Agenda Item H.4.a
Supplemental GMT Report 1
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DEVELOPMENT OF GENERALIZED DISCARD MORTALITY RATES REFLECTING THE USE OF DESCENDING DEVICES FOR ROCKFISHES OF THE GENUS SEBASTES

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Executive Summary

Members of the Groundfish Management Team (GMT), led by Dr. Chantel Wetzel from the National Marine Fisheries Service Northwest Fisheries Science Center, have been working to develop mortality rates for additional rockfish species when descending devices are used to release rockfish at depth. This analysis builds upon previous analysis conducted in 2014 to estimate discard mortality rates for three rockfish species: cowcod, yelloweye rockfish, and canary rockfish. The modeling approach was retained from the 2014 analysis and applied to a dataset incorporating data from four rockfish barotrauma studies. This analysis was presented to the Scientific and Statistical Committee (SSC) for their review in September 2022. SSC comments and recommendations have been addressed (Agenda Item H.4.a, Supplemental GMT Report 2) and are included in this report.

Based on existing barotrauma studies, there is insufficient data to develop species-specific mortality rates across depth bins. Therefore, rates based on guilds (demersal, pelagic, and dwarf) are proposed. Similar to the development of the 2014 rates, a range of percentiles calculated from the estimated posterior predicted distributions are provided for consideration.

Overview

In 2014, the Pacific Fishery Management Council (Council) adopted depth-dependent discard mortality rates reflecting the use of descending devices for cowcod, canary and yelloweye rockfishes based on data from cage/barrel studies and acoustic tagging research (Agenda Item D.3.b GMT Report, March 2014, pages 254-275 and Agenda Item D3.b GMT Report 2, March 2014, pages 277-279). The 2014 analysis applied a Bayesian hierarchical analytical model to combine short-term and delayed mortality estimates (i.e., additional mortality from barotrauma incurred after the short-term observation period termed long-term mortality) from these studies using data from several species to provide proxy estimates where species-specific data was not available. Based on the 2014 analysis, the Council chose the 90th percentile (i.e., referred to as the upper 90 percent confidence interval in the 2014 analysis) estimates of the resulting mortality rates in each depth bin to provide a buffer for uncertainty given the sharing of data across species. Since then, additional acoustic tagging and cage studies samples have been conducted for an array of rockfish species.

The 2021 stock assessments of nearshore stocks (i.e., vermilion/sunset, quillback, and copper rockfishes) indicated the need to reduce mortality via either prohibition on retention or reduced bag, or sub-bag, limits. Depth-dependent discard mortality rates when using descending devices are currently only available for cowcod, canary rockfish, and yelloweye rockfish. All other rockfish species use discard mortality rates based on surface release observations, regardless of how the fish was released. Nearshore rockfish species are commonly encountered in depths of 30 fathoms or greater and the surface release discard rates assume 100 percent discard mortality for fish captured at these depths. The assumption of 100 percent mortality based on surface release discard mortality estimates may not reflect the realized mortality for rockfish returned with descending devices and has the potential to limit access to these deeper depths for rockfish species with constraining harvest limits.

The use of descending devices for returning discarded rockfish species back to depth has the ability to reduce barotrauma mortality. If descending devices are used, the application of existing surface mortality rates may result in overestimates of discard mortality for depths greater than 10 to 20 fathoms. Developing estimates of discard mortality rates reflecting the use of descending devices for a wide range of rockfish species, beyond cowcod, canary rockfish, and yelloweye rockfish, would allow discard mortality estimates to better reflect realized mortality from release of discarded fish with descending devices.

While discard mortality may vary by species based on their anatomical and physiological adaptations to changes in pressure affecting barotrauma, there are likely to be general trends across species that allow for a generalized estimate of discard mortality for grouping of species (e.g., demersal, pelagic, and dwarf species guild groups) that can be applied to those species without sufficient data to inform a species-specific estimate. The existing surface release mortality rates that are used to estimate mortality of discarded rockfish apply a similar grouping approach where there are pelagic or demersal specific mortality rates (i.e., they are additionally broken out into shallow and deep by guild). In this analysis, the Groundfish Management Team (GMT) applies the same Bayesian hierarchical model as was used in the 2014 analysis but with an updated hyper-prior to develop posterior predicted estimates of discard mortality when descending devices (referred to as simply "discard mortality") are used for each species and grouped across species. Additionally, we proposed a simplified approach to determine the final mortality rates used by management, termed "cumulative mortality" (i.e., an approach that can combine both model estimated discard mortality and an additional unaccounted mortality component). Finally, we propose that the cumulative mortality rates by species groups can provide generalized discard mortality rates that could be applied to all remaining species in the genus *Sebastes*.

Methods

Data

Data from four studies examining mortality when using descending devices for West Coast nearshore rockfish species were used to estimate mortality for multiple rockfish species: Jarvis and Lowe (2008), Hannah et al. (2012), Hannah et al. (2014), and Wegner et al. (2021). The previous analysis in 2014 used data from Jarvis and Lowe (2008), Hannah et al. (2012), limited observations from unpublished data from Hannah et al. (2014), and the limited observations from pilot research that were available at that time from Wegner et al. (2021).

Data collected by Jarvis and Lowe (2008), Hannah et al. (2012), and Hannah et al. (2014) account for observed mortality and survival across 2-3 days post-recompression for rockfish descended using descending devices. Jarvis and Lowe (2008) captured fish off Ventura and Santa Catalina Island in California between October 2004 and March 2006. Rockfish were descended using sea cages and observed after two days for survival and incurred barotrauma. A total of 257 fish from 17 rockfish species were captured between 30-50 fathoms and observed for barotrauma by Jarvis and Lowe (2008) (Table 1). Data collected by Hannah et al. (2012) and Hannah et al. (2014) were collected between May 2009 and October 2013 along Stonewall Bank, Seal Rock, Cape Perpetua, and Lincoln City in Oregon. Similar to Jarvis and Lowe (2008), fish were descended and held in a sea cage between two to three days for observation. Hannah et al. (2012) and Hannah et al. (2014) observed a total of 427 fish from 10 rockfish species captured across a wide depth range between 0-100 fathoms (Table 2).

Data were collected between December 2011 and March 2015 by Wegner et al. (2021) from the 43 Fathom Bank, an underwater plateau approximately 80 km west of San Diego, California within the Cowcod Conservation Area. Fish captured by Wegner et al. (2021) were tagged with pressure-sensing acoustic transmitters. Wegner et al. (2021) observed a total of 102 fish across 5 rockfish species between 30-100 fathoms (Table 3) with the majority of fish observed from depths between 50-100 fathoms. In the 50-100 fathom depth range a total of 10 observations were from depths ≥ 90 fathoms with the deepest observation occurring at 100 fathoms. Wegner et al. (2021) observed survival or mortality of fish across a period of time ranging from 0 - 365+ days (Table 3). For comparison with the cage studies that observed outcomes across 2-3 days, the number of observations from Wegner et al (2021) that occurred after 3 days are shown in Table 3 within parentheses.

Wegner et al. (2021) observed post-release mortality using acoustic tags and estimated post-release survivorship curves for four rockfish species: cowcod (N = 46), bocaccio (N = 41), sunset rockfish (N = 13), and bank rockfish (N = 12). The last observed mortality days post-capture varied across these four species. Sunset rockfish had no additional mortality observed after day 0. In contrast, the last observed mortality for cowcod occurred 17.1 days post-capture. The last observed mortality for bocaccio and bank rockfish was 9.1 and 1.6 days post-capture, respectively. The estimated post-release survivorship curves estimated that a total of 99.9 percent of the mortality occurred between 0 to 47.5 days post-capture (cowcod 47.5 days, bocaccio 22.7 days, sunset rockfish 0, and bank rockfish 2.9 days). The majority of these observations occurred at depths greater than 50 fathoms (Table 3). This information should be considered when evaluating the Bayesian hierarchical model estimates, particularly for the 10-30 and 30-50 fathom depth bins which were either informed by only cage study observations between 2-3 days or only limited observations across a longer time period (9 observations in the demersal guild 30-50 fathom depth bin) which may miss additional incurred mortality post-release.

