $1.14 per lb (the 2007-09 coastwide average for trawl landings in the PacFIN database).*

Expected ACL	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Alt 3 (Final Preferred)	976	1,160	1,432	1,680	1,853	1,963	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*
Alt 1	459	624	791	945	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*	*2,080*
Annual +/- (mt)	517	536	641	735	-227	-117	0	0	0	0	0
Annual +/- ($ thou)	$1,299	$1,347	$1,610	$1,848	-$569	-$294	$0	$0	$0	$0	$0
Cumulative +/- (mt)	517	1,053	1,694	2,429	2,202	2,085	2,085	2,085	2,085	2,085	2,085
Cumulative +/- ($ thou.)	$1,299	$2,646	$4,257	$6,104	$5,535	$5,241	$5,241	$5,241	$5,241	$5,241	$5,241

3. Rebuilding and Yield

As noted in the introduction, *NRDC v. Locke* raised fundamental questions about the conservation merits of three of the Council's rebuilding plans. A few months prior to the issuance of *NRDC v. Locke*, the Council's rebuilding policies were questioned by Hilborn and Stokes (2010) in the journal *Fisheries* based on concerns quite different than those expressed by the court. Both gave the GMT cause to look closely at the bigger picture goals and objectives of rebuilding overfished stocks when advising the Council on 2011-12 rebuilding harvest specifications.

3.1. Rebuilding and Yield

The review of Hilborn and Stokes examined the performance of rebuilding policies across jurisdictions employing modern fisheries management techniques. The authors generally criticize the policies for having "little if any basis in the science or the legislation" on which they are based. Most striking was this conclusion: "[i]n practice, rebuilding times have often/usually been dictated arbitrarily, with no underlying justification being given."

The crux of Hilborn and Stokes' critique relates to fisheries management's "traditional concern about yield lost from overfishing." They argue that the biological reference points created to prevent the loss of yield have not been configured appropriately. In fact the authors found that the threshold used to define overfished status in many jurisdictions is placed near to the abundance level where MSY is expected for many stocks. The implication of this finding is that:

> many stocks now (or potentially) classified as overfished, depleted, or collapsed are producing at very close to their maximum sustainable yield and meeting the intent of national and international legislation.

Hilborn and Stokes commented specifically on the biological reference points of the Groundfish Fishery Management Plan (FMP):

> If the purpose of definitions of "overfished," and associated thresholds, is to identify stocks that are at levels where potential yield is being lost, the "sin" that Larkin referred to earlier, then thresholds such as the 25% B0 adopted by the Pacific Fisheries [sic] Management Council for groundfish are inappropriate.

Hilborn and Stokes also remarked on how overfished status might affect public perception:

> We have no doubt the general public perceives overfished stocks as having been fished so hard that they are not producing near their sustainable yield. It seems ironic that many agencies choose high thresholds for defining stocks as overfished and then use these thresholds to evaluate their own performance, making themselves look bad as a result.

The GMT echoed this same perception issue to the Council in June 2010, suggesting that the Council had been evaluated against a very high standard that it had set with the rebuilding of rockfish. The result was that the Council was viewed as not being conservative enough by the court and as being arbitrarily conservative by the Hilborn and Stokes article.

3.1. Yield and Scientific Uncertainty – Pretty Good Yield

The divergent views of the Council's rebuilding policies can be explained, at least in part, by the scientific uncertainty inherent in estimating and applying biological reference points and harvest control rules. As described in the Groundfish FMP, the Council uses a proxy B_{MSY} biological reference point and F_{MSY} harvest control rule. Proxies are necessary because the "true" B_{MSY} and F_{MSY} for a stock are unknown.

The Council revisited proxy B_{MSY} and F_{MSY} estimates for petrale sole and flatfish this cycle. In making their recommendation to adopt species proxies for flatfish, the SSC reminded the Council that proxies were intended as best available estimates that "perform at least adequately for each member of the group" for which they are designed (e.g., flatfish). By "perform at least adequately," the SSC was referring to performance in terms of the long-term yield expected from the stock.

With respect to yield objectives, the SSC advised that proxy harvest rates should not be characterized as "overly aggressive" or "too precautionary". The reason for this advice was explained in a workshop on groundfish harvest policies earlier this decade (Ralston, S. et al. 2000):

> For less resilient stocks, [the Council's F_{MSY} proxy harvest rate of] $F_{40\%}$ will reduce biomass to a lower level, possibly much lower, while still providing a yield near MSY. That is possible because yield is not very sensitive to equilibrium biomass over a wide range of biomass levels, so a yield near MSY can be obtained even when biomass is well below B_{MSY}. It is this feature of yield curves that makes it possible for a rate like $F_{40\%}$ to perform well in terms of yield over a wide range of spawner-recruit productivity curves. For some curves $F_{40\%}$ is well above F_{MSY} and for some of the curves it is well below, but in none of the cases considered is it so far below F_{MSY} that yield is much lower than MSY.

Hilborn (2010) describes this relationship between harvest rates, stock size, and sustainable yield as Pretty Good Yield (PGY) and explains how improved scientific understanding of the relationship has surprised even many experts.[8] Echoing the advice given to the Council by the SSC in simpler terms, Hilborn summarizes PGY with the statement that "good yields can be obtained over a range of stock sizes that might result from management imprecision or natural variation."

Importantly, PGY is the reason for the putative incongruities noted with the Council's rebuilding policies and rebuilding policies in general.[9] Stocks that are at lower abundances can be harvested sustainably still

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[8] Hilborn (2010) attributes the origination of PGY to Alec MacCall, a NMFS fisheries scientist involved with advising the Council on the Groundfish FMP harvest control policies:

> The location of the optimal stock size and harvest rates in relation to different values of compensation in the stock recruitment relationship are widely recognized among scientists working in population dynamic, but it is not recognized how broad the range of PGY is. Indeed, the idea that good sustainable yields could be obtained at stock sizes below 10% of unfished levels will shock many fisheries scientists and managers as such stocks are often referred to as "collapsed". Admittedly this occurs only for stocks with high steepness, but many stocks do display such intense compensation and have produced high sustainable yields for long periods at high levels of depletion.

