GROUNDFISH MANAGEMENT TEAM REPORT ON PROPOSED DISCARD MORTALITY FOR COWCOD, CANARY ROCKFISH, AND YELLOWEYE ROCKFISH RELEASED USING DESCENDING DEVICES IN THE RECREATIONAL FISHERY

Contents

GMT Recommendations:

1. **Approve the use of mortality rates reflecting the use of descending devices for canary rockfish, yelloweye rockfish and cowcod in recreational catch accounting.**
2. **Consider the selection of mortality estimates that incorporate confidence intervals according to the level of perceived risk and uncertainty in the estimates to provide a precautionary buffer.**

Introduction

At the November 2012 Pacific Fisheries Management Council (PFMC or Council) meeting, the Groundfish Management Team (GMT) submitted a progress report on developing mortality estimates for rockfish caught by hook-and-line gear, and released using descending devices (PFMC, November 2012, I.3b, GMT Report). Comments on the content of that report were provided by the Scientific and Statistical Committee (SSC; PFMC, November 2012, I.3b, Supplemental SSC Report). At that meeting, the Council directed the GMT to work with the SSC to further refine the mortality estimates for yelloweye rockfish and cowcod, and to develop estimates for canary rockfish. Additional guidance was provided by the Council to develop buffers against uncertainties as suggested by the SCC. A joint meeting between members of the SSC groundfish sub-group and the GMT was held in January to provide an opportunity for discussion and refinement of the methods, the results of which are provided in this report. This document describes the GMT preferred method of estimating mortality for cowcod, canary rockfish, and yelloweye rockfish released with a descending device. These estimates account for short- and long-term mortality based on current research, mortality from sources unaccounted for in the studies used to generate mortality estimates, and additional buffer alternatives that the Council may wish to consider.

Short-Term Mortality

Species-specific estimates

Data to inform short-term mortality of canary and yelloweye rockfishes when descending devices are used is available from cage studies conducted by Hannah et al. (2012) off the Oregon coast, and unpublished data subsequently collected by the Oregon Department of Fish and Wildlife (ODFW). Mortality of discarded fish varied with capture depth, ranging from 0 - 17 percent for 41 canary rockfish caught between 10 and 45 fathoms (Table 1) and 0 – 5 percent for 99 yelloweye rockfish caught between 10 and 50 fathoms (Table 2). Sample size within some of the 10 fathom depth bins was small (Table 1 and Table 2). To help address this issue, the GMT recommends stratifying the data based on 10-30 fathoms, 30-50 fathoms, and greater than 50 fathoms. This does not alleviate the issue of low sample size in some cases; however, the SSC recommended, and the GMT supports, the use of additional data from other species to supplement estimates made with limited sample sizes. The use of data from other species as a proxy for species with limited data but with similar life history and anatomy is discussed below.

Table 1. Canary rockfish mortality (1-day survival; %) for 2-4 day barrel studies by Hannah et al. (2012) and subsequent ODFW research (unpublished data).

Capture depth (fm)	Alive	Dead	Total	Mortality (%)
0-10	NA	NA	NA	NA
10-20	15	0	15	0%
20-30	30	0	30	0%
30-40	5	1	6	17%
40-50	4	1	5	20%
Grand Total	54	2	56	4%

Table 2. Yelloweye rockfish mortality (1-day survival; %) for 2-4 day barrel studies by Hannah et al. (2012) and subsequent ODFW research (unpublished data).

Capture depth (fm)	Alive	Dead	Total	Mortality (%)
0-10	NA	NA	NA	NA
10-20	5	0	5	0%
20-30	31	0	31	0%
30-40	43	1	44	2%
40-50	18	1	19	5%
Grand Total	97	2	99	2%

The number of sampled cowcod from studies informing species specific mortality was low or non-existent in each depth bin, and varied between studies (Table 3). Data from the Smiley and Drawbridge (2007) hyperbaric chamber study conducted in 50-70 fathoms reflects cowcod survival assessed by whether or not the fish was actively feeding after seven days, potentially overestimating true mortality. Five out of the 16 cowcod were deemed "dead" based on that assessment. Results from a recent acoustic tagging study informing mortality when using descending devices conducted by the National Marine Fisheries Service (NMFS) Southwest Fishery Science Center by Wegner et al. (in prep) was presented to the Council in June 2012 (http://www.pcouncil.org/wp-content/uploads/D2c_SUP_SWFSC_PPT_VETTER_JUN202BB.pdf). Though this constitutes unpublished data not yet subject to a peer review, a presentation summarizing the results is provided for reference in the briefing book and members of the GMT have been in direct correspondence with the author regarding interpretation of the results provided. While estimates of mortality from other species and from studies conducted at shallower depths were considered as a proxy for cowcod, data from the acoustic tagging study by Wegner et al. (in prep) was conducted in deeper depths (70-100 fathoms) and had the only direct mortality estimates for cowcod. The study showed that all nine tagged cowcod were still alive two days after release. Five fish left the array prior to 10 days, their survivability was unknown. For the purpose of our analysis, we only used the data from fish remaining within the array to provide an estimate of mortality from this study. This is discussed further under the section regarding uncertainties reflected in the choice of the unaccounted for mortality added to the estimates of mortality from this study to address the additional uncertainty resulting from this assumption.

Table 3. Cowcod mortality (1-day survival; %) from acoustic tagging by conducted by Wegner et al. (in prep).

Capture Depth (fm)	Alive	Dead	Total	Mortality (%)
0-50	NA	NA	NA	NA
51-70	NA	NA	NA	NA
70-100	4	0	4	0%
Grand Total	4	0	4	0%

Indirect estimates of discard mortality from other species

Species-specific mortality estimates are not available for cowcod, canary, and yelloweye rockfish caught at some depths; data do not currently exist for canary and yelloweye rockfish caught at depths greater than 50 fathoms, or for cowcod caught at depths less than 50 fathoms (see Table 1,
Table 2 and Table 3). As such, mortality estimated for species other than cowcod, canary, and yelloweye rockfish returned to the depth using descending devices may be considered as proxy-estimates for application to these three species. In addition, a combination of data for species having similar life history and anatomy serves to supplement the sample size to provide acceptable estimates of mortality at a given depth. Proxy data was selected for each species and depth bin to make the best use of the available data for representative species given sample sizes. Descriptions of supplemental or proxy data used to estimate mortality rates, and justifications for their use are provided in Table 4 for each species and depth bin.

The GMT considered a variety of mortality estimates that could be used as proxies of short-term mortality for cowcod, yelloweye, and canary rockfish where direct estimates do not exist, or where supplementation may improve estimates (GMT Report I.3.b, PFMC, November 2012). Data from 119 quillback, yelloweye, canary and copper rockfish are available from 10-30 fathoms to inform mortality estimates for canary and yelloweye rockfish for which no mortality was observed in the 2-day cage study by Hannah et al (2012). There are sufficient data for 63 yelloweye rockfish for 2-4 days from Hannah et al (2012) to make species specific estimates for 30-50 fathoms; however, there were insufficient species-specific data available for canary rockfish at this depth range. Only 11 samples of canary rockfish were available in this depth bin. To alleviate the data gaps, the 11 samples from canary rockfish were combined with the 63 yelloweye from Hannah et al (2012) and the 182 sunset, bocaccio and flag rockfish from Jarvis and Lowe (2008) for a total of 256 samples resulting in a short-term mortality estimate of 17 percent for canary rockfish in the 30-50 fathoms depth bin.

The GMT recommends discard mortalities provided by Wegner et al. (in prep) as the proxy estimates for canary and yelloweye rockfish for depths greater than 50 fathoms. Wegner et al. (in prep) provided mortality estimates for a variety of rockfishes caught at depths greater than 50 fathoms, tagged with acoustic transmitters, and released using descending devices. Wegner et al.