Bayesian Hierarchical Model

Bayesian hierarchical models can be used to account for differences between groups within a larger set of data while allowing all data to provide some information about the overall distribution. They have been applied in fisheries context to account for inter-species differences in stock-recruit parameters (Dorn, 2002) and spatial-differences in maturity (Punt et al., 2006).

The hierarchical model described here was used to account for inter-species differences in mortality estimates within each depth bin for species groups. The model could be extended to include links between depth bins, but that additional complexity has not been included at this time. The equations below have not been subscripted by depth bin as the applications to each bin were independent.

For each species s included with a collection of proxy species, the number of fish observed dead D_s out of a total sample of N_s for a given species is assumed to have a binomial distribution with a mortality probability of p_s,

$$D_s \sim binomial(N_s, p_s) \tag{1}$$

where the probabilities p_s for each species are assumed to have a prior probability given by a beta distribution,

$$p_s \sim beta(\alpha\ , \beta) \tag{2}$$

The beta distribution is parameterized as proposed by (Mäntyniemi et al., 2005) in terms of an expected value μ and a scale parameter, η,

$$\alpha\ = \mu\ \eta \tag{3}$$

$$\beta = (1 - \mu)\eta \tag{4}$$

These parameters have hyper-prior distributions given by

$$\mu \sim uniform(0, 1) \tag{5}$$

$$\eta \sim gamma(0.01, 0.01) \tag{6}$$

The gamma distribution was parameterized as:

$$f(x) = \frac{\lambda^x x^{r-1} e^{-\lambda x}}{\Gamma(r)} \tag{7}$$

where r is the shape parameters and λ is the scale parameter (i.e., the conversion of the scale parameter in the default parameterization in R is $s = 1/\lambda$ with the shape parameter $a = r$).

Earlier analyses included in the 2014 analysis used a more informed hyper-prior for η where α = 1 and β = 0.1. The parameterization was updated based on feedback from the SSC in this analysis to a more uninformed hyper-prior in order to allow the data to have a greater influence in the posterior predicted estimates.

Posterior distributions were estimated using Monte Carlo Markov Chain (MCMC) sampling in software Just Another Gibbs Sampler (JAGS, Plummer, 2003). The combination of these priors in the absence of data are represented by the post-model-pre-data distributions with a comparison to the posterior distributions for each quantity when applying the hierarchical analysis to two sets of parameters corresponding to selected depth bins.

The Bayesian hierarchical model provides species-specific discard mortality estimates based on the species-specific data within a depth bin as well as an estimate for an unobserved species (i.e., estimate based on all species data combined within a depth bin and guild) based on the priors and the species-species data included in each bin analysis.

2022 Updated Analysis

Since 2014, data for additional species, samples, and duration of time at liberty are now available to inform expanded discard mortality estimates when using descending devices. Sample sizes and fate (i.e., survival or mortality) of encountered species in each capture depth bin are provided from the cage studies conducted by Jarvis and Lowe (2008; N = 257, Table 1) and Hannah et al. (2012 and 2014; N = 427, Table 2), as well as acoustic tagging by Wegner et al. (2021; N = 113, Table 3). In the 2014 analysis, data on discard mortality by species was grouped into three depth bins: $10 \leq$ depth < 30, $30 \leq$ depth < 50, and $50 \leq$ depth ≤ 100 fathoms. The same binning approach was applied in this work and depth bins will be referred to as 10-30, 30-50, and 50-100 fathom depth bins for simplicity.

Select observations in Tables 1-3 were removed from the updated analysis due to two factors (Table 4). First, data collected between 0-10 fathoms, which included observations of black rockfish only, were removed (Table 4, Hannah et al. 2012, 2014) since the 2014 analysis opted to use surface mortality estimates to reflect discard mortality given the limited observations within this depth bin. The second reason data were removed was in cases where only a single observation for a species was available within a depth bin and guild (guild definitions and groupings discussed in detail below). The Bayesian hierarchical model was unable to estimate discard mortality if only one fish was observed in a depth bin and that fish died. However, if the single observation reflected a fish that survived, the model would successfully estimate a discard mortality rate. In order to avoid biasing estimates, species of rockfish with only one observation in a depth bin were removed, which resulted in removing 6 fish from the data: 1 from the pelagic guild in the 10-30 fathom depth bin, 1 from both the pelagic and dwarf guilds in the 30-50 fathom depth bin, and 3 from the demersal guild in the 30-50 fathom depth bin (Table 4).

Data from a total of 22 rockfish species were combined across the four studies and categorized into three separate species groups, termed guilds, based on biological attributes:

- Demersal Guild: bank rockfish, bocaccio, China rockfish, copper rockfish, cowcod, flag rockfish, greenspotted rockfish, quillback rockfish, speckled rockfish, starry rockfish, sunset rockfish, tiger rockfish, vermilion rockfish, and yelloweye rockfish;
- Pelagic Guild: black rockfish, deacon rockfish, canary rockfish, chilipepper rockfish, and olive rockfish; and,
- Dwarf Guild: halfbanded rockfish, honeycomb rockfish, and squarespot rockfish.

The observations used in the analysis by species according to guild (i.e., demersal, pelagic, and dwarf) are summarized in Table 5. In earlier analyses the pelagic guild included bocaccio, which was moved to the demersal guild for this analysis based on feedback from the SSC. Observations of bocaccio were of adult fish (mean length 53.5 cm ± 4.0 cm standard deviation, Wegner et al. 2021) at which stage bocaccio are more likely to be found at a demersal depth rather than in the upper water column. Additionally, demersal and pelagic species were combined into a single group and posterior predicted estimates by depth bin and species were calculated. There were limited observations of pelagic species (only 5 species) with limited data across the 3 depth bins. These estimates could be used rather than the guild-specific depth bin estimates if those are deemed insufficiently informed given the limited species or total observations.

This updated analysis attempted to follow similar decision making to that used in 2014, where appropriate. However, based on the additional data available, combined with the process of estimating discard mortality across a wider range of species, there was a need to diverge slightly from the decision making within the 2014 analysis. The largest diversion is the calculation of the final cumulative discard mortality where the cumulative mortality represents both the model estimated mortality but can also account for additional mortality components (i.e., not modeled). In the 2014 analysis, cumulative discard mortality was calculated using three components: discard mortality estimated by the Bayesian hierarchical model, and two more components to account for additional mortality that occurs post the study period (i.e., potential mortality incurred after 2-3 days) and an unaccounted for mortality component. This analysis set cumulative discard mortality equal to the estimated posterior prediction from the Bayesian hierarchical model termed "Estimated Discard Mortality":

$$\text{Cumulative Mortality}_s = \text{Estimated Discard Mortality}_{i,s} \tag{8}$$

where *i* is a selected percentile calculated from the estimated posterior predictions and *s* species. The estimated discard mortality is set equal to a pre-specified percentile from the posterior predictions where five percentiles are reported for consideration: 50th, 60th, 70th, 80th, and 90th. The general interpretation of selected percentile is the percentage of values that would be expected to be less than the given value, For example, 80 percent of outcomes (or observations) would be expected to be less than the 80th percentile value. In the context of this analysis, the discard mortality estimate associated with the 80th percentile for the posterior prediction would be that 80 percent of discard mortality values would fall below this given value based on available data. If the selection of a percentile is considered not sufficient for a species (or guild), additional mortality can be incorporated by adding a fixed (not estimated) additional unaccounted mortality component:

$$\text{Cumulative Mortality}_s = 1 - (1 - \text{Estimated Discard Mortality}_{i,s})(1 - \text{Additional Unaccounted Mortality}) \tag{9}$$

The additional unaccounted mortality which can range between 0 and 1 provides that ability for an additional buffering if there were additional mortality factors that were considered to not be adequately captured within the model-based posterior predicted estimates based on the available data. Figure 1 provides a visual demonstration around the selection of a percentile (Figure 1a) from the Estimated Discard Mortality distribution and potential adjustments to include additional unaccounted mortality using Equation 9 (Figure 1b) in the calculation of the Cumulative Mortality.