[9] {Hilborn, R., 2010} explain the likely novel perspective PGY provides to most fisheries management professionals:

> To scientists who have spent many hours exploring model responses to alternative harvest regimes the basic results in this paper will be familiar. However, most people involved in fisheries management are less familiar with the robustness of yield to stock abundance levels, and these results will prove enlightening and help them to evaluate the consequences of alternative management policies.

sustainably produce yield. As shown with petrale, PGY means that considerations of long-term yield in rebuilding are not as straightforward as perhaps commonly assumed.

As consequence, the PGY that can be obtained for many stocks over a wide range of abundance levels—Including levels currently considered overfished or in need of rebuilding—undermines long-term economic return as a compelling justification for rebuilding quickly. In such situations, the "payoff" from quick rebuilding will likely be smaller than the cost of achieving that payoff.[10] If no other justifications are provided, then the reasons for rebuilding in a time period that is as short as possible, as required by MSA §304(e)(4)(A), can take on the appearance of being—in the words of Hilborn and Stokes—"dictated arbitrarily."

3.2. Analyzing Benefits and Costs

Yield is not the only consideration in fisheries management, or in rebuilding. The MSA's rebuilding requirements are ultimately intended to achieve optimum yield, with the concept of optimum defined based on consideration of multiple social, economic, and ecological policy objectives. MSY is the foundation—and a prerequisite—of optimum yield. From the perspective gained from PGY, Hilborn (2010) explains that:

> the primary concern in fisheries policy is biological sustainability and production of goods and services, and that producing optimum yield is distinctly less important than producing yields that are reasonably high, or indeed "pretty good". Part of this recognition comes from the multiple objective nature of most fisheries management; a broad a range of harvest policies provide good yield while also producing other desired outputs, be they biological or economic.

All "desired outputs" from a fish stock are ultimately a function of the stock's abundance. PGY suggests that higher abundance levels may be where the multiple objectives are best balanced.[11]

Stocks managed under rebuilding plans, however, are already "at lower abundance than we would choose to operate if we had our choice."[12] Overfished status is undesirable, yet the costs of not being at higher abundances are now irrelevant in the analysis of the best path forward.[13]

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[10] Hilborn (2010):

> This may explain, for instance, why fishing groups are reluctant to engage in rebuilding plans when stocks fall into those ranges. Intuitively they might feel, and the analysis presented in this paper confirms, that there are few gains in yield to be had from increasing the stock abundance from 20% of unfished abundance to the widely accepted target ranges of 35–40% and yet there is considerable short-term cost in foregone yield during the rebuilding.

[11] Hilborn (2010):

> this analysis also suggests that PGY can be obtained at quite high stock sizes, and there is little long term yield to be lost by keeping most stocks at 50% of unfished stock size. Given the growing social acceptance of more intact ecosystems as an objective of fisheries management, higher target stock size ranges than 35-40% should be considered desirable. Furthermore, it is generally expected that fisheries will be more profitable at the higher end of stock sizes, and economic arguments would favor aiming at or above the 35-40% target levels.

[12] Hilborn and Stokes (2010).

[13] *See also* Anderson, L.G. (2010):

> The formal analysis of how an appropriate control rule . . . is a policy decision based upon, among other things, tradeoffs between present and future benefits and the desired time in which to achieve [the target stock size]."

Rebuilding stocks back to higher abundances inevitably involves costs as well. As phrased by Hilborn and Stokes, the two fundamental questions for examining benefits and costs in rebuilding thus become:

(1) What is the value of rebuilding to higher stock abundances given we are at lower abundance, and
(2) How quickly should this rebuilding take place?

The first question serves as a point of reference with which to evaluate second. It is not aimed at a choice of whether or not to rebuild, especially under the MSA where rebuilding is mandated. Instead, taken together the two questions describe the benefit-cost approach used by the GMT for petrale sole. Costs and benefits are a function of the trajectory back to the rebuilding target and will differ for each stock based on the stock's status and biology.

Hilborn and Stokes recommend examination of costs and benefits "on a case-by-case basis." They encourage management agencies to evaluate the "legitimacy" of biological reference points and to "distinguish between stocks that are losing yield due to overfishing, and stocks that are at lower biomass than would be desired for ecological or economic reasons." On the advice of the SSC, the Council did the former with petrale sole. As for the latter, they recognize policy preferences that "seek to hold stocks, on average, at high stock sizes for economic, ecological, or social reasons." While they acknowledge that this is "a perfectly viable approach," they warn that justifications based on considerations other than sustainable yield "must be recognized as totally arbitrary unless supported with an underlying quantitative basis." In light of this potential arbitrariness, Hilborn and Stokes underscore the "need to be very clear what it is that causes larger stock sizes to be socially desirable."

4. Conservation and the Groundfish FMP

As has been described, the underlying rationale for the MSA's overfished mandate is that rebuilding produces long-term conservation benefits. Delays in rebuilding are thought to delay attainment of those benefits at some future cost. The court's evaluation in *NRDC v. Locke* considered fisheries conservation to have two major benefits: (a) "providing long-term economic return" and (b) "improving the environment." In their reports to the Council in June, the GMT further divided these benefits into consideration of: (i) long-term yield from a stock; (ii) population viability risk; and, (iii) ecological function. All three are somehow a function of a stock's abundance and fundamental issues in fisheries science and policy. The team was therefore able to consider the three factors either quantitatively, using the estimates from the rebuilding analyses, or qualitatively, based on the team's understanding of the scientific basis for the Council's harvest control rules and biological reference points.