(in prep) found that 23 percent of these fish (n = 30) that were within the array after 10 days no longer exhibited depth movement or acceleration indicative of survival and were deemed dead. No additional mortality was observed for fish remaining within the array from the sixth day until the end of the four month study, thus the 10-day mortality estimate may be representative of mortality for the extent of the study. Data from 30 cowcod, bocaccio, sunset, starry and bank rockfish that remained in array at day 10, seven of which died, were used to provide a 10+ day mortality estimate of 23 percent. This value was applied as the total mortality estimate for canary and yelloweye rockfish in deeper than 50 fathoms (Table 4).

Direct mortality estimates of 25 percent for cowcod in 50-100 fm were available from combining data from Wegner et al (in prep) and Smiley and Drawbridge (2007). The SSC expressed concern regarding the use of data from the barometric chamber study to estimate mortality in cowcod, since treatment of these fish differs greatly from that expected when anglers release fish with a descending device. In addition, the definition of mortality in the barometric chamber study was based on ability to feed after seven days rather than actual mortality. Therefore, data from Smiley and Drawbridge (2007) was not included in developing mortality estimates for cowcod.

The sample size for cowcod in 50 – 100 fathoms from the acoustic tagging study (Wegner at al., in prep) provided only 4 fish, though data for an additional 26 shelf rockfish are available from Wegner et al (in prep). Proxy data from the cage study by Jarvis and Lowe (2008) provides data from 182 shelf rockfish to inform mortality in shallower depths. Thus data from the four cowcod combined with other shelf rockfish (Wegner et al., in prep) were employed to provide a suitable proxy for cowcod. Estimates of 10+ day mortality for the four cowcod and 26 additional shelf rockfish sampled from 70 to 100 fathoms by Wegner et al (in prep) provide a mortality estimate of 23 percent to apply in the 50-100 fathom depth bin. Two-day mortality estimates of 22 percent from Jarvis and Lowe (2008) for shelf rockfish species returned to depths of 30 - 50 fathoms in cages in the Southern California Bight are used to inform mortality in 10-30 fathom and 30-50 fathom depth bins assuming mortality rates in shallower depths would be equal or less than observed in 30-50 fathoms.

No data were available from studies to inform mortality estimates when using descending devices from 0-10 fathom for any of the three species. For these cases, we used the lesser value between surface release mortality and mortality when using descending devices for the bin in question. The rationale was that mortality is expected to be lower in the 0-10 fathom depth bin than in the 10-30 fm depth bin. Either should provide a suitable proxy since the majority of the fish are able to escape the surface and return to depth under their own power, as reflected by relatively low cumulative mortality rates (<25 percent) for surface release in this shallowest depth bin (PFMC 2009). Proxy mortality rates applied in each depth bin for each species are provided in Table 4.

Table 4. **Species and sources of data used in proxy estimates of mortality for canary, cowcod and yelloweye rockfish and associated sample sizes and rates in each depth bin.**

Species	Depth (fm)	Source of Short Term Mortality Data	Reason for Use of Proxy Data	Sample Size	Lived	Died	Mortality
Canary Rockfish	0-10	Surface Release Mortality (PFMC 2009) or 10-30 fm	No data at this depth. Devices likely not needed	NA	NA	NA	NA
	10-30	Canary, yelloweye, copper and quillback rockfish (Hannah et al 2012)	Similar life history and anatomy	119	119	0	0%
	30-50	Bocaccio, flag and vermilion rockfish (Jarvis and Lowe 2008) / yelloweye and canary rockfish (ODFW unpublished data)	Only 11 samples for canary rockfish. Similar life history and anatomy.	256	212	44	17%
	>50	Cowcod, bocaccio, bank, sunset (Wegner et al. in prep)	No observations for subject species. Similar life history and anatomy.	30	23	7	23%
Yelloweye Rockfish	0-10	Surface Release Mortality (PFMC 2009) or 10-30 fm	No data at this depth. Devices likely not needed	NA	NA	NA	NA
	10-30	Canary, yelloweye, copper and quillback rockfish (Hannah et al 2012)	Similar life history and anatomy	119	119	0	0%
	30-50	Yelloweye (Hannah et al. 2012, ODFW, unpublished data)	NA-Sample size sufficient.	63	61	2	3%
	>50	Cowcod, bocaccio, bank, sunset rockfish (Wegner et al. in prep)	No observations for subject species. Similar life history and anatomy.	30	23	7	23%

Cowcod	0-10	Surface Release Mortality (PFMC 2009) or 10-30 fm	No data at this depth. Devices likely not needed	NA	NA	NA	NA
	10-30	Bocaccio, flag and vermilion rockfish 30-50 fm (Jarvis and Lowe 2008)	No observations for subject species. Similar life history and anatomy.	NA	NA	NA	22%
	30-50	Flag, vermilion and bocaccio (Jarvis and Lowe 2008)	No observations for subject species. Similar life history and anatomy.	182	142	40	22%
	>50	Cowcod, bocaccio, bank, sunset rockfish (Wegner et al. in prep)	NA-Limited data available for subject species. Similar life history and anatomy.	30	23	7	23%

Long-Term Mortality

Short-term mortality estimates for cowcod canary and yelloweye rockfish in less than 50 fm shown in Table 4 were based on studies that observed mortality within 2 - 4 days and are considered short-term mortality. Although many researchers have demonstrated that most discard mortality occurs during the initial 2 – 5 days post release, literature also shows additional mortality occurring beyond 2 – 5 days (Davis 2005; Parker et al 2006, Suuronen and Erickson 2010). To account for this expected additional mortality beyond 2 - 4 days for canary and yelloweye in 10 to 50 fathoms, the GMT applied the 3 – 10+ day mortality of 15 percent (4 dead out of 27 present after 2 days and remaining in array at day 10; Table 5) from the acoustic-tagging study by Wegner et al. (in prep) that was estimated for shelf rockfish species caught between 70-100 fathoms. Even though this estimate was derived using rockfishes other than canary and yelloweye rockfish, it may provide a reasonable proxy of long-term mortality because this rate was based on fish that were at large for up to 4 months (i.e., not caged) and unprotected from predators. The 15 percent long-term mortality estimate was also applied to cowcod in less than 50 fathoms based on cage studies conducted by Jarvis and Lowe (2008).

Table 5. Short-term, long-term, unaccounted and cumulative discard mortality estimates reflecting the use of descending devices in the release of cowcod, canary and yelloweye rockfish.

Species	Depth (fm)	Short-Term Mortality	Long-Term Mortality	Additional Unaccounted for Mortality	Cumulative Mortality
Canary	0-10	NA	NA	NA	NA
	10-30	1%	15%	5%	20%[1]
	30-50	17%	15%	5%	33%[1]
	>50	23%	NA	10%	31%[2]
Yelloweye	0-10	NA	NA	NA	NA
	10-30	1%	15%	5%	20%[1]
	30-50	3%	15%	5%	22%[1]
	>50	23%	NA	10%	31%[2]
Cowcod	0-10	NA	NA	NA	NA
	10-30	22%	15%	5%	37%[1]
	30-50	22%	15%	5%	37%[1]
	>50	23%	NA	10%	31%[2]

1. M =1 – (1–Short-Term Mortality) * (1–Long-Term Mortality)* (1-Unaccounted for Mortality)
2. M =1 – (1- 0.23 Wegner All RF 10+ Days) * (1-Unaccouted for Mortality))

The other option considered was to use the precautionary five percent per 10 fathoms long-term mortality estimate that is currently applied to fish released at the surface (PFMC 2012, November, Agenda Item I.3.b, GMT Report). This option may be less representative than using data from Wegner et al. (in prep) because it is a precautionary value intended to provide a buffer for the higher mortality observed in surface release, especially in deeper depths. The 15 percent mortality estimate provided by the acoustic tagging study is applied in a multiplicative fashion to provide an estimate of total mortality, which includes short- and long-term mortality estimates (equations are provided in the section reviewing cumulative mortality rate estimates).