Discard mortality due to barotrauma is expected to be strongly correlated with the depth of capture, however, there may be additional factors that impact mortality of discarded rockfish species. For example, the size of the fish may potentially impact the probability of survival or mortality due to barotrauma. However, lengths for all fish observed were not available for all four studies. Additionally, the range of sizes observed for studies with recorded lengths were limited, potentially due to the selectivity of the sampling gear. Estimating mortality by depth bins may capture some potential interactions between mortality and size since there are often correlations between size and depth observed for some rockfish species. Future analysis could examine the ability to predict discard mortality based on size if sufficient observations were available across a wide range of sizes.

The Bayesian hierarchical model was run for all species within a guild (demersal, pelagic, and dwarf) and depth bin (10-30, 30-50, and 50-100 fathoms; Table 5). The model estimated posterior distributions of species-specific discard mortality based on the data and the priors. Additionally, a posterior predicted distribution for the unobserved species discard mortality rate was estimated based on all observed species and the priors within the depth bin by guild.

Two statistical tests were conducted to determine whether the species-specific posterior predicted distribution was significantly different from the guild and depth bin unobserved species posterior predicted distribution. The first test was a two-sided Kolmogorov-Smirnov test (KS test) to determine the probability that the two samples come from the same distribution. To conduct the KS test the posterior predicted distribution was sampled from without replacement equal to the initial species-specific or the unobserved species sample size. The cumulative distributions were then plotted and the Kolmogorov-Smirnov statistical distance (D) that measures the maximum vertical distance between the empirical cumulative distribution function was calculated and the associated p-value was reported.

The second analysis applied a power analysis to determine if a species-specific percentile, given the sample size, was sufficient to reject the null hypothesis that the species-specific percentile was not significantly different from the corresponding percentile for the unobserved species. The `pwr` package in R (Champely, 2020) was used to perform a two-sample comparison with unequal sample sizes where the effect size, h, is calculated as:

$$h = |2*asin(\sqrt{p_1}) - 2*asin(\sqrt{p_2})| \qquad (11)$$

where p_1 and p_2 are estimated species-specific and the unobserved species proportion of discard mortality being compared. The h and the corresponding sample sizes, n_1 and n_2 with a significance level of 0.05 were passed to the `pwr::pwr.2p2n.test` function to calculate the power. A power ≥ 0.80 was used to indicate where the effect and sample size were great enough to support using a species-specific value over the "unobserved" value.

Results

Pelagic Guild

Estimates of discard mortality derived by the Bayesian hierarchical model for the pelagic guild are shown in Table 6. Post-model pre-data distributions and species-specific and the unobserved species posterior predicted distributions are available in the Appendix (Figures A.1-A.4). The species-specific 50th percentile within the 10-30 fathom depth bin ranged between 1-19 percent with the unobserved species 50th percentile estimated at an intermediate value of 10 percent (Table 6), while the 90th percentile across species ranged between 5-63 percent (Table 6 and Figure 2). In the 10-30 fathom depth bin the estimated discard mortality rate posterior predicted distribution for the unobserved species was left-skewed with a long upper tail resulting in a larger difference between the 50th and the 90th percentile compared to the species-specific estimates within the pelagic guild (Table 6 and Figure A.2). The KS test comparing the cumulative distribution functions for each species was determined to be significantly different from the unobserved species cumulative distribution (Figure 2). Of the pelagic species within the 10-30 fathom bin, canary rockfish, was the only species where all percentile estimates (50 - 90th) reflected a significant effect (power > 0.80) from the corresponding percentiles from the unobserved species given the sample sizes (Table 6).

Estimates of discard mortality by species in the 30-50 fathom depth bin were generally higher than those in the 10-30 fathom depth bin (Table 6). The 80th percentile from the posterior predicted distributions of discard mortality ranged between 18 to 75 percent by species, with the unobserved species 80th percentile at 53 percent (Table 6 and A.3). Chilipepper, when compared to the unobserved, was the only pelagic species that had a higher species-specific estimated discard mortality, ranging between 58 to 82 percent for the 50th to 90th percentile, however, these values were not considered significantly different from the unobserved species percentiles based on sample sizes (power < 0.80, Table 6). None of the species-specific 50th percentiles were significantly different from the unobserved species given the sample size (Table 6) with only the 80th and 90th percentiles from canary rockfish being determined significantly different from the corresponding unobserved species percentile. Only canary rockfish and chilipepper had significantly different cumulative distribution functions compared to the unobserved species (Figure 3).

The pelagic guild included data from only canary rockfish in the 50-100 fathom depth bin. The estimated posterior predicted distribution of estimated discard mortality from canary rockfish ranged between 78 to 91 percent across the reported percentiles (Table 6 and Figure A.1.4). None of the percentiles were significantly different between canary rockfish and the unobserved species (Table 6) and the cumulative distribution functions were determined to not be significantly different (Figure 4).

Demersal Guild

The 50th percentile of all posterior predicted distributions for all species and the unobserved species were 0 percent (Table 7). Post-model pre-data distributions and species-specific and the unobserved species estimated posterior predicted distributions are available in the Appendix (Figures A.5-A.8). The four demersal species (China, copper, quillback, and yelloweye rockfishes) in the 10-30 fathom depth bin had low estimated discard mortality with the 90th percentile ranging between 0 to 1 percent discard mortality (Table 7 and A.6). The posterior of the unobserved species that incorporated data from all species within the depth bin and the prior distribution resulted in similar 50th - 80th percentiles (Table 8 and A.6). Only quillback rockfish was determined by the KS test to have a cumulative density function significantly different from the unobserved species (Figure 5).

In the 30-50 fathom depth bin, the 50th percentiles for the species-specific estimates ranged between 8 to 31 percent with the unobserved species value of 19 percent (Table 7). The percentiles from the unobserved species increased from 19 percent to 38 percent between the 50th to 90th percentiles (Table 7). Yelloweye rockfish had lower values across percentiles compared to all other species and the 70th to 90th percentiles were significantly different from the unobserved species given the sample sizes (Table 7). The KS test determined that bocaccio, flag rockfish, speckled rockfish, vermilion rockfish, and yelloweye rockfish all had significant differences in their cumulative density functions compared to the unobserved species (Figure 6).

The estimated percentiles of the unobserved species in the 50 - 100 fathom depth bin increased compared to the corresponding estimates from the 30-50 fathom depth bin, with estimates ranging between 25 to 48 percent (Table 7). The species-specific 50th percentiles ranged between 16 to 39 percent and were not determined to be significantly different from the unobserved species estimate. The species-specific estimates from the 80th percentile ranged between 21 to 45 percent, bracketing the unobserved species estimate of 38 percent (Table 7). None of the species-specific percentiles were significantly different from the unobserved species given samples sizes. However, the KS test identified that the cumulative density function from both bocaccio and cowcod was significantly different compared to the unobserved species (Figure 7).

Demersal and Pelagic Guild Species Combined

The Bayesian hierarchical model was also run combining both the demersal and pelagic species within each depth bin. Post-model pre-data distributions and species-specific and the unobserved species estimated posterior predicted distributions are available in the Appendix (Figures A.9-A.12). The estimated species-specific percentiles were generally similar to the corresponding species-specific estimates by guild for species with larger sample sizes (greater than 10, Table 8 vs Tables 6-7). The species-specific quantiles for species with low sample sizes shifted closer to the unobserved species percentiles, especially for species with the largest difference in posterior predicted distributions (see chilipepper in the 30-50 fathom depth bin, Table 8 and Figure A.11). The quantiles for the unobserved species when all demersal and pelagic species were combined, generally resulted in estimates that were less than the corresponding pelagic guild and greater than the demersal guild percentiles (Table 9 vs. Tables 6 and 7). Comparisons of the cumulative density functions and KS tests are shown in Figures 8-10.

Dwarf Guild

Only three dwarf guild species were observed: halfbanded rockfish, honeycomb rockfish, and squarespot rockfish, all within the 30-50 fathom depth bin (Table 9). Post-model pre-data distributions and species-specific and the unobserved species estimated posterior predicted distributions are available in the Appendix (Figures A.13-A.14). The species-specific 50th percentiles for discard mortality ranged between 44 to 60 percent, which were generally higher than the corresponding demersal and pelagic species-specific estimates for the same depth bin (Table 9 versus Tables 6-8). The species-specific percentile were not significantly different from the corresponding unobserved species estimates. However, the cumulative density functions for both halfbanded and squarespot rockfishes were significantly different from the unobserved species (Figure 11).