4.1. The Council's Biological Reference Points.

Punt and Smith (2001) provide a review of the modern MSY-based fisheries management. They describe how the MSY concept has transformed F_{MSY} from "a management target to an 'upper limit'" and operationalized the achievement of MSY based on "three closely linked concepts: fisheries reference points, the precautionary approach and feedback-control decision rules."

Restrepo et al. (1998) describe the connection between the modern MSY paradigm and the overfishing and overfished requirements added to the MSA and the NS1 guidelines after the Sustainable Fisheries Act of 1996:

> A common element in the application of the precautionary approach to fisheries management worldwide is the definition of "limits" intended to safeguard the long-term productivity of a stock. . . The Magnuson-Stevens Act encompasses this concept in that it constrains OY to be no greater than MSY.
>
> The NSGs identify two limits for fishery management (referred to as "thresholds") that are necessary to maintain a stock within safe levels, capable of producing MSY: A maximum fishing mortality threshold (MFMT) and a minimum stock size threshold (MSST). The MFMT and MSST are intended for use as benchmarks to decide if a stock or stock complex is being overfished or is in an overfished state. In the NSGs, these two limits are intrinsically linked through an "MSY Control Rule" that specifies how fishing mortality or catches could vary as a function of stock biomass in order to achieve yields close to MSY.

The Groundfish FMP describes in more detail how the Council has operationalized the NS1 guidelines and technical guidance of Restrepo et al. In brief, the MFMT demarcates the overfishing limit and the MSST the overfished threshold. The MFMT is defined by the F_{MSY} harvest control rule, which again, is intended to keep stocks at the MSY stock size (B_{MSY}). For all groundfish except flatfish, B_{MSY} has been set at 40 percent of the estimated unfished abundance ($B_{40\%}$). For flatfish, B_{MSY} has been revised on the advice of the SSC to 25 percent of the estimated unfished abundance ($B_{25\%}$) beginning with this 2011-12 harvest specification cycle. The MSST is set at 50 percent of the MSY stock size for flatfish ($B_{12.5\%}$) and 62.5 percent of the MSY stock size ($B_{25\%,}$) for all other stocks.

4.2. Harvest Control Rules and Population Viability

Both *NRDC v. Locke* and an earlier precedent setting case, *Natural Resources Defense Council v. NMFS*, made reference to the "dire" condition of certain overfished stocks.[14] The GMT noted that "dire" was more commonly used with reference to species facing an appreciable risk of extinction or extirpation and that the best estimates of status and biology before the Council did not reflect such risks. The team's conclusion follows directly from the science of harvest control rules.

As Restrepo et al. describe, the harvest control rules are designed primarily to "safeguard the long-term productivity of a stock" and to "maintain a stock within safe levels, capable of producing MSY." Maintaining stocks at such safe levels presupposes that stocks are also kept viable.

The scientific consensus is that stocks can be sustainably managed with the biological reference points and feedback decision rules employed in the Groundfish FMP.[15] The consensus derives from the

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[14] The early case, discussed more below, was Natural Resources Defense Council v. National Marine Fisheries Service, 421 F.3d 872 (9th Cir. 2005). The perception seemed to factor into both courts' reasoning. As phrased in *NRDC v. Locke*: "This Court has made its ruling and the ruling should be implemented, due to the dire circumstances of several of the species."

[15] *See* Walters and Martell (2004) at p.15-16 (emphasis in original):

> the only possible long-term ("sustainable") outcome of harvesting given only density-independent variation . . . is extinction. Thankfully, this outcome is not what has been observed in virtually every case in which populations have been monitored during harvest development . . . What we have seen, in fact, is at least some "density-dependent" or "compensatory" change . . . leading to improved survival and/or fecundity in

theoretical foundations of population biology and the study of density dependence. Density dependence describes how per capita rates of survival and reproduction vary in response to changes in population abundance, i.e. density. Population viability concerns relates to the uncertainty in how those rates of survival and reproduction behave at low stock size. It is a key concern in the question of how a particular stock will respond to a rate of harvest over time.

Harvest rates have been evaluated extensively in the scientific literature and in their application to the Groundfish FMP. The review of Punt and Smith (2001) refers to the harvest rate at which population viability concerns arise as F_{crash}, which they describe "as the lowest fishing mortality, which if fishing continued at that level, would eventually render the resource extinct." Mace's (2001) review, referring to that rate as $F_{extinction}$, explains how some scientists believed it would be a more appropriate limit harvest rate than F_{MSY} for implementing the precautionary approach because F_{MSY} is actually the best estimate of the rate that achieves the MSY objective. Mace, and Punt and Smith, both discuss the probability that F_{MSY} could equal F_{crash} and conclude that F_{MSY} is likely much more conservative (i.e. harvests at a lower rate) than F_{crash} for the vast majority of fish populations. With fishing rates appropriately adjusted to stock size, the theoretical foundations of fisheries science suggests that fish stocks can be harvested sustainably even at relatively low abundance. And rates at or below F_{MSY} are expected to allow the stock to increase back toward B_{MSY}.

Worm et al. (2009) assessed the status of fish stocks in ten marine ecosystems around the world and concluded that their assessment "provide[s] hope that despite a long history of overexploitation marine ecosystems can still recover if exploitation rates are reduced substantially." It was such consensus that GMT echoed to the Council with the statement that "[f]ishing pressure is the major threat faced by these stocks [and if] fishing pressure is set appropriately, the stocks are expected to increase" in abundance.[16]

4.3. Population Viability and Uncertainty

Although the theory of fishing is well established, there is still considerable uncertainty in applying the theory to actual fish populations. As described by Punt and Smith (2001), we have limited "ability to estimate MSY given uncertainty regarding models and data." They caution that it "would be naïve to believe that all . . .[concerns] have been overcome by the use of F_{MSY} and B_{MSY} as limit rather than target reference points and by developing management plans that include decision rules whose performance has been evaluated by simulation."