The GMT points out that the additional long-term mortality estimate of 15 percent includes data from bank rockfish, which appear to be more sensitive to barotrauma than the other species in the Wegner et al. (in prep) study. Including discard-mortality of bank rockfish in this proxy may add an additional layer of precaution for canary and yelloweye rockfish, because the latter species appear to be more resistant to deleterious effects of barotrauma (Wegner et al., in prep and Hannah et al. 2012). In addition, the acoustic tagging was carried out in southern California where the thermocline typically is stronger than to the north of Point Conception where yelloweye and canary rockfish are found, adding a potential additional layer of precaution when applied to these more northerly distributed species where temperature differences are typically less extreme (Jarvis and Lowe, 2008). Note that the Wegner et al study was conducted during March when the thermocline is weakest. It should also be pointed out that during El Nino years, the thermocline may also be strong north of Point Conception.

No additional mortality was observed from six days to four months post-release in the acoustic tagging study. The additional "3 - 10+ day" mortality estimate is therefore considered representative of expected additional long-term mortality over the duration of the four month study. Other studies suggest that including an additional 15 percent to account for long-term mortality for rockfish may be higher than might be expected. For example, barometric chamber studies conducted on 90 black rockfish indicated only 3.3 percent mortality for fish held for at least 21 days after rapid decompression from 4 atmospheres of pressure equivalent to 20 fathoms then subsequent recompression (Parker et al. 2006). In this study, two fish died within the first nine days and only one fish died thereafter, indicating the potential for much lower long-term mortality; though these fish were protected from predation and reflect the response of black rockfish to barotrauma rather than species included in Wegner et al. (in prep). Finally, the GMT notes that even though mortality estimates from Wegner et al. (in prep) were derived using other rockfish species, the majority of fish in that acoustic tagging study were caught in depths between 70 and 100 fathoms, whereas the rates were applied to depths less than 70 fathoms for canary and yelloweye rockfish. Since many assume that discard mortality may increase with increasing depth, application of discard-mortality estimates obtained from rockfish caught at deeper depths to those caught at shallower depths may also be considered precautionary.

Mortality estimates shown for cowcod, canary and yelloweye rockfish in greater than 50 fm (Table 5) were provided by an acoustic tagging study (Wegner et al., in prep), where mortality was estimated at 10 days (with no additional mortality observed up to four months). As such, the GMT assumes that the mortality shown in Table 3 (7 of 30 sampled fish died = 23 percent) includes long-term mortality for fish caught and returned to the seabed using descending devices. Short- and long-term mortality are therefore included in the 10+ day estimates of 23 percent applied in waters deeper than 50 fathoms.

Buffers for Unaccounted Mortality, Confidence Intervals to Account for Management Uncertainty and Cumulative Mortality Estimates

The GMT addresses uncertainty in two ways. The first is the evaluation of potential bias and uncertainty from studies informing mortality estimates and incorporation of estimates of additional unaccounted for mortality to be combined with long and short-term mortality estimates to reflect these biases. The second is an additional precautionary buffer based on upper confidence intervals surrounding point estimates of discard mortality for the Council to select in addressing risk, based on their comfort level with the uncertainty in the estimates to account for management uncertainty.

Buffers for Unaccounted Mortality

Key uncertainties in mortality estimates for fish released with descending devices include: the effect of depth of capture; limited species-specific research on cowcod and canary rockfish; the effect of time on deck; the effect of thermal shock (e.g., temperate gradient across the thermocline); long-term mortality; potential negative effects on reproduction and productivity; and others. To provide a suitable buffer for missing aspects of mortality that might result from biases that cause underestimation of mortality rates, we examined potential biases between the mortality of fish in the research studies compared to that expected with use of descending devices by anglers on a typical fishing trip (Appendix A). These include both negative biases that would cause the rates from the studies to underestimate mortality expected when anglers use a descending device and positive biases that reflect aspects of the study that may cause the estimate to exceed mortality likely to result from use of a device on a fishing trip. Descriptions of the potential causes of differences between estimates from each study and mortality of fish released by anglers are provided in Appendix A.

The wide range of potential biases affecting mortality either positively or negatively makes a net balance hard to determine. To avoid over complicating the issue while still attempting to acknowledge some level of unaccounted for mortality, the GMT recommends additional buffers on the order of five to ten percent depending on the depth of capture be applied to point estimates of total mortality (Table 5). To be consistent with guidance provided by the Council, the same buffer was applied over all depth bins that used mortality rate from sources with similar biases.

To address the potential for unaccounted mortality in studies used to estimate discard mortality when a descending device is used, we added an additional five percent mortality to estimates from the results of cage studies, and an additional 10 percent to estimates from acoustic tagging results. As discussed above, the fate of fish that left the array in the acoustic tagging studies (Wegner et al. in prep) is uncertain. The actual fate of the fish that left the array is unknown and it could also be argued that these fish died after leaving the array. To address this uncertainty, a higher additional mortality was applied to estimates derived from tagging studies. A five percent buffer was applied multiplicatively to mortality estimates from cage studies for cowcod, canary and yelloweye rockfish in depths less than 50 fathoms. A 10 percent buffer was applied for mortality estimates that were derived from acoustic tagging studies (Table 5). Equations used to combine mortality components and values used in the calculation are provided below Table 5 and are referenced therein.

No additional mortality was added to estimates of long-term mortality since the estimates were obtained from fish sampled in depths greater than 70 fathoms and applied to depths shallower than 50 fathoms, which already add a layer of precaution, assuming mortality is higher at deeper depths. Previous research suggests that this estimate may be higher than expected over the period in question given supporting data from mark recapture study (Hochhalter 2012) and barometric chamber studies (Parker et al. 2006) indicating that estimates are unlikely to underestimate mortality.

To address positive bias from inclusion of overlapping time periods of four day barrel trials in recent Hannah data with the 3-10 day long-term mortality, the GMT considered the SSC suggestion to extrapolate two day mortality to longer periods or adjust four day mortality. Extrapolating daily mortality from two day trials out to four days was not possible because of low mortality sample sizes (i.e. number of dead fish) each day. Thus the GMT decided not to adjust the estimates and include two and four day estimates (combined) as two day estimates.

Buffers for Management Uncertainty Selected by the Council

The point estimates of total mortality result from methods suggested by the SSC that incorporates short-term, long-term and unaccounted for mortality. Additional mortality reflecting levels of precaution using the 60, 75, 90 or 95 percent confidence interval (CI) of the short-term mortality estimates in less than 50 fathoms and the 10+ day mortality estimates in greater than 50 fathoms can be selected by the Council to further address uncertainty. Short-term mortality estimates along with confidence intervals are provided in Table 6 for each species in 10-30 fathom, 30-50 fathom and greater than 50 fathoms depth bins. These upper confidence intervals were included as a measure of risk that the Council may wish to apply when selecting mortality values that account for the use of descending devices (Table 6).

Table 6. Estimates of total mortality reflecting point estimates of short-term mortality associated with the use of descending devices in the release of cowcod, canary and yelloweye rockfish and precautionary estimates using the 60, 75, 90 and 95 percent confidence interval for short-term mortality in less than 50 fathoms and 10+ day mortality in greater than 50 fathoms.

Species	Depth (fm)	Mortality Estimate	Upper 60% CI	Upper 75% CI	Upper 90% CI	Upper 95% CI
Canary Rockfish	0-10	NA	NA	NA	NA	NA
	10-30	1%	1%	2%	2%	2%
	30-50	17%	19%	20%	22%	22%
	>50	23%	32%	35%	39%	42%
Yelloweye Rockfish	0-10	NA	NA	NA	NA	NA
	10-30	1%	1%	2%	2%	2%
	30-50	3%	7%	8%	10%	11%
	>50	23%	32%	35%	39%	42%
Cowcod	0-10	NA	NA	NA	NA	NA
	10-30	22%	25%	26%	28%	29%
	30-50	22%	25%	26%	28%	29%
	>50	23%	32%	35%	39%	42%

The estimates resulting from application of the upper 95 percent CI of mortality are very close to the point estimate when sample sizes are high (e.g., in less than 50 fathom), but low sample size in greater than 50 fathoms increases the 95 percent CI. The 60 percent CI provides a moderate buffer for uncertainty. The 75 percent upper confidence interval estimate provides an estimate for which half of the expected binomial upper confidence interval distribution of mortality rates are higher and half are lower than the estimated value. The 90 and 95 percent CI provide more precautionary mortality, though they reflect values of mortality near the upper tail of the confidence interval distribution resulting in greater potential for overestimation relative to the unknown true mortality.