Discussion

Combined Cumulative Mortality by Guild and Depth Bin

This analysis proposes that the cumulative mortality rates be set equal to a predefined percentile (Eqn. 8) or adjusted to include a predefined additional unaccounted for mortality component (Eqn. 9) if additional precaution is deemed necessary. In 2014, the Council selected the 90th percentile from the species-specific posterior predictions for canary rockfish, yelloweye rockfish, and cowcod which were combined with additional mortality buffers (termed long-term and unaccounted for mortality) to calculate the final cumulative mortality rates.

This analysis used a more uniformed gamma prior, compared to the 2014 analysis, for the η hyper-prior which resulted in the prior probability of p_s having weight at either 0 or 1 (see Figure A.1 for example of the prior distribution for p_s). This resulted in the 90th percentile, in some instances, being quite a bit higher than the next highest percentile reported. For example, the 10-30 fathom depth bin for the demersal guild 80th percentile was 9 percent while the 90th percentile was 100 percent discard mortality. Figure 12 shows the estimated percentile across depth bins for each species grouping: pelagic, demersal, pelagic and demersal, and dwarf rockfishes. A table with the 80th percentiles from the unobserved species for each guild and the demersal and pelagic species combined is shown in Table 10 where the 80th percentile represents a discard mortality rate that would be expected to be greater than 80 out of 100 values. Additionally, a table of the 80th percentiles for species-specific estimated mortality rates for all species included in this analysis is provided in Table 11 which allows for comparison of the species-specific discard mortality rates, whether the species-specific 80th percentile was considered significantly different from unobserved species, and the unobserved estimated discard rates by guild or with guilds combined.

If any specific depth bin by guild was deemed to have insufficient data to result in informed estimates a range of options could be applied to determine discard mortality rates. First, if a shallower depth bin was deemed insufficient the estimated cumulative discard mortality from the next deeper bin could be used for that specific bin. Alternatively, surface release mortality rates could be used in lieu of the estimated cumulative discard mortality, assuming the surface release estimates had higher mortality assumptions. A third alternative would be to combine observations between the demersal and pelagic species into a single analysis where the unobserved species cumulative discard mortality could be used for any poorly informed guild specific depth bin estimates. Finally, additional mortality could be added to the calculation of the cumulative discard mortality using Eqn. 9.

Comparison to Adopted Species-Specific Discard Mortality

Canary rockfish, cowcod, and yelloweye rockfish have adopted cumulative discard mortality rates from the 2014 analysis. The species-specific cumulative mortality estimate using the 80th percentile was considerably lower than the adopted rates for both the 10-30 and 30-50 fathom depth bin (Table 12). However, the species-specific estimates from this analysis were notably higher than the adopted values for the 50-100 fathom depth bin (Table 12). The unobserved grouped pelagic guild estimates were higher than the adopted values for each depth bin (Table 12).

Yelloweye rockfish were observed in each of the depth bins in this analysis. The species-specific cumulative discard mortality estimates varied from the adopted values for each depth bin (Table 12). The species-specific rates for yelloweye rockfish for all depth bins from this analysis were less than the adopted cumulative mortality rates (Table 12). The species-specific cumulative discard mortality based on the 80th percentile for the 50-100 fathom depth bin was considerably lower than the adopted values (27 verses 57 percent), noting that the 2014 analysis used cowcod, bocaccio, bank and sunset rockfishes as proxy species for yelloweye rockfish within this depth bin. The unobserved grouped demersal guild estimates resulted in lower values for the 10-30 and 50-100 fathom depth bins and a higher cumulative discard mortality in the 30-50 fathom depth bin compared to the adopted and species-specific for all depth bins (Table 12).

Cowcod were observed only in the 30-50 and 50-100 fathom depth bins, while only 2 observations informed the 30-50 fathom depth bin estimate. The species-specific cumulative mortality estimates based on the 80th percentile were lower than the adopted values for these bins (Table 12). The grouped demersal guild estimates were lower than the adopted values across all depth bins.

References

Dorn, M.W. 2002. Advice on west coast rockfish harvest rates from Bayesian meta-analysis of stock-recruit relationships. North American Journal of Fisheries Management, 22: 280–300.

Jarvis, E.T. and C.G. Lowe. 2008. The effects of barotrauma on the catch-and-release survival of southern California nearshore and shelf rockfish (Scorpaenidae, *Sebastes* spp.). Canadian Journal of Fishery and Aquatic Science, 65: 1286-1296.

Hannah, R.W., Rankin, P.S. and M.T.O. Blume. 2012. Use of a novel cage system to measure postrecompression survival of northeast Pacific rockfish. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science, 4: 46-56.

Hannah, R.W., Rankin, P.S. and M.T.O. Blume. 2014. The divergent effect of capture depth and associated barotrauma on post-recompression survival of canary (*Sebastes pinniger*) and yelloweye rockfish (*S. ruberrimus*). Fisheries Research, 157: 106-112.

Mäntyniemi, S., Romakkaniemi, A., and E. Arjas. 2005. Bayesian removal estimation of a population size under unequal catchability. Canadian Journal of Fishery and Aquatic Science, 62: 291-300. doi: 10.1139/F04-195.

Plummer, M. 2003. JAGS: A Program for Analysis of Bayesian Graphical Models Using Gibbs Sampling, Proceedings of the 3rd International Workshop on Distributed Statistical Computing (DSC 2003), March 20–22, Vienna, Austria. ISSN 1609-395X.

Punt, A.E., D.K. Hobday, R. Flint. 2006. Bayesian hierarchical modelling of maturity-at-length for rock lobsters, *Jasus edwardsii*, off Victoria, Australia. Mar. Freshwater Research, 57: 503-511.

Wegner, N. C., Portner, E. J., Nguyen, D. T., Bellquist, L., Nosal, A. P., Pribyl, A. L., Stierhoff, K. L., Fischer, P., Franke, K., Vetter, R. D., Hastings, P. A., Semmens, B. X., and Hyde, J. R. 2021. Post-release survival and prolonged sublethal effects of capture and barotrauma on deep-dwelling rockfishes (genus *Sebastes*): implications for fish management and conservation. ICES Journal of Marine Science, 78: 3230-3244.

Tables

Data

Table 1. Sample size and fate of rockfish in cage studies conducted by Jarvis and Lowe (2008) grouped into three depth bins in fathoms (fm).

Rockfish Species	**10 - 30 fm**			**30 - 50 fm**			**50 - 100 fm**		
	Live	**Dead**	**Total**	**Live**	**Dead**	**Total**	**Live**	**Dead**	**Total**
bocaccio				53	11	64			
canary				0	1	1			
chilipepper				2	5	7			
copper				2	0	2			
flag				23	6	29			
freckled				1	0	1			
greenspotted				2	1	3			
greenstriped				1	0	1			
halfbanded				2	3	5			
honeycomb				11	6	17			
olive				2	0	2			
rosy				1	0	1			
speckled				6	5	11			
squarespot				10	18	28			
starry				9	2	11			
vermilion				50	23	73			
yellowtail				0	1	1			
Total				**175**	**82**	**257**			

Table 2. Sample size and fate of rockfish in cage/barrel studies conducted by Hannah et al. (2012) and Hannah et al. (2014) grouped into four depth bins in fathoms (fm).

Rockfish Species	0 - 10 fm			10 - 30 fm			30 - 50 fm			50 - 100 fm		
	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total
black	33	0	33	94	14	108	3	0	3			
blue	1	0	1	1	0	1						
canary				45	0	45	36	4	40	2	8	10
China				3	0	3						
copper				10	0	10						
deacon				27	7	34						
quillback				27	0	27	1	0	1			
tiger							4	0	4			
vermillion							1	0	1			
yelloweye				36	0	36	57	3	60	9	1	10
Grand Total	**34**	**0**	**34**	**243**	**21**	**264**	**102**	**7**	**109**	**11**	**9**	**20**

Table 3. The total sample size and fate of rockfish from observations using acoustic tagging conducted by Wegner et al. (2021) grouped into three depth bins in fathoms (fm). Observations that occurred at 3 days or greater by species, depth bin, and fate are shown in parentheses.