Whether the scientific theory bears out in practice depends on whether its main assumption—compensatory density dependence—holds true. This assumption can break down if the amount of compensation is overestimated or where a stock's biology shows depensation.[17] Depensation, or

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> response to a reduction in [stock abundance]. For modest [harvest rates], such compensatory change tends to return [the population growth rate] to a mean of 1.0, i.e., to stop the decline. *Hence, compensatory change in survival rates and/or fecundity is the fundamental ecological basis of sustainable harvesting.* So, if someone argues that a given population exhibits no density-dependent or compensatory rate changes, . . ., then that person is, in fact, asserting that the population is incapable of producing a sustainable yield (and is incapable of exhibiting any sort of stable population size under natural conditions either).

[16] Agenda Item B.3.b, Supplemental GMT Report 2, June 2010.

[17] As Walters and Martell (2004) characterize this uncertainty: the "theory tells us that there should be a compensatory response, but it does not tell us how strong that response should be." Punt and Smith (2001) describe the fundamental scientific uncertainty in the yield-per-recruit approach taken to develop the harvest control policies in the Groundfish FMP:

depensatory density-dependence, is the opposite of compensatory density-dependence and describes the situation where per capita rates of survival or reproduction or both decrease at low stock sizes. Punt and Smith (2001) report that F_{MSY} and F_{crash} can be similar under depensatory stock dynamics.

Depensation is a key focus of fisheries and conservation biology because of the risk it poses to population viability in all organisms. Hilborn and Stokes (2010) reviewed studies of depensatory dynamics in fish stocks and concluded "that there remains little evidence for depensatory dynamics as a frequent phenomenon in exploited fish populations," and although there is "good evidence that recruitment declines at low stock abundance," it does not decline "in a depensatory fashion that could lead to collapse."

Even absent depensatory dynamics, F_{MSY} rates are estimates that may overestimate the amount of compensatory density dependence in a stock. As described above, the Council's proxy harvest rates are designed to account for this uncertainty and be robust to varying levels of compensation. And Hilborn (2010) explains how B_{MSY} reference points established in the range of 30–40% are "robust to any uncertainty" in the stock-recruitment relationship.

Yet overestimation of stock abundance poses another risk. The estimate of the appropriate harvest rate has to be applied to an uncertain estimate of stock size. Regular monitoring, assessment, and adjustment can account for such errors, yet when stocks are at low abundance there is less margin for error. It is largely on account of the potential for overestimating stock abundance that the Council's rebuilding strategy for rockfish combines the Cowcod Conservation Area and the Rockfish Conservation Area closures in combination with the conservative harvest rates.[18]

4.4. Harvest and Ecological Considerations

As highlighted above, the MSA concept of optimum yield involves consideration of ecological factors. Also highlighted above was the warning of Hilborn and Stokes (2010) on the potential arbitrary nature of justifying rebuilding on ecological considerations and other non-consumptive considerations. That potential for arbitrariness, as the GMT advised the Council in June, is at least partly an artifact of the state of the science and the technical difficulties of quantifying the ecological impacts associated with stock abundance.

The MFMT and MSST biological reference points of modern MSY management do not explicitly factor in the ecosystem effects of harvesting.[19] Evaluation of the ecosystem effects of harvesting is an increasing focus of fisheries management and analytical techniques for doing so are being advanced under scientific efforts referred to as either ecosystem-based fisheries management or ecosystem approaches to

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> The problem that F_{crash} may be similar to F_{MSY} for some species is exacerbated by uncertainty regarding the estimation of F_{MSY} and current fishing mortality from actual fisheries data. Imprecision in these estimates could lead to the estimate of F_{MSY} greatly exceeding F_{crash} for stocks for which F_{MSY} is really similar to F_{crash}. Unfortunately, F_{MSY} (and F_{crash}) is often poorly estimated using fisheries data because to estimate F_{MSY} accurately requires good information not only on growth rates but also on the shape of the stock-recruitment relationship. The latter is, however, seldom well determined because of uncertainty regarding estimates of spawner stock size and recruitment, and lack of contrast in spawner stock size.

[18] *See* Walters and Martell (2004) at p. 69 (identifying "time-area closures and other measures that provide bounds on the exploitation rate independent of the annual stock-size estimate" as one tactical option for reducing the risks posed by depensation.).

[19] *See, e.g.*, Walters and Martell (2004) at p. 18 (Explaining that losses from natural mortality "are not just disappearances from ecosystems," but instead, at least in part, "represent 'trophic support' provided by [the stock] to higher trophic levels" that the modern MSY paradigm has treated as either "having no economic or social value, or [pretended] that there is ample supply" of other species to compensate.).

fisheries. As described by Walters and Martell (2004), such ecosystem approaches are focused on improved understanding of trophic interactions in the marine environment with the aim of "provid[ing] a capability for fisheries scientists to respond to a broader set of policy questions and predictive demands than can single-species analysis." This broader set of policy questions will involve a complicated set tradeoffs and likely disagreement between those that primarily value consumptive use of fish stocks and those more concerned with biodiversity and existence value.[20]

Although the B_{MSY} and F_{MSY} biological reference points are established primarily on considerations of sustainable yield, the Council certainly may choose to justify faster rebuilding timeframes on ecological considerations. A recent international symposium on the multiple objectives of rebuilding, however, suggested a differentiation between stock "recovery" and stock "rebuilding" with the former referring to broader ecological concerns and out of necessity, requiring a longer timeframe.[21] Accounting for some of the considerations discussed in the context of stock "recover" may require the Council to revisit the policy objectives currently incorporated in to the Groundfish FMP's B_{MSY} and F_{MSY} biological reference points.

5. Considering Rockfish

In past cycles, the Council has not taken a direct look at long-term tradeoffs with rockfish. Detailed economic analysis is difficult because of the complexities caused by the many interrelationships between fisheries and the long time horizons involved with rebuilding. In June, the GMT used the same approach as used for petrale to consider the basic tradeoffs of individual rockfish. When the different productivity of each stock, the tradeoffs are not substantially different than those seen with petrale, they just occur over a longer period of time. Despite the longer time periods, the rockfish plans are similar to petrale in their long-term conservation impacts.