It is important to recognize that the confidence interval reflects the precision of the estimate expected, given the sample size used to generate the mortality estimate. The point estimate could be either above or below the true mortality rate (i.e. is bi-directional). Although we acknowledge that confidence intervals are bi-directional of the point estimate, we only consider the upper confidence interval to provide a measure of the highest mortality that can be expected with the precision of the estimate given the sample size.

Total Discard Mortality Estimate for Descending Device Use

In November of 2012, the Council asked the GMT to consider buffers and combine depth bins with similar results. One alternative provided in Council guidance to illustrate their intent was to have depth bins of 0-30 fathoms, 31-59 fathoms, and greater than 59 fathoms, with a 15 percent buffer added for each depth bin. The 15 percent buffer added to each depth bin was intended to be analogous to the 5 percent added to each 10 fathom depth bin in the surface mortality calculations. During Council discussion, it was clarified that the motion was intended to be general guidance and not prescriptive. A subgroup of the GMT discussed the bins and buffers specifically mentioned in the Council motion, however for some depth bins the additional 15 percent buffer created a higher mortality using descending devices than mortality currently in place for fish released at the surface. Therefore, those specific buffers were not examined further. However the GMT believes that the mortality estimates and buffers that were subsequently examined and presented here fit within the intent, and clarification, of the motion, by combining depth bins with similar results and including buffers for uncertainty.

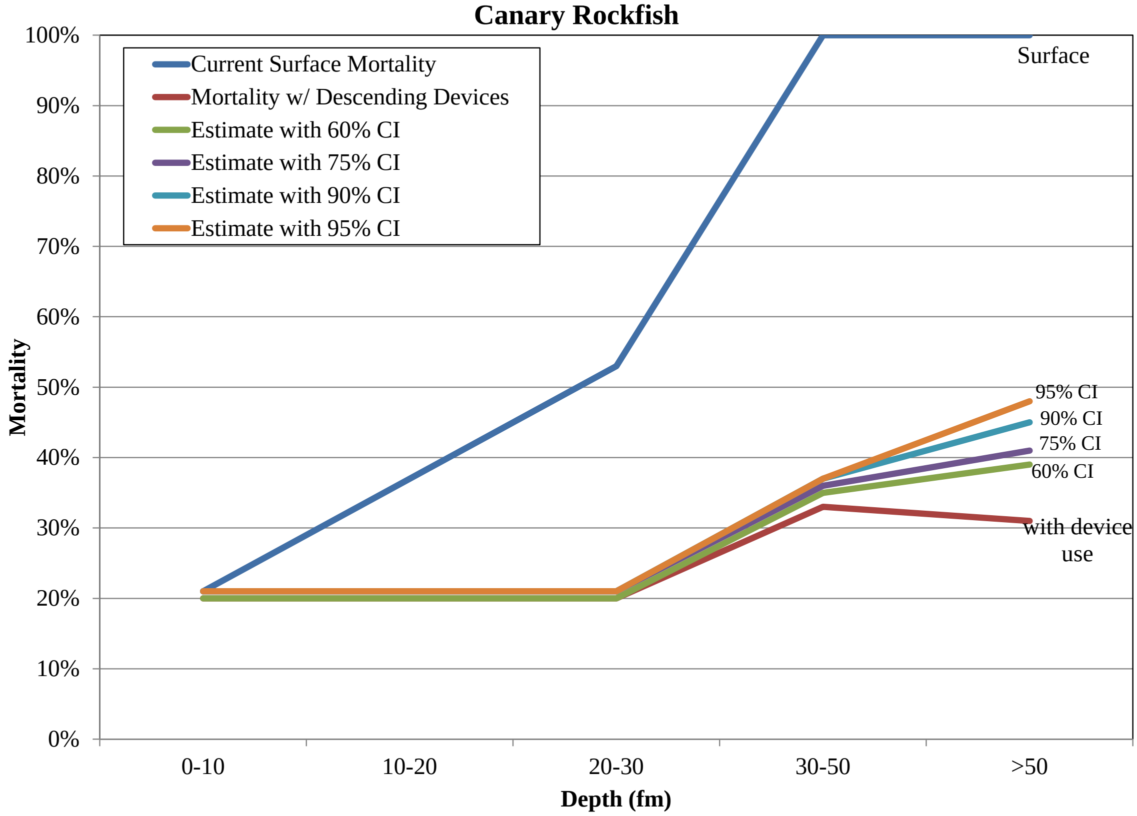
Surface mortality (currently applied to recreational discards), proposed cumulative mortality when using descending devices, and associated upper confidence intervals are provided in Table 7 and Figure 1. These estimates allow easy comparison between surface-release mortality estimates and cumulative mortality estimates with and without upper confidence intervals when using descending devices. When mortality reflecting the use of descending devices was higher than that for surface release, or surface mortality was higher than the mortality shown for the next deeper depth bin, the lower of the estimates was used. Mortality when using descending devices is not expected to be higher than surface release. Similarly, mortality is expected to be lowest in shallower depths. Substitution of values with estimates from surface mortality or estimates of discard mortality from deeper depth bins are noted in the table. Equations used in calculating the estimates of total mortality reflecting precautionary estimates from upper confidence intervals are analogous to those provided below Table 5 with the exception that the upper confidence interval of short-term mortality estimates from Table 6 were used instead of the point estimates.

Table 7. Total discard mortality (%) for cowcod, canary and yelloweye rockfish and reflecting the use of descending devices incorporating short-term mortality, long-term mortality, unaccounted for mortality and upper 60, 75, 90, and 95 percent confidence intervals as precautionary buffers for uncertainty.