Rockfish Species	10 - 30 fm			30 - 50 fm			50 - 100 fm		
	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total
bank							6 (3)	4 (0)	10 (3)
bocaccio				7 (6)	0 (0)	7 (6)	30 (27)	4 (1)	34 (28)
cowcod				2 (2)	0 (0)	2 (2)	25 (24)	19 (10)	44 (34)
starry							2 (2)	0 (0)	2 (2)
sunset							10 (7)	3 (0)	13 (7)
Total				**9 (8)**	**0 (0)**	**9 (8)**	**73 (63)**	**30 (11)**	**103 (74)**

Table 4. Summary of samples that were removed is grouped by the removal reason with the observations by rockfish species, the depth bin in fathoms (fm), the guild, the number of observations (N), and the observed percent mortality.

Removal Reason	Species	Depth Bin (fm)	Guild	N	Mortality (%)
Single Observation	blue rockfish	10-30	Pelagic	1	0%
	freckled rockfish	30-50	Dwarf	1	100%
	greenstriped rockfish	30-50	Demersal	1	100%
	quillback rockfish	30-50	Demersal	1	0%
	rosy rockfish	30-50	Demersal	1	100%
	yellowtail rockfish	30-50	Pelagic	1	100%
Shallow 0-10 fm	black rockfish	0-10	Pelagic	34	0%

Table 5. Summary of data by depth bin in fathoms (fm) and guild used and rockfish species within each guild, the number of observations (N), and the observed percent mortality.

Guild	Species	10 - 30 fm		30 - 50 fm		50 - 100 fm	
		N	Mortality (%)	N	Mortality (%)	N	Mortality (%)
Demersal	bank rockfish	-	-	-	-	10	40%
	bocaccio	-	-	71	17%	34	12%
	china rockfish	3	0%	-	-	-	-
	copper rockfish	10	0%	2	0%	-	-
	cowcod	-	-	2	0%	44	43%
	flag rockfish	-	-	29	21%	-	-
	greenspotted rockfish	-	-	3	33%	-	-
	quillback rockfish	27	0%	-	-	-	-
	speckled rockfish	-	-	11	45%	-	-
	starry rockfish	-	-	11	18%	2	0%
	sunset rockfish	-	-	-	-	13	23%
	tiger rockfish	-	-	4	0%	-	-
	vermilion rockfish	-	-	74	31%	-	-
	yelloweye rockfish	36	0%	60	5%	10	10%
Pelagic	black rockfish	108	13%	3	0%	-	-
	canary rockfish	45	0%	41	12%	10	80%
	chilipepper rockfish	-	-	7	71%	-	-
	deacon rockfish	34	21%	-	-	-	-
	olive rockfish	-		2	0%	-	-
Dwarf	halfbanded rockfish	-	-	5	60%	-	-
	honeycomb rockfish	-	-	17	35%	-	-
	squarespot rockfish	-	-	28	64%	-	-

Results

Table 6. Percentiles by depth bin in fathoms (fm) of the estimated discard mortality when using descending devices for pelagic species by the Bayesian hierarchical model by species and for unobserved species with sample sizes (N). The combined estimate of the "unobserved species" by depth bin is shown in bold. The * indicate species-specific percentiles with a power of ≥ 0.80 compared to the corresponding unobserved species percentile. See the appendix figures reflecting the estimated posterior predicted distribution for the species-specific and unobserved species corresponding to the percentiles.

Depth (fm)	Species	N	Percentiles (%)				
			50th	60th	70th	80th	90th
10-30	black rockfish	108	13	14	15	16*	17*
	canary rockfish	45	1*	1*	2*	3*	5*
	deacon rockfish	34	19	21	23	25	28*
	unobserved	**187**	**10**	**14**	**21**	**34**	**63**
30-50	black rockfish	3	8	12	17	24	33
	canary rockfish	41	13	14	16	18*	21*
	chilipepper	7	58	64	69	75	82
	olive rockfish	2	10	15	21	27	38
	unobserved	**53**	**21**	**29**	**38**	**53**	**78**
50-100	canary rockfish	10	78	81	84	87	91
	unobserved	**10**	**73**	**80**	**86**	**92**	**99**

Table 7. Percentiles by depth bin in fathoms (fm) of the estimated discard mortality when using descending devices for demersal species by the Bayesian hierarchical model by species and for "unobserved" species with sample sizes (N). The combined estimate of the "unobserved species" by depth bin is shown in bold. The * indicate species-specific percentiles with a power of ≥ 0.80 compared to the corresponding unobserved species percentile. See the appendix figures reflecting the estimated posterior predicted distribution for the species-specific and unobserved species corresponding to the percentiles.

Depth (fm)	Species	N	Percentiles (%)				
			50th	**60th**	**70th**	**80th**	**90th**
10-30	China rockfish	3	0	0	0	0	1*
	copper rockfish	10	0	0	0	0	0*
	quillback rockfish	27	0	0	0	0	0*
	yelloweye rockfish	36	0	0	0	0	0*
	unobserved	**76**	**0**	**0**	**0**	**9**	**100**
30-50	bocaccio	71	16	17	18	20	22
	copper rockfish	2	16	19	22	25	31
	cowcod	2	16	19	22	25	31
	flag rockfish	29	20	22	23	26	29
	greenspotted rockfish	3	21	24	27	32	39
	speckled rockfish	11	31	34	37	41	47
	starry rockfish	11	18	20	23	26	30
	tiger rockfish	4	14	16	19	22	27
	vermilion rockfish	74	29	30	32	33	36
	yelloweye rockfish	60	8	9	10*	11*	13*
	unobserved	**267**	**19**	**22**	**25**	**30**	**38**
50-100	bank rockfish	10	32	35	38	42	48
	bocaccio	34	16	17	19	21	24
	cowcod	44	39	41	43	45	48
	starry rockfish	2	21	24	28	32	38
	sunset rockfish	13	24	26	29	32	37
	yelloweye rockfish	10	18	21	23	27	31
	unobserved	**113**	**25**	**29**	**33**	**38**	**48**

Table 8. Percentiles by depth bin in fathoms (fm) of the estimated discard mortality when using descending devices for demersal and pelagic species combined by the Bayesian hierarchical model by species and for unobserved species with sample sizes (N). The * indicate species-specific percentiles with a power of ≥ 0.80 compared to the corresponding unobserved species percentile. See the appendix figures reflecting the estimated posterior predicted distribution for the species-specific and unobserved species corresponding to the percentiles.

Depth (fm)	Species	N	Percentiles (%)				
			50th	60th	70th	80th	90th
10-30	black rockfish	108	13*	13*	14	15	17
	canary rockfish	45	0	0	0	1*	1*
	China rockfish	3	0	1	2	5	11
	copper rockfish	10	0	0	1	2	5*
	deacon rockfish	34	19*	21*	23	25	28
	quillback rockfish	27	0	0	0	1*	2*
	yelloweye rockfish	36	0	0	0	1*	2*
	unobserved	**263**	**1**	**3**	**7**	**15**	**41**
30-50	black rockfish	3	14	17	20	24	30
	bocaccio	71	15	17	18	20	22*
	canary rockfish	41	14	15	16	18	21
	chilipepper rockfish	7	41	46	50	56	64
	copper rockfish	2	15	18	22	26	33
	cowcod	2	16	18	22	26	33
	flag rockfish	29	20	22	24	26	29
	greenspotted rockfish	3	23	26	29	34	42
	olive rockfish	2	15	18	22	26	33
	speckled rockfish	11	33	36	40	44	50
	starry rockfish	11	19	21	23	27	31
	tiger rockfish	4	13	16	19	22	28
	vermilion rockfish	74	30	31	32	34	36
	yelloweye rockfish	60	7	8*	9*	10*	12*
	unobserved	**320**	**19**	**23**	**27**	**32**	**42**
50-100	bank rockfish	10	37	40	44	48	54
	bocaccio	34	15	16	18*	20*	23*
	canary	10	64	68	72	77	82
	cowcod	44	42	43	45	48	51
	starry rockfish	2	21	26	31	37	45
	sunset rockfish	13	25	28	31	35	40
	yelloweye rockfish	10	17	20	23	27	32
	unobserved	**123**	**31**	**37**	**43**	**52**	**66**

Table 9. Percentiles by depth bin in fathoms (fm) of the estimated discard mortality when using descending devices for dwarf rockfish species by the Bayesian hierarchical model by species and for unobserved species with sample sizes (N). The * indicate species-specific percentiles with a power of ≥ 0.80 compared to the corresponding unobserved species percentile. See the appendix figures reflecting the estimated posterior predicted distribution for the species-specific and unobserved species corresponding to the percentiles.