As highlighted above, the inferences that can be made based on the scientific foundations of F_{MSY} apply equally to rockfish. Rockfish, being less productive and showing sporadic recruitment, are rebuilt with much more precautionary, risk averse harvest rates than F_{MSY}. The harvest rate for yelloweye rockfish, for example, is less than half of F_{MSY}. A few of the rockfish are being rebuilt using harvests closer to 15 percent of F_{MSY}. There are many sources of uncertainty that create risk with respect to the achievement of long-term conservation objectives. Using the best available science, the Council is able to judge those

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[20] *See* Walters and Martell (2004) at p. 32:

> we cannot convincingly argue that the maintenance of a natural community structure is a win-win option for everyone, including fishers as well as people who value creatures (and diversity itself) for other reasons (or who feel that other creatures have some intrinsic right to existence and protection). Producing catch is damaging to other ecosystem values, and we have to face this trade-off more and more often today as people demand consideration of these other values.

[21] *See* comments attributed to Dr. Steve Murawski, NMFS Director of Scientific Programs and Chief Science Advisor in Hammer, C. et al (2010}:

> [Dr. Murawski] concluded that the most successful recovery programmes are characterized by immediate, measurable, and drastic reductions in fishing mortality, instead of gradual, long-term reductions, but emphasized that a distinction should be made between "recovery" and "rebuilding"; the former referring to a straightforward increase in stock biomass, whereas the latter implies fulfilling a suite of additional criteria, including the restoration of age structure, evolutionary mechanisms, and behavioural traits. Murawski's message, echoed by subsequent presenters, clarified that "rebuilding" has a much longer time horizon than "recovery". Moreover, these two terms reflect different philosophies. The typical prime objective of fishery management is to restore stocks to some target fishable biomass, largely ignoring specific biological features, such as age structure or size- and/or age-at-maturity. However, when put into a broader, ecological context, it is important to restore a stock to such a condition that it again fulfils its original ecological role in the ecosystem.

risks. And as the GMT showed the Council in June with yelloweye rockfish, the Council's rebuilding plans are more likely to be forgoing yield that could harvested under a less risk averse approach while safely increasing stock abundance over the long term.

5.1. Biology and Time to Rebuild

In advising the Council, the GMT referenced the mean generation time based approach recommended by the National Standard 1 (NS1) guidelines. In revisiting guidelines after the recent reauthorization of the MSA, NMFS declined to revise this mean generation time standard.

NMFS received public comment specific to potential interpretations of *NRDC v. NMFS*, which the agency characterized as taking the position that:

> per *NRDC* v. *NMFS,* 421 F.3d 872 (9th Cir. 2005), T_{target} should be as close to T_{min} as possible without causing a short-term disaster; rebuilding timeframes should only be extended above T_{min} where "unusually severe impacts on fishing communities can be demonstrated, and where biological and ecological implications are minimal."[22]

In response to these specific comments, NMFS disagreed that the guidelines "should be revised to focus on 'short-term disasters' or 'unusually severe' community impacts, as the MSA provides for several factors to be considered."[23] The several factors NMFS was making reference to are the factors named in §304(e)(4)(A)(i), including the "needs of fishing communities." And the guidelines were left with the statement that the Councils should chose a "target time for rebuilding (Ttarget) [that] shall be as short as possible, taking into account [the factors in MSA §304(e)(4)(A)(i)]."[24] NMFS continued to recommend that the delay associated with a particular T_{target} should still be evaluated on mean generation time.

On the question of the magnitude of delay associated with particular T_{target}, the GMT emphasized that one year of year of delay for a species like petrale was not equivalent, biologically speaking, to one year of delay for a species like yelloweye. To demonstrate this point, the GMT presented the Council with the information reproduced in Table 3. The shortest time to rebuild can be examined using the expected rate of increase with no fishing mortality from the rebuilding projections. That estimated rate can be used to compare the rebuilding alternatives for each stock can then be compared

As shown in Table 3, when compared against this benchmark the amount of delay involved for yelloweye rockfish looks quite similar to the amount of delay involved with petrale. With petrale, reducing the expected rate of increase from the fastest possible by half only results in a delay of a few years. With yelloweye, it becomes a few decades. This does not answer the question what the difference long-term conservation impacts might be. It simply helps illustrate and explain why the concept of mean generation time forms the basis for the NS1 guidelines.

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[22] Agency Response to Comments, Comment 86; *NMFS final action amending the guidelines for MSA National Standard 1*. 74 Fed. Reg. 3178, 3200 (January 16, 2009).
[23] *Id.*
[24] 50 C.F.R § 600.310(j)(3).

Table 3. *Projected annual rates of increase per year by rebuilding alternative for six rebuilding rockfish stocks and petrale sole. The rate of increase was calculated as $(B_{MSY}/\text{Current Status})^{1/n} - 1$, where n is the projected number of years to T_{Target}. The bottom panel expresses the rate of increase as a percentage of the rate of increase to the shortest biologically possible time to rebuild (F=0 scenario).*

Projected rate of increase to Ttarget (%/year)	Canary	Yelloweye	Darkblotched	POP	Cowcod	Petrale	Bocaccio
F=0	3.4%	1.7%	3.8%	3.8%	4.0%	25.1%	4.0%
Alt 1	3.1%	1.2%	2.8%	3.8%	4.0%	25.1%	4.0%
Alt 2	2.9%	1.0%	1.9%	3.8%	3.7%	16.1%	3.6%
Alt 3	2.8%	0.9%	1.3%	3.4%	3.5%	13.7%	3.0%
Projected rate as a % of the rate at F=0	**Canary**	**Yelloweye**	**Darkblotched**	**POP**	**Cowcod**	**Petrale**	**Bocaccio**
Alt 1	93%	67%	75%	100%	100%	100%	100%
Alt 2	87%	58%	50%	100%	93%	64%	90%
Alt 3	82%	50%	35%	90%	88%	54%	75%

5.2. Long-term Economic Return and Yelloweye

The GMT choose to present the results of its analysis of yelloweye to the Council because yelloweye represents the opposite end of the spectrum compared to petrale in terms of length of rebuilding. Despite the long mean generation time for a stock like yelloweye, the long-term conservation impacts associated with rebuilding appear similar to petrale.