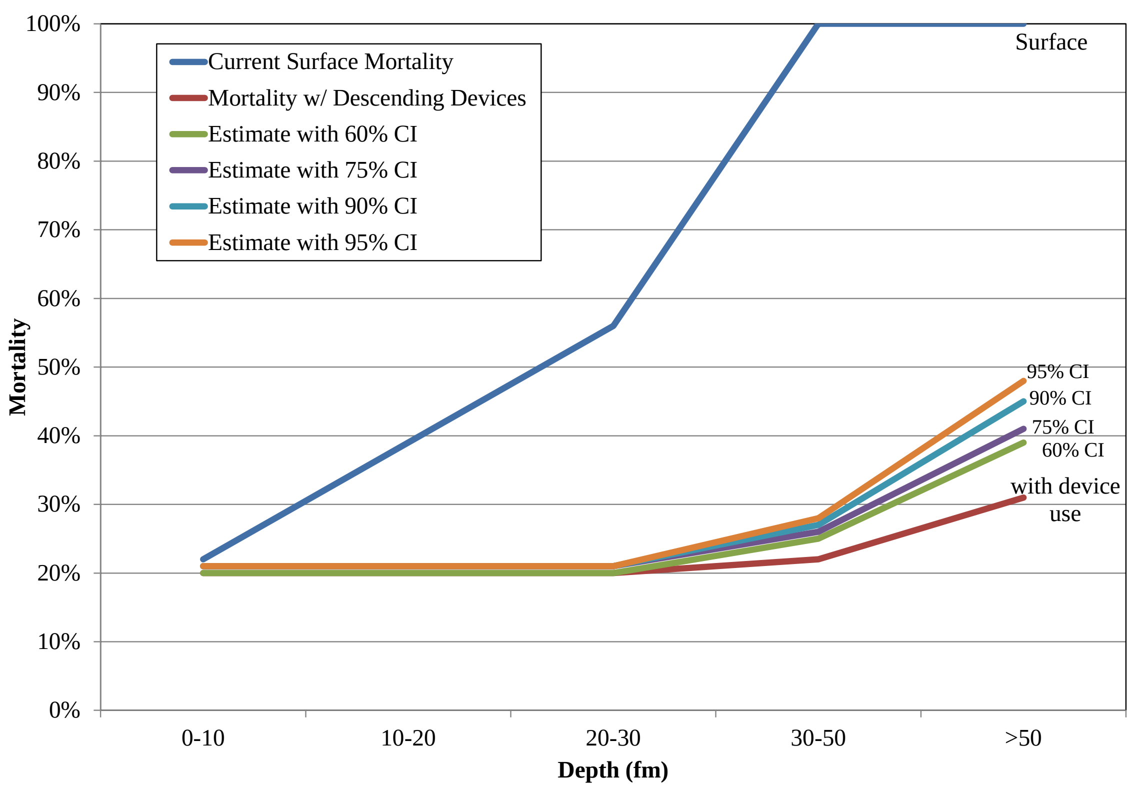
Species	**Depth (fm)**	**Current Surface Mortality**	**Mortality w/ Descending Devices**	**Estimate with 60% CI**	**Estimate with 75% CI**	**Estimate with 90% CI**	**Estimate with 95% CI**
Canary Rockfish	0-10	21%	20%[1]	20%[1]	21%	21%	21%
	10-20	37%	20%	20%	21%	21%	21%
	20-30	53%	20%	20%	21%	21%	21%
	30-50	100%	33%	35%	36%	37%	37%
	>50	100%	31%	39%	41%	45%	48%
Yelloweye Rockfish	0-10	22%	20%[1]	20%[1]	21%[1]	21%[1]	21%[1]
	10-20	39%	20%	20%	21%	21%	21%
	20-30	56%	20%	20%	21%	21%	21%
	30-50	100%	22%	25%	26%	27%	28%
	>50	100%	31%	39%	41%	45%	48%
Cowcod	0-10	21%	21%[2]	21%[2]	21%[2]	21%[2]	21%[2]
	10-20	35%	35%[2]	35%[2]	35%[2]	35%[2]	35%[2]
	20-30	52%	37%	39%	40%	42%	42%
	30-50	100%	37%	39%	40%	42%	42%
	>50	100%	31%	39%	41%	45%	48%

[1]The value reflects mortality rates from the 10-20 fathom bin since mortality rates are expected to be lower in shallower depths and less than surface mortality.
[2]The value reflects surface mortality since mortality rates for descending devices are not expected to exceed surface release.

Canary Rockfish



Yelloweye Rockfish



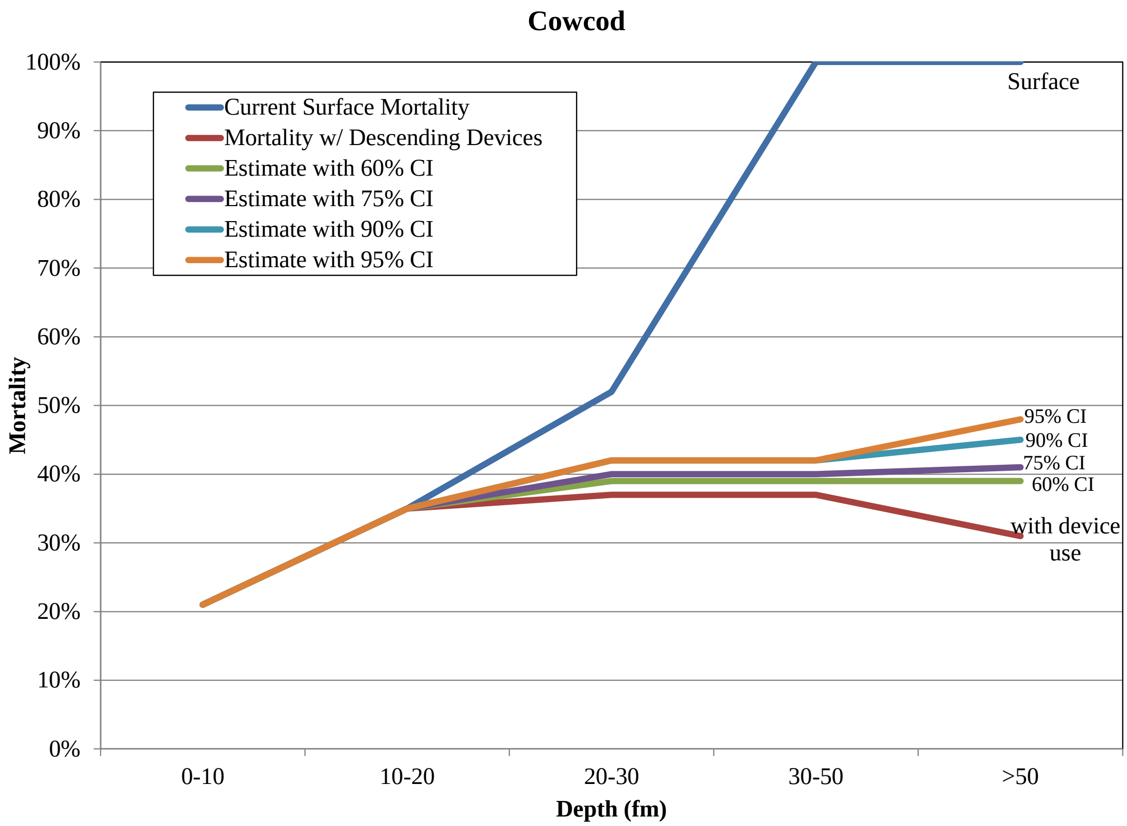


Figure 1. Total discard mortality (%) for cowcod, canary and yelloweye rockfish and reflecting the use of descending devices incorporating short-term mortality, long-term mortality, unaccounted for mortality and upper 60, 75, 90, and 95 percent confidence intervals as precautionary buffers for uncertainty.

GMT Recommended Total Discard Mortality and Associated Risks of Choice

The GMT acknowledges that addressing discard mortality is difficult and that final selection of the most appropriate mortality for rockfishes discarded using descending devices should be made after careful review of Appendix A and after extensive discussion and input from other advisory bodies, the public, and among Council members. The GMT recommends use of a buffer for management uncertainty based on an upper confidence interval be selected by the Council (Table 7 and Figure 1) to mitigate the potential for risk of underestimating mortality, while bearing in mind that there is also the potential to overestimate mortality through the application of confidence interval values from the upper end of the distribution. The risk associated with uncertainty in each estimate of mortality should be carefully considered in selecting a mortality rate that reflects the degree of comfort with the related assumptions. As new data becomes available the estimates should be updated, since current research will continue to provide additional data to inform and improve mortality estimates over time.

Future Analyses and Research

The uncertainty concerning the successful use of descending devices in returning fish to depth should be addressed when mortality rates reflecting successful release are applied. Estimates providing the best estimate of mortality assume that fish were successfully returned to depth. A buffer for failure to return fish to a sufficient depth when using descending devices when they are reported to have been used to release a fish may need to be accounted for when applying the mortality estimate. It may be more appropriate to further explore a buffer for this uncertainty with regard to the estimates of the frequency of use of devices, which will be provided by each state. Thus it is not reflected in the estimates of mortality or buffers provided herein and will be addressed in the application of mortality rates.