Depth (fm)	Species	N	Percentile (%)				
			50th	60th	70th	80th	90th
30-50	halfbanded rockfish	5	55	58	62	66	73
	honeycomb rockfish	17	44	47	49	53	57
	squarespot rockfish	28	60	62	65	67	71
	unobserved	**50**	**53**	**57**	**62**	**67**	**77**

Table 10. The cumulative mortality percent based on the 80th percentile when using descending devices of the unobserved species from each guild.

Depth Bin (fm)	Pelagic Percentile (%)	Demersal Percentile (%)	Pelagic and Demersal Percentile (%)	Dwarf Percentile (%)
10-30	34	9	15	-
30-50	53	30	32	67
50-100	92	38	52	-

Table 11. Comparison between the estimated discard mortality 80th percentile by species and the guild based estimates. The values in parentheses reflect the demersal and pelagic combined estimates. The * indicate species-specific 80th percentiles with a power of ≥ 0.80 compared to the corresponding unobserved species percentile.

Species	Guild	80th Percentile (%)		
		10-30	30-50	50+
bank rockfish	demersal	-	-	42 (48)
black rockfish	pelagic	16* (15)	24 (24)	-
bocaccio	demersal	-	20 (20)	21* (20*)
canary rockfish	pelagic	3* (1*)	18* (18)	87 (77)
chilipepper	pelagic	-	75 (56)	-
China rockfish	demersal	0 (0)	-	-
copper rockfish	demersal	0 (2)	25 (26)	-
cowcod	demersal	-	25 (26)	45 (48)
deacon rockfish	pelagic	25 (25)	-	-
flag rockfish	demersal	-	26 (26)	-
greenspotted rockfish	demersal	-	32 (34)	-
halfbanded rockfish	dwarf	-	66	-
honeycomb rockfish	dwarf	-	53	-
olive rockfish	pelagic	-	27 (26)	-
quillback rockfish	demersal	1* (1*)	-	-
speckled rockfish	demersal	-	41 (44)	-
squarespot rockfish	dwarf	-	67	-
starry rockfish	demersal	-	26 (27)	32 (37)
sunset rockfish	demersal	-	-	32 (35)
tiger rockfish	demersal	-	22 (22)	-
vermilion rockfish	demersal	-	32 (34)	-
yelloweye rockfish	demersal	1* (1*)	11* (10*)	27 (27)
Guild	pelagic	34	53	92
	demersal	9	30	38
	demersal & pelagic	15	32	52
	dwarf	-	67	-

Table 12. Comparison between the adopted cumulative mortality when using descending devices from the 2014 analysis and the new species-specific (demersal, pelagic, or demersal and pelagic) and the unobserved species by guild (demersal, pelagic, or demersal and pelagic) estimates using the 80th percentiles for canary rockfish, yelloweye rockfish, and cowcod. The * indicate species-specific percentiles with a power of ≥ 0.80 compared to the corresponding unobserved species percentile.

Species	Depth Bin (fm)	N	Cumulative Mortality Rates (%)				
			Adopted	Species-Specific	Unobserved Guild Specific	Species-Specific Combined Demersal & Pelagic Guild	Unobserved Combined Demersal & Pelagic Guild
canary rockfish	10-30	45	25	3*	34	1	15
	30-50	41	48	18*	53	18	32
	50-100	10	57	87	92	77	66
	100+	-	100	-	-	-	-
yelloweye rockfish	10-30	36	26	0	9	1	15
	30-50	60	27	11*	30	10*	32
	50-100	10	57	27	38	27	66
	100+	-	100	-	-	-	-
cowcod	10-20	-	35	-	9	-	15
	20-30	-	52[1]	-	9	-	15
	30-50	2	57	25*	30	26	32
	50-100	44	57	45	38	48	66
	100+	-	100	-	-	-	-

[1] The value reflects surface mortality since mortality estimates for descending devices are not expected to exceed surface release.

Figures

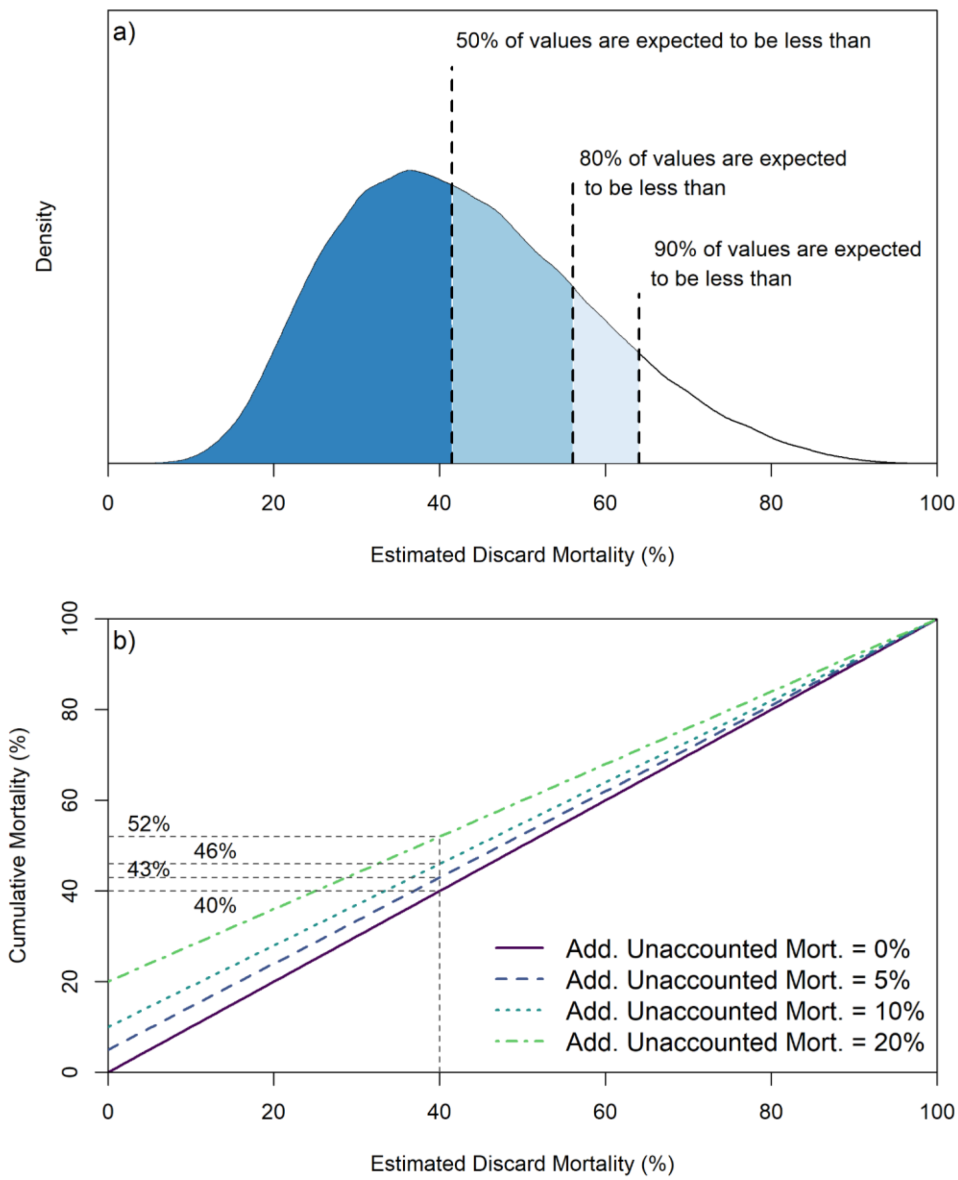

Figure 1. Illustration around the interpretation of a selected percentile from the Estimated Discard Mortality distribution (panel a) and the adjustment to the final Cumulative Mortality depending upon the selection of additional unaccounted mortality based on Equation 9 (panel b).