In terms of annual yield available from the stock, in 2011 the F_{MSY} yield is already more than 80 percent of the expected yield at B_{MSY} (which is not expected to be reached for decades). And if there were no rebuilding requirement and the Council employed the standard 40-10 harvest control rule instead, the 2011 ACL would be set at over 30 mt instead of at 20 mt. The yelloweye rebuilding analysis illustrates the Pretty Good Yield concept rather well.

The GMT depicted this to the Council with the estimates shown in Table 4. As shown, the trajectory set by the Council's preferred alternative produces more than 600 mt of yield overall before the shortest time possible to rebuild begins allowing harvest during the 2050s. The same data is presented graphically on an annual basis in Figure 1. And the corresponding estimates of stock abundance are shown by Figure 2. The F_{MSY} rebuilding trajectory stabilizes the stock near current abundance levels and yet produces the most overall yield of all the alternatives.

Table 4. *Expected cumulative yield, by decade, based on the annual median catch estimates from the yelloweye rockfish rebuilding analysis.*

Year	F=0	Alt 1	Alt 2	Alt 3	40-10	FMSY
2020	0	139	186	209	361	481
2030	0	297	394	440	757	959
2040	0	475	625	696	1,177	1,444
2050	169	674	880	976	1,621	1,933
2060	733	891	1,155	1,277	2,083	2,423
2070	1,297	1,289	1,452	1,599	2,563	2,916
2080	1,861	1,853	1,840	1,942	3,055	3,410
2090	2,425	2,417	2,404	2,423	3,559	3,906
2100	2,989	2,981	2,968	2,987	4,071	4,402

As with petrale, a benefit-cost analysis would be performed on an annual basis. Appendix G of the draft environmental impact statement (DEIS) for the 2011-12 harvest specifications contains such an analysis for yelloweye and canary rockfish. That analysis shows that rebuilding yelloweye as quick as possible is not in the best long-term economic interests of fishing communities. As indicated by the negative discount rates needed to improve the net present value of faster rebuilding, any economic justification for fast rebuilding strongly favors the economic interests of future fishery participants.

The analysis in Appendix G of the DEIS does not take into account that the fact that the economic value of yelloweye is derived from the harvesting opportunities yelloweye constrains. Yelloweye ceases to become constraining to other fisheries at some point so that the marginal value of additional yield shows a decreasing relationship. The 30 mt that could be harvested in 2011 under the 40-10 harvest control rule in 2011 may well be enough to allow the fisheries that the stocks constrain to be prosecuted at levels that produce their full economic value.

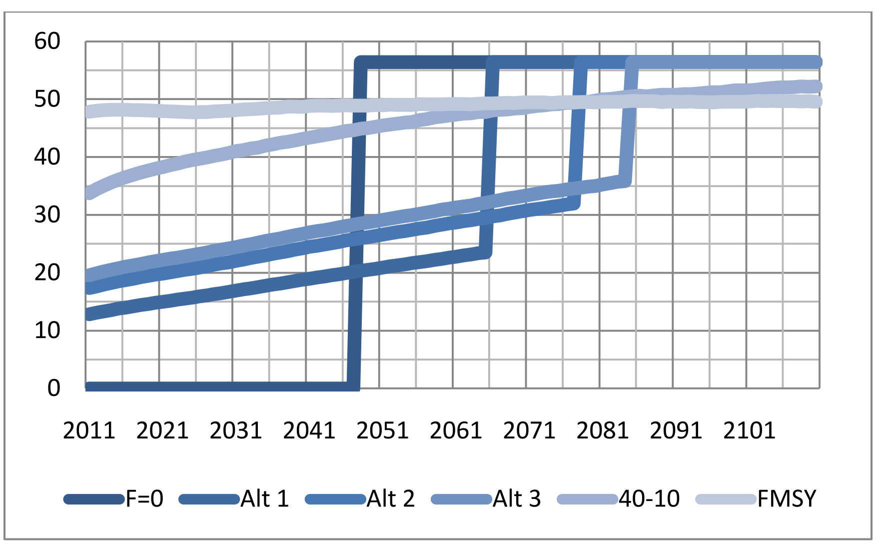

Figure 1. *Rebuilding analysis median catch estimates (mt)by year for yelloweye rockfish.*

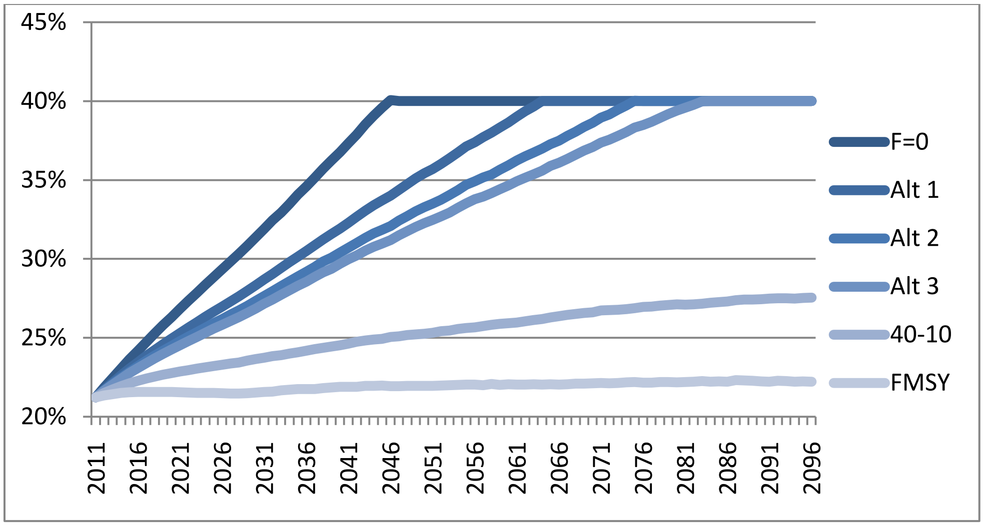

Figure 2. *Rebuilding analysis projections of yelloweye relative abundance by year.*