The GMT sees the above work for cowcod, canary rockfish, and yelloweye rockfish in the recreational fisheries as a first step. We see the potential for application to other rockfish species in the recreational fisheries, which we would be interested in exploring, when such data become available. Additionally, the Council asked the GMT to consider the applicability of descending devices and associated mortality estimates for the commercial nearshore fishery. The team discussed the application of new mortality estimates reflecting the use of descending devices in the commercial nearshore fishery. However some on the team feel that there are many issues in the commercial fishery that are very different from the recreational fishery, and concluded that mortalities reflecting the use of descending devices and implementation assumptions may be very different between the two fisheries. As such, a full analysis for application to the commercial fishery was not possible in the time frame that the Team was working under. This analysis, if recommended by the Council, would be a separate and distinct analysis from that shown in this document.

Barotrauma and the Magnuson-Stevens Fisheries Management and Conservation Act Reauthorized National Standard Guidelines

Accounting for the use of descending devices and the decreased mortality rates associated with their use fits under National Standards 1, 2, 6, 8, and 9 (Appendix B) of the Magnuson-Stevens Fishery Management and Conservations Act Reauthorized (MSA).

<u>National Standard 1:</u> *Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield (OY) from each fishery for the U.S. fishing industry.* Using the current mortality estimates for fish released at the surface, which are higher than for fish released at depth, may be overestimating the impacts to overfished species from the recreational fisheries. This means that regulatory actions may be taken prior to the individual sector harvest guidelines being actually achieved, and therefore the optimum yield would not be achieved.

<u>National Standard 2</u>: *Conservation and management measures shall be based upon the best scientific information available.* The GMT has examined literature on the use of

descending devices and the effects of barotrauma that have been published to date. Additionally the GMT has contacted researchers currently working on projects to get information on unpublished data. The data available is somewhat limited by species and depth strata, but the best information available at this time (March 2013) has been incorporated into the analysis.

National Standard 6: *Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.* The GMT uses the best information available when setting up season structures and associated management measures during the biennial harvest specifications and management measures cycle. However, what actually occurs in the fisheries often varies from the modeling due to a variety of factors: weather, El Nino, other fishing opportunities, gas prices, state of the economy, and fish movement. The recreational fisheries in recent years have shown this variability in catches of overfished species, particularly yelloweye rockfish. Since this is a species for which retention is prohibited in all three states, anglers must release any they encounter. Currently surface mortality rates are being applied. As more anglers use descending devices for the overfished species they encounter, the mortality of released fish may likely be overestimated. Incorporating mortality estimates for fish released at depth into inseason tracking will help account for the variability in encounters (and discards) and apply a more meaningful mortality percentage to those discarded fish.

National Standard 8: *Conservation and management measures shall, consistent with the conservation requirements of the Magnuson-Stevens Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to: (1) provide for the sustained participation of such communities; and (2) to the extent practicable, minimize adverse economic impacts on such communities.* The current use of surface mortality estimates applied to all released overfished species may result in an overestimation of the impacts, or total mortality. This potential overestimation may cause fisheries managers to unnecessarily restrict or even close fisheries. These restrictions or closures have a negative impact on the coastal economies; fewer anglers go to coastal communities, which decrease their associated expenditures (gas, lodging, bait, meals, tackle).

National Standard 9: *Conservation and management measures shall, to the extent practicable: (1) minimize bycatch; and (2) to the extent bycatch cannot be avoided, minimize the mortality of such bycatch.* The use of descending devices may reduce mortality of rockfish that are caught, but not retained. The mortality of rockfish released at depth is less than for fish released at the surface. As more anglers use descending devices, the mortality associated with released rockfish, primarily overfished species, will decrease.

GMT Recommendations

1. **Approve the use of mortality rates reflecting the use of descending devices for canary rockfish, yelloweye rockfish and cowcod in recreational catch accounting.**
2. **Consider the selection of mortality estimates that incorporates confidence intervals according to the level of perceived risk and uncertainty in the estimates to provide a precautionary buffer.**

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Appendix A. Biases and Uncertainty in Discard-Mortality Estimates

Key uncertainties in mortality estimates for fish released with descending devices include the effect of depth of capture, limited species-specific research on cowcod and yelloweye, the effect of time on deck, the effect of thermal shock (e.g., temperate gradient across the thermocline), long-term mortality, potential negative effects to reproduction and productivity, and others. Following is an examination of potential biases between the mortality of fish in the research studies from which discard-mortality rates were derived compared to that expected when descending devices are used on a regular fishing trip. A description of the potential causes for differences between estimates from each study and mortality of fish released by anglers are provided below.

<u>Hannah et al. (2012) Cage Study</u>

Handling of Fish Prior to Release

Fish in this study were handled to remove hooks, measured, tagged prior to release and confined in limited space without food for two to four days. Fish handled by anglers are removed from the hook and returned to depth using a descending device. Recreational anglers will most likely have different impacts on released fish due to handling than researchers do. The difference in stress, injury and resulting mortality due to handling between researchers and anglers using descending devices is variable depending on the experience level of the angler in handling rockfish and their regard for the survival fish, thus a bias in either direction is difficult to quantify.

Anglers Handling Time prior to Release Compared to Researchers

Some information is provided from Jarvis and Lowe 2008. On page 1294 is a figure with probability of survival with deck time from a generalized linear model (GLM) analysis. A point estimate of mortality of 29 percent using data from all species in this study corresponds to a little more than 15 minutes on deck in the curve. How long fish will be left on deck is questionable, but fishermen are likely to return fish to the water by the end of a drift if not immediately before continuing to fish. Drift lengths can vary depending on the size of the reef, orientation of the reef compared to windage and whether they are catching fish or not. Most drifts last between 5-30 minutes. At 30 minutes, the probability of mortality is approximately 50 percent.

Cages Protect Fish from Potential Predation

Most rockfish in lingcod stomachs were smaller than cowcod, yelloweye and canary rockfish encountered in the recreational fishery (Beaudreau 2012). Take by pinnipeds is relatively uncommon as indicated by their infrequent presence around boats fishing for rockfish in the CRFS data. Though pinnipeds do eat rockfish (Love et al. 2002, Lowery et al. 1991), removal of fish from descending devices is not expected to be common since discarded fish are still expected to be available at the surface as not all fish will be released with a device. Predation by sharks is another consideration, but sharks are rarely caught as bycatch while fishing for rockfish, though they may be in the vicinity.

Many fish that are returned to the seabed take some time to recover from the stress and may lie on their side, venting rapidly, for some time. These fish are protected from large predators by cages, but not small "scavengers" such as sand fleas. Suuronen and Erickson (2010) discuss the possibility of increased scavenging on live but caged fishes held on the seabed by sand fleas (amphipods) and hagfish. While caged fish clearly may not be able to escape scavengers, those that are stunned when returned to depth also may not be able to move at a sufficient speed and distance to get away from them. The Hannah (2012) study relied on a new novel cage designed to protect fish from hagfish and sand fleas, to address increased mortality due to predation.

Stress Induced by Captivity

Fish were subjected to stress of confinement and repeated contact with the walls of barrels in which they were confined. In addition, they did not have access to prey and were unable to feed resulting in the potential for additional stress that would not be experienced by fish released at depth using a descending device.

<u>Wegner et al. (in prep) Acoustic Tagging Study</u>

Equal Mortality Inside and Outside of the Acoustic Array

The estimates of mortality assume fish that left the array area had the same mortality rate as those that remained within the receiver array. This assumption may be valid since fish that left the array appear to have been making diel migrations in the water column within the array prior to leaving the array as indicated by depth and accelerometry data (Wegner, personal communication). However, there is no way to verify whether or not these fish lived or died after they left the array.

Mortality through Day 10 reflects Mortality through the 4 Month Study

After the sixth day of the study, no additional mortality was observed in fish that remained within the array until the end of the four month study. Thus it is assumed that there no additional mortality beyond ten days at which the estimates were made. While 10+ days is noted as the duration of the long-term mortality estimate, the estimate reflects long-term mortality representative of the duration of the four month study.