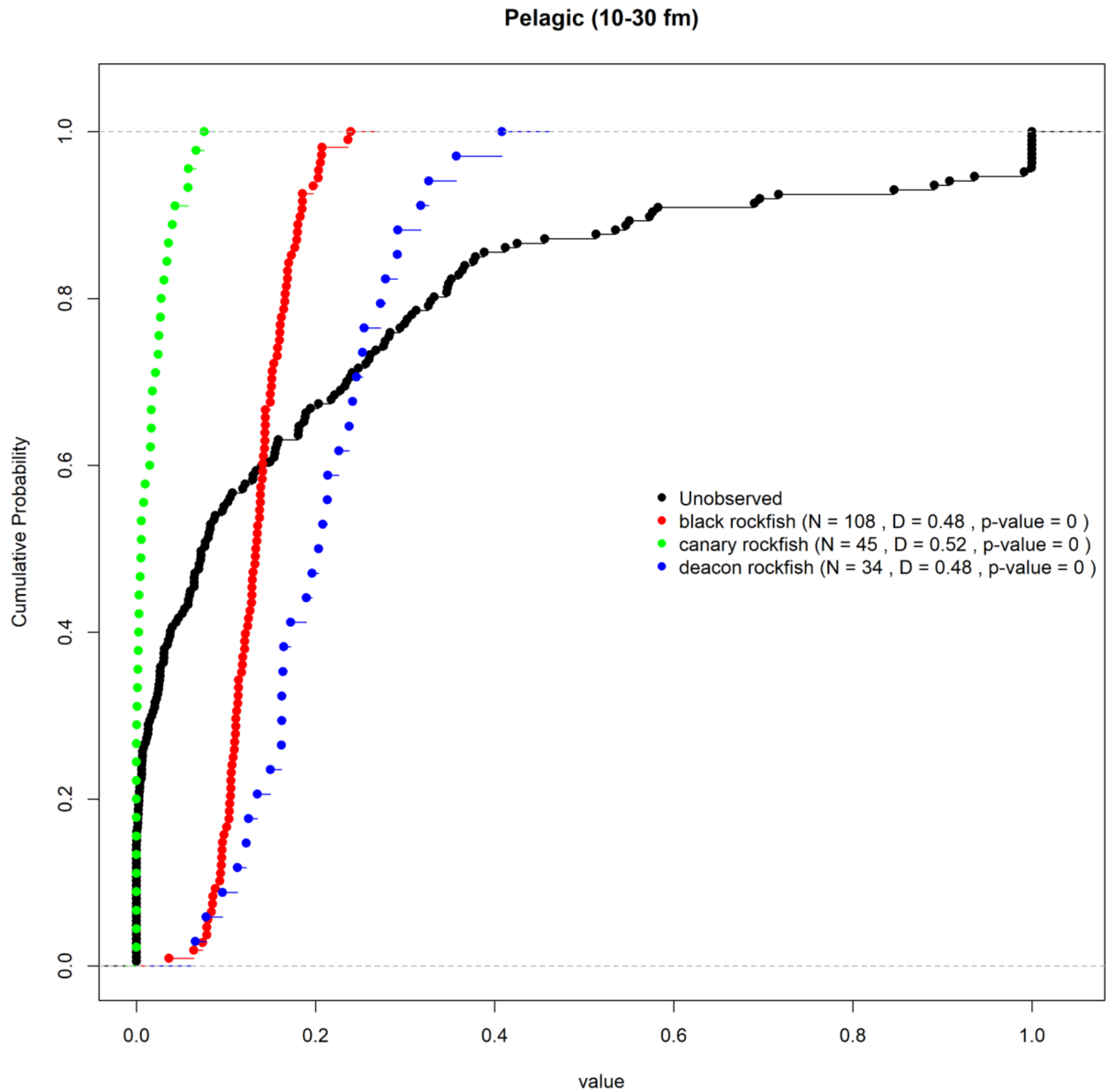

Figure 2. The cumulative distributions for each pelagic species compared with the unobserved species cumulative distribution for the 10-30 fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

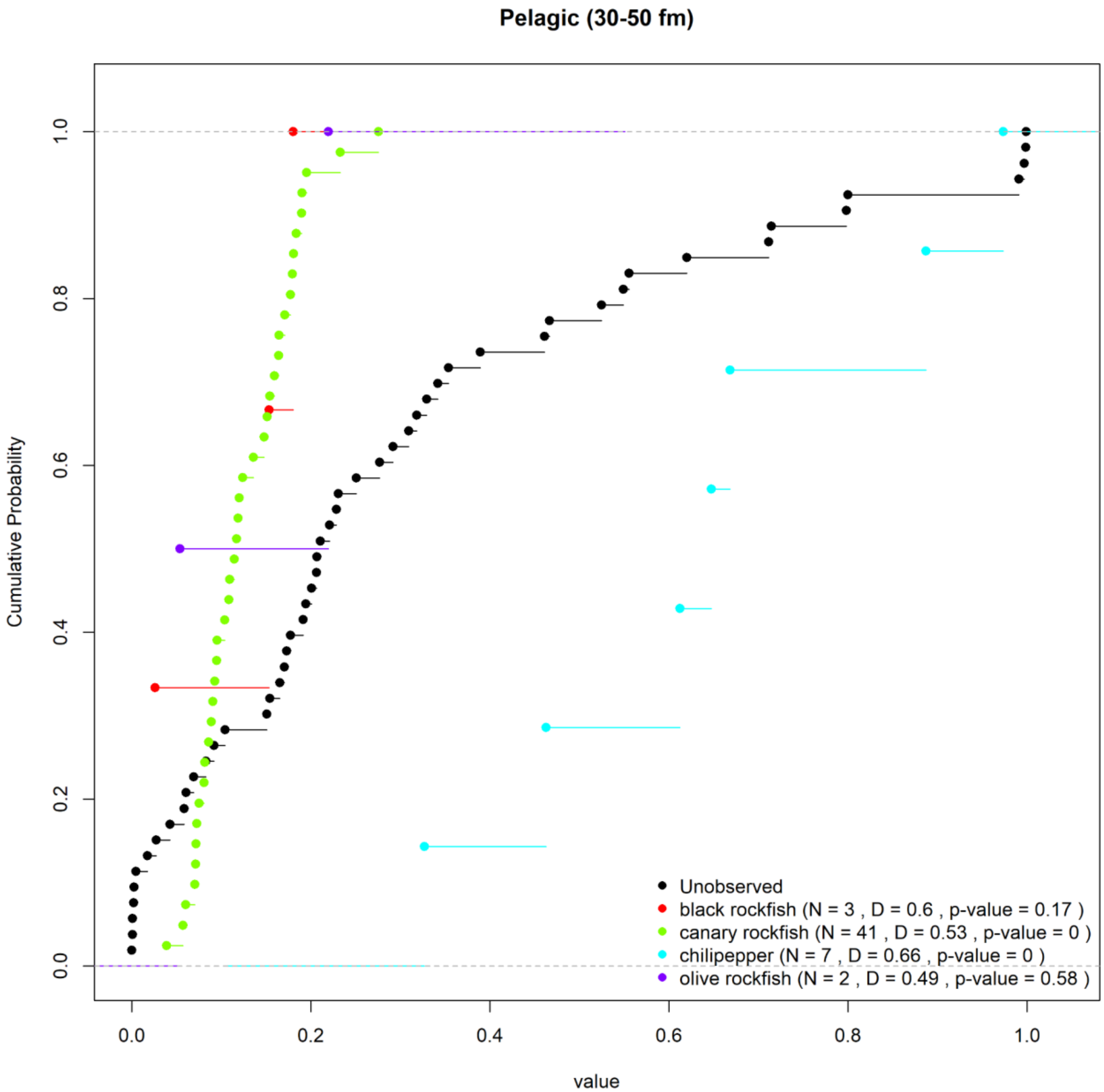

Figure 3. The cumulative distributions for each pelagic species compared with the unobserved species cumulative distribution for the 30-50 fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