Figure 3 depicts in the comparison between the Council's final preferred rebuilding trajectory and the fastest possible rebuilding trajectory. Considering the costs necessary to achieve the fastest possible trajectory, the slightest of positive discount rates, and the likely marginal value relationship for yelloweye, the economic payoff of rebuilding under the F=0 strategy is not enough to outperform the Council's preferred rebuilding trajectory. Only those with no interest in the fishery until the 2050s would prefer the F=0 trajectory based on economic considerations. For perspective, Figure 4 depicts the same comparison between the Council's preferred alternative and the F_{MSY} and 40-10 harvest control rules.

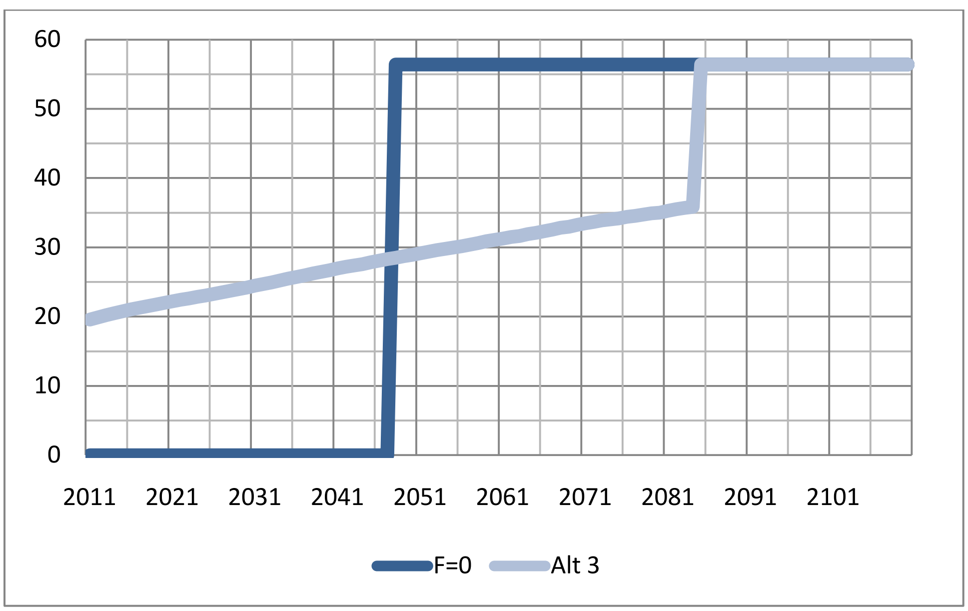

Figure 3. *Same annual median catch estimates (mt) shown by year in Figure 1for F=0 and Council's preferred alternative only.*

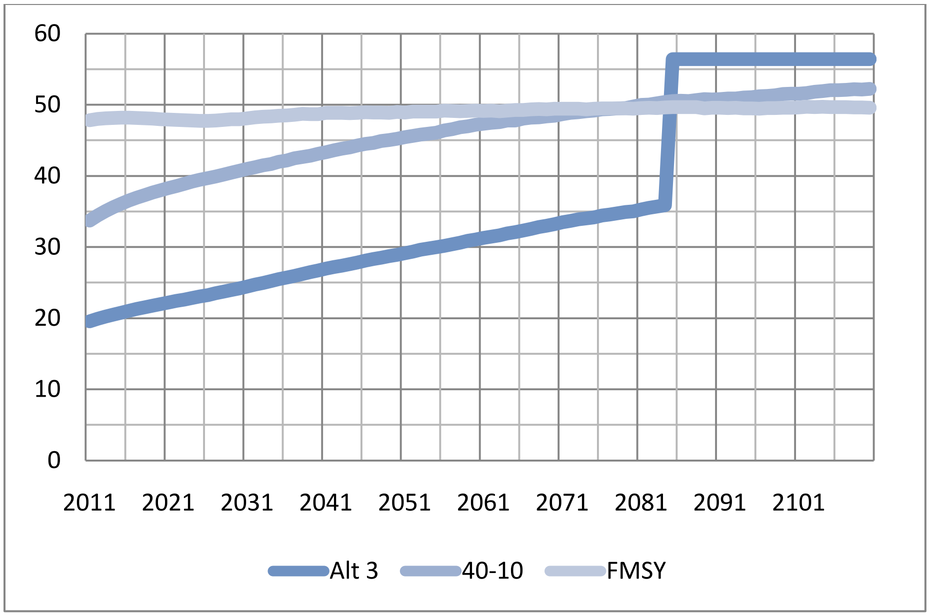

Figure 4. *Same annual median catch estimates (mt) shown by year in Figure 1 for the Council's preferred alternative and the 40-10 and F_{MSY} rebuilding trajectories.*

The same data is available from the rebuilding analyses for the remaining rebuilding species, as summarized in Table 5.