Effects of Thermal Shock in the Southern California Bight

The results reflect the greater thermocline in the Southern California Bight and potential for exacerbating effects of thermal shock. Data provided by Wegner et al. (in prep) was collected in March when the thermocline is expected to be relatively weak, making the mortality estimates derived from the data low compared to the potentially higher mortality during the summer and early Fall when the thermocline is at a maximum. Data from Jarvis and Lowe was collected in mid summer when the thermocline is at or near its maximum and the results are comparable to that observed in Wegner et al. (in prep). These effects may be less severe for canary rockfish and yelloweye rockfish primarily distributed in the area north of Point Conception where water temperatures differences with depth are typically not as extreme as discussed further below (except in El Nino years). However, changes in water temperature patterns fluctuate over time making the difference in net effects of thermal shock north and south of Point Conception difficult to quantify at a given point in time.

Inclusion of Less Robust Species in the 3-10+ day Mortality Rate Estimate
Estimates from this study reflect potential positive bias from inclusion of the more susceptible bank rockfish in the pool of species used to estimate 3-10+ day mortality rates. A mark- recapture estimate of mortality from Hochhalter et al. (2012) provided a mortality estimate of 1 percent for yelloweye rockfish for 17 days after fish were marked. Results of barometric chamber study by Parker et al. (2006) indicated a mortality rate of 3.3 percent for black rockfish subjected to simulated ascent; re-compression and observation for at least 21 days indicate that the results of this study should be considered to provide estimates of long-term mortality that may be biased high when applied to more robust species.

The 3-10+ Day Long-term Mortality Rates Reflect Depths Greater than those to which they are applied
When the 3-10+ day mortality rates or 10+ day estimates are applied in depths less than 70 fathoms, they may represent a positive bias in the estimate since they were collected in deeper depths where the effects of barotrauma are expected to be more severe.

<u>Other Uncertainties</u>
Overlap in the Period of Mortality Rate Estimation between Short-term and Long-term Estimates
Cage study data from Hannah et al. (2012) and subsequent research by ODFW was representative of fish retained between 2 and 4 days, while the long-term mortality rates from Wegner et al. reflect mortality for day 3 to day 10+. The overlap for day 3 and 4 present the potential for double counting of mortality during this period presenting a positive bias in the estimates. If fish died in days 2 to 4 in both studies, this would be accounting for mortality in the same time frame in two sources resulting in an overestimation of aggregate mortality.

Effects of Repeated Capture on Survival Rates
These concerns surround the question of probability of multiple captures and increased rates of mortality with multiple capture events. This is accounted for to some degree as each encounter has an associated the mortality rate applied to it, but mortality for the second event may be marginally higher than the estimate from research resulting in an underestimation of mortality. Rockfish may be less susceptible to mortality on second contact due to perforation of swim bladder in the short term (John Hyde, Personal Communication). Tagging studies typically result in return rates of 3 percent on average and depending on how heavily a spot is fished, recapture may be relatively infrequent.

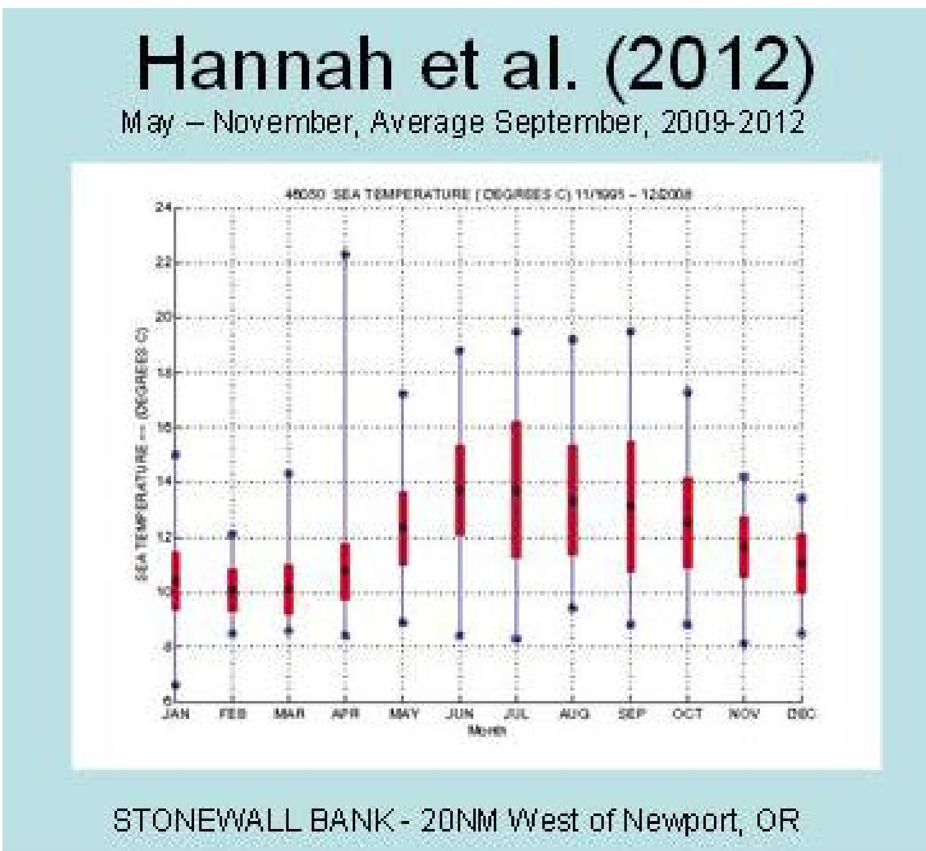
Environmental Conditions at Time of Study
Given the significant contribution of the degree of thermocline posed by the difference in water temperature between surface and the bottom to mortality rates observed in Jarvis and Lowe, the seasonal or inter-annual variability (El Nino, La Nina) may have an effect on survival estimated by the study depending on the environmental conditions at the time the research was conducted and to which it is being applied. The following figures

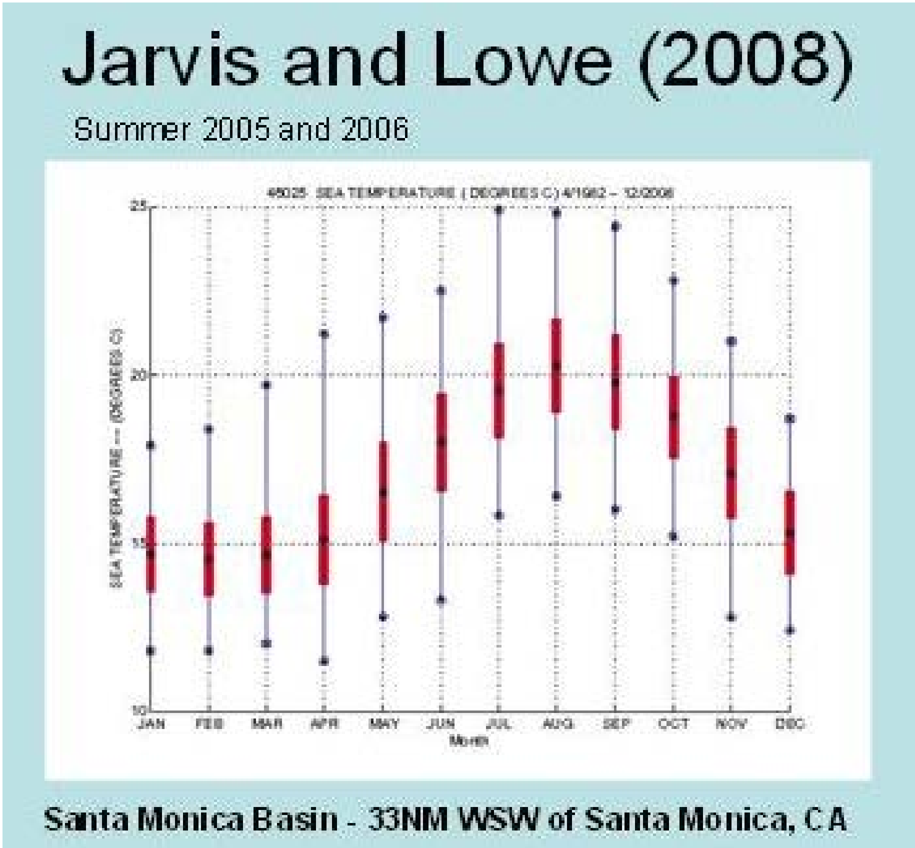
describe monthly average water temperatures (and standard deviations) for locations near studies referenced in this paper.