***Table 5** Cumulative yield summary for bocaccio, canary, cowcod, darkblotched, and POP rebuilding plans.   projected ACL from the respective rebuilding analyses. The intervals for reporting cumulative yield are set by the various T_{Target} estimates for each stock. The basic methodology for estimating cumulative yield for each stock was the same used for petrale and yelloweye rockfish described above.*

Bocaccio

	F=0	Alt 1	Alt 2	Alt 3	40-10	FMSY
T_{MIN}/ALT1 T_{TARGET} (2024)	0	657	1,326	3,047	6,831	7,745
Alt2 T_{TARGET} (2020)	1,258	1,915	2,584	3,479	7,732	8,701
Alt3 T_{TARGET} (2022)	3,774	4,431	5,100	5,184	9,614	10,663
T_{MAX} (2031)	15,096	15,753	16,422	16,506	18,731	19,844

Canary

	F=0	Alt 1	Alt 2	Alt 3	40-10	FMSY
T_{MIN} (2024)	0	903	1,716	1,850	7,847	9,187
Alt1 T_{TARGET} (2025)	959	987	1,873	2,020	8,508	9,892
Alt2 T_{TARGET} (2026)	1,918	1,946	2,035	2,194	9,180	10,606
Alt3 T_{TARGET} (2027)	2,877	2,905	2,994	2,374	9,869	11,329
T_{MAX} (2046)	21,098	21,126	21,215	20,595	24,341	25,767

Cowcod

	F=0	Alt 1	Alt 2	Alt 3	40-10	ABC
T_{MIN} (2060)	0	289	460	609	1,110	1,400
Alt1 T_{TARGET} (2064)	428	340	527	712	1,358	1,602
Alt2 T_{TARGET} (2068)	856	768	600	825	1,626	1,820
Alt3 T_{TARGET} (2071)	1,177	1,089	921	916	1,838	1,992
T_{MAX} (2097)	3,959	3,871	3,703	3,698	3,984	3,793

Darkblotched

	F=0	Alt 1	Alt 2	Alt 3	40-10	FMSY
T_{MIN} (2016)	0	801	1,340	1,964	2,742	2,915
Alt1 T_{TARGET} (2019)	1,752	1,233	2,045	2,968	4,087	4,334
Alt2 T_{TARGET} (2022)	3,504	2,985	2,793	4,018	5,470	5,786
Alt3 T_{TARGET} (2027)	6,424	5,905	5,713	5,884	7,901	8,298
T_{MAX} (2037)	12,264	11,745	11,553	11,724	13,098	13,529

POP

	F=0	Alt 1	Alt 2	ACT	Alt 3	40-10	OFL
T_{MIN} (2018)	0	679	946	1,318	1,520	7,096	7,692
Alt1&2 T_{TARGET} (2019)	1,124	773	1,076	1,498	1,727	7,950	8,616
ACT T_{TARGET} (2020)	2,248	1,897	2,200	1,682	1,939	8,810	9,538
Alt3 T_{TARGET} (2021)	3,372	3,021	3,324	2,806	3,063	9,670	10,459
T_{MAX} (2045)	30,348	29,997	30,300	29,782	30,039	30,895	32,777

5.3. Population viability and ecological considerations

The abundance trajectories shown in Figure 2 also demonstrate how the best available scientific estimates suggest that the Council's rebuilding plans are sufficiently protective of population viability for yelloweye and unlikely to differ in how they affect the marine ecosystem. As shown, the F_{MSY} rebuilding trajectory is expected to stabilize population abundance. All others show an increasing trend. And on ecological factors, when Alternative 1 rebuilds to B_{MSY}, Alternative 3 is near 35 percent of the estimated unfished level. The difference in marine ecosystem impact between these alternatives cannot be quantified.

5.4. Changing Estimates of Status and Biology

Estimates of stock status and biology change from cycle to cycle, making the evaluation of long-term conservation impacts difficult. Punt and Ralston (2007) advise that scientific uncertainty will result in the need for frequent revisions to rebuilding plans, with revisions likely requiring adjustments to harvest rates and expected rebuilding times. Many of the changes in estimates of stock status seen from biennial cycle to biennial cycle may be more attributable to scientific uncertainty than to real changes in stock status. The 2009-10 cowcod harvest specifications considered in *NRDC v. Locke*, provide an extreme example in which past estimates of stock status and biology had been produced in error and did not represent a valid estimate of stock status and biology.[25]

In considering changes from cycle to cycle, the GMT advised the Council to consider three major dimensions of stock status and biology: (1) stock productivity, (2) absolute stock abundance (or stock "scale"), and (3) relative stock abundance (or stock "status"). Each dimension is subject to uncertainty and all influence rebuilding projections. These estimates are not mutually exclusive, but can act in concert to change the perception and interpretation of how catches interact with stock persistence.

When evaluating long-term conservation impacts, the most current stock assessment and rebuilding analysis offers the Council the best available scientific estimates and projections of stock status and biology.

6. Conclusion

Prior to *NRDC v. Locke*, the Council was operating under legal precedent set forth by *NRDC v. NMFS*. *NRDC v. NMFS* established the rule that:

> the needs of fishing communities may still be taken into account even when the biology of the fish dictates exceeding the 10-year cap—so long as the weight given is proportionate to the weight the Agency might give to such needs in rebuilding periods under 10 years. This interpretation would allow the Agency's rebuilding periods to account for short-term concerns such as bycatch in the same manner whether the rebuilding period exceeds 10 years or not.

The determination of how much weight was proportionate and disproportionate was largely left an open question. The court's suggestion, however, was that the weight given to short-term economic interests

[25] Agenda Item B.7.b, Supplemental GMT Report, June 2010 at p. 7.

should be measured against the conservation mandate of the MSA. The court of *NRDC v. Locke* applied this same rule to evaluate the Council's 2009-10 harvest specifications.

The GMT's analysis of petrale sole was an attempt to directly examine the impact of short-term harvests on conservation objectives for a stock that was able to rebuild within the 10 year cap. The same technique proved useful for the rebuilding rockfish after the issuance of *NRDC v. Locke*, providing insight into some of the court's concerns about the long-term conservation impacts of rebuilding. The analysis framework can be furthered for the Council's reconsideration of rebuilding plans in the 2013-14 harvest specifications cycle.

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