Water temperatures observed during the Hannah et al. studies average 11.9^{o} C and ranged between 9.5 – 15.4^{o} C. These observed water temperatures fall between or are within annual monthly mean water temperatures in the area of study (i.e., higher than November – April average temperatures and lower than May – October temperatures; see Figure below). Note that maximum standard errors off southern Oregon may reach or exceed 20 ^{o}C.

Jarvis and Lowe's study was conducted during summer months in the Southern California Bight. Although we are uncertain what the observed water temperature was during the time of this study, the summer and early fall months represent the high-water temperature months in this region. Studies by Jarvis and Lowe were not conducted during El Nino or La Nina conditions.

Wegner et al., (in prep) was conducted during March 2012 in the San Clemente Basin. This period represents one of the coolest water-temperature months in that area during a single year (see Figure below).




Jarvis and Lowe (2008)
Summer 2005 and 2006
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Santa Monica Basin - 33NM WSW of Santa Monica, CA

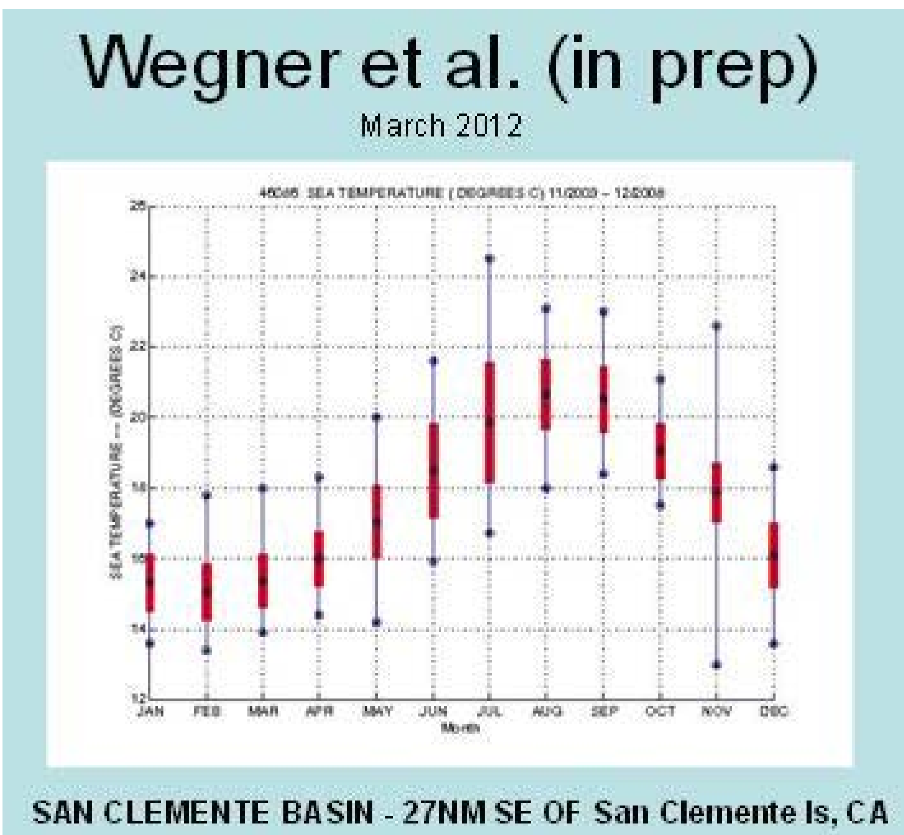

Wegner et al. (in prep)
March 2012
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
SAN CLEMENTE BASIN - 27NM SE OF San Clemente Is, CA

Table 8. Sources of bias in studies informing discard mortality rates reflecting the use of descending devices.

Data Source	Affected Estimates	Uncertainty	Direction	Measure	Considerations
Cage Studies: Hannah et al. (2012), Jarvis and Lowe (2008)	All Species in <50 fm	Handling Bias	Neutral	Qualitative	Measuring and Tagging = Assumed Angler Treatment
	All Species in <50 fm	Time on Deck Bias	Negative	Data	Likely released using device immediately if at all.
	All Species in <50 fm	Cage Protection Bias	Negative	Data	Predation upon release at depth appears limited.
	All Species in <50 fm	Stress Induced Mortality from Captivity	Positive	Qualitative	Confined fish may be stressed or deprived of food.
	Canary Rockfish 30-50 fm	Jarvis and Lowe Conducted in Southern California	Positive	Qualitative	Temperature difference due to thermocline is typically lower north of Point Conception where canary rockfish are more common
Acoustic Tagging: Wegner et al. (in prep)	All Species >50 fm	Mortality Inside vs. Outside Array	Neutral	Qualitative	Behavior same as others before departing array
	All Species >50 fm	Mortality at 10 days = 4 month	Neutral	Data	No mortality in array beyond 6 days up to 4 months.
	Canary and Yelloweye >50 fm	Data collected in Southern California	Positive	Qualitative	Temperature difference due to thermocline is typically higher than north of Point Conception
	All Species >50 fm	Estimate Includes Less Robust Species	Positive	Data	Bank rockfish was included in estimate despite higher mortality rate than expected.
	Long-term Mortality All Species <50 fm	Depth of Estimate Greater than Depth Applied	Positive	Data	Rates were developed using data from greater than 70 fm, but is applied to shallower depths where mortality may be lower.

General	All Species <50 fm	Overlap in Mortality between Estimates	Positive	Data	Overlap in time for 0-50 fm short-term and long-term mortality rates for days 3 and 4 included in both studies.
	All Species All Depths	Repeated Capture Bias	Negative	Qualitative	Depends marginal increase rates and probability of multiple encounters
	All Except Yelloweye 30-50 fm, Cowcod >50 fm	Use of Proxy Species	Neutral	Data	Appropriate species were selected as proxies, minimizing potential biases, which could be positive or negative.

Appendix B. National Standard Guidelines in the Magnuson-Stevens Fisheries Conservation and Management Act Reauthorized

(http://www.nmfs.noaa.gov/msa2007/docs/act_draft.pdf)

Standard 1. Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield (OY) from each fishery for the U.S. fishing industry.

Standard 2. Conservation and management measures shall be based upon the best scientific information available.

Standard 3. To the extent practicable, an individual stock of fish shall be managed as a unit throughout its range, and interrelated stocks of fish shall be managed as a unit or in close coordination.

Standard 4. Conservation and management measures shall not discriminate between residents of different states. If it becomes necessary to allocate or assign fishing privileges among various U.S. fishermen, such allocation shall be:

(1) Fair and equitable to all such fishermen.
(2) Reasonably calculated to promote conservation.
(3) Carried out in such manner that no particular individual, corporation, or other entity acquires an excessive share of such privileges.

Standard 5. Conservation and management measures shall, where practicable, consider efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose.

Standard 6. Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.

Standard 7. Conservation and management measures shall, where practicable, minimize costs and avoid unnecessary duplication.

Standard 8. Conservation and management measures shall, consistent with the conservation requirements of the Magnuson-Stevens Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to:

(1) Provide for the sustained participation of such communities; and
(2) To the extent practicable, minimize adverse economic impacts on such communities.

Standard 9. Conservation and management measures shall, to the extent practicable:

(1) Minimize bycatch; and
(2) To the extent bycatch cannot be avoided, minimize the mortality of such bycatch.

Standard 10. Conservation and management measures shall, to the extent practicable, promote the safety of human life at sea.