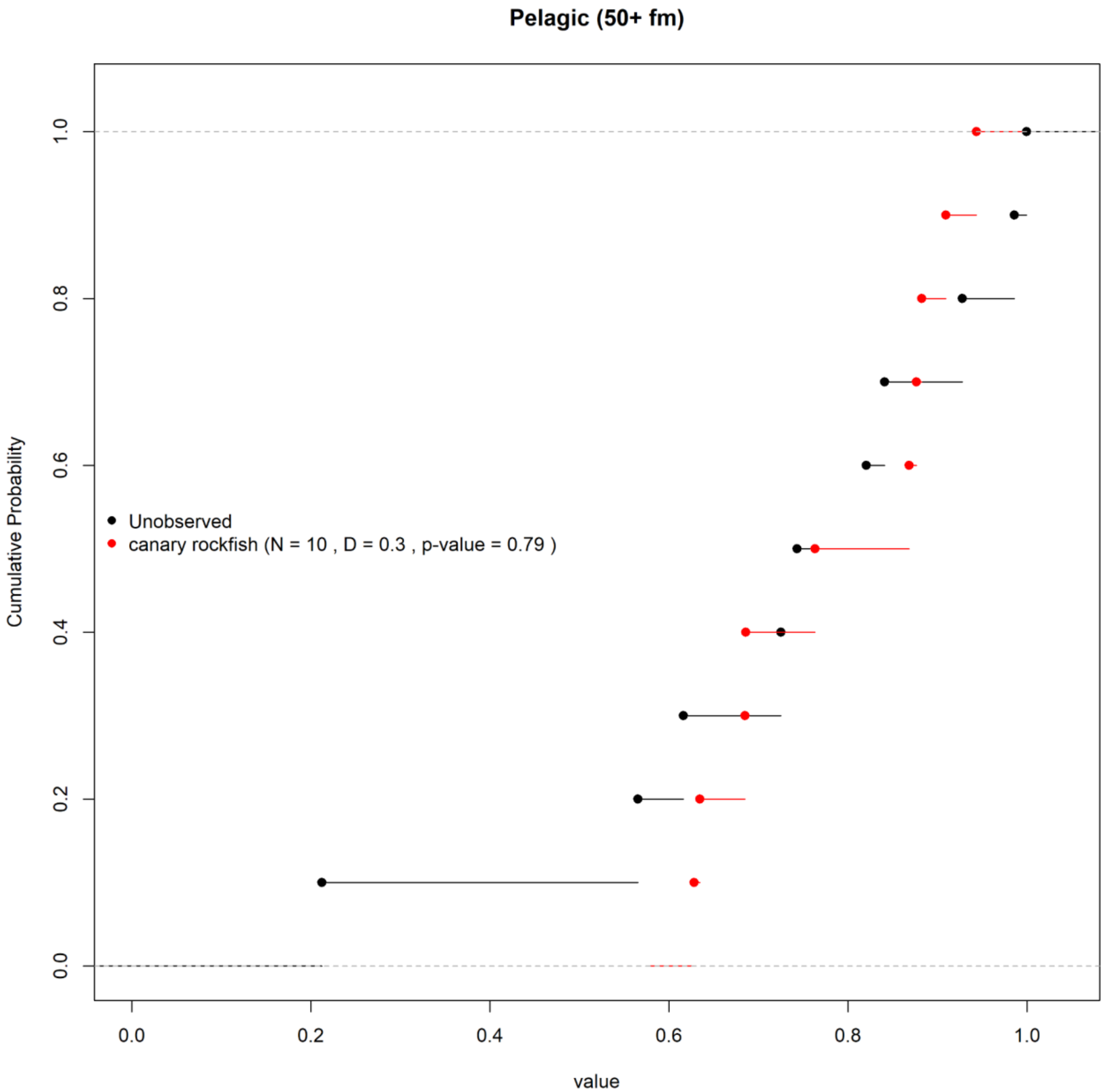

Figure 4. The cumulative distributions for each pelagic species compared with the unobserved species cumulative distribution for the 50+ fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

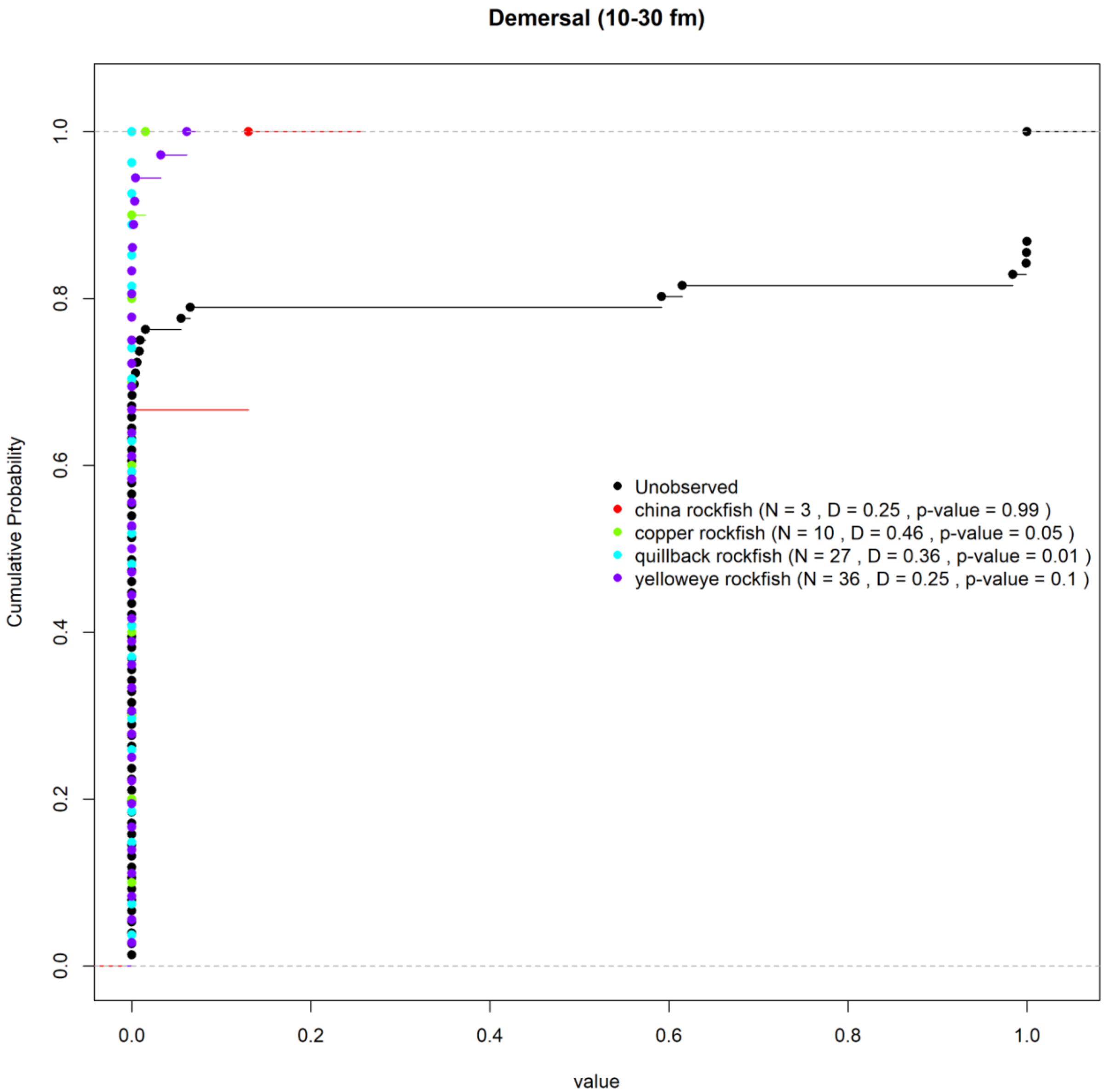

Figure 5. The cumulative distributions for each demersal species compared with the unobserved species cumulative distribution for the 10-30 fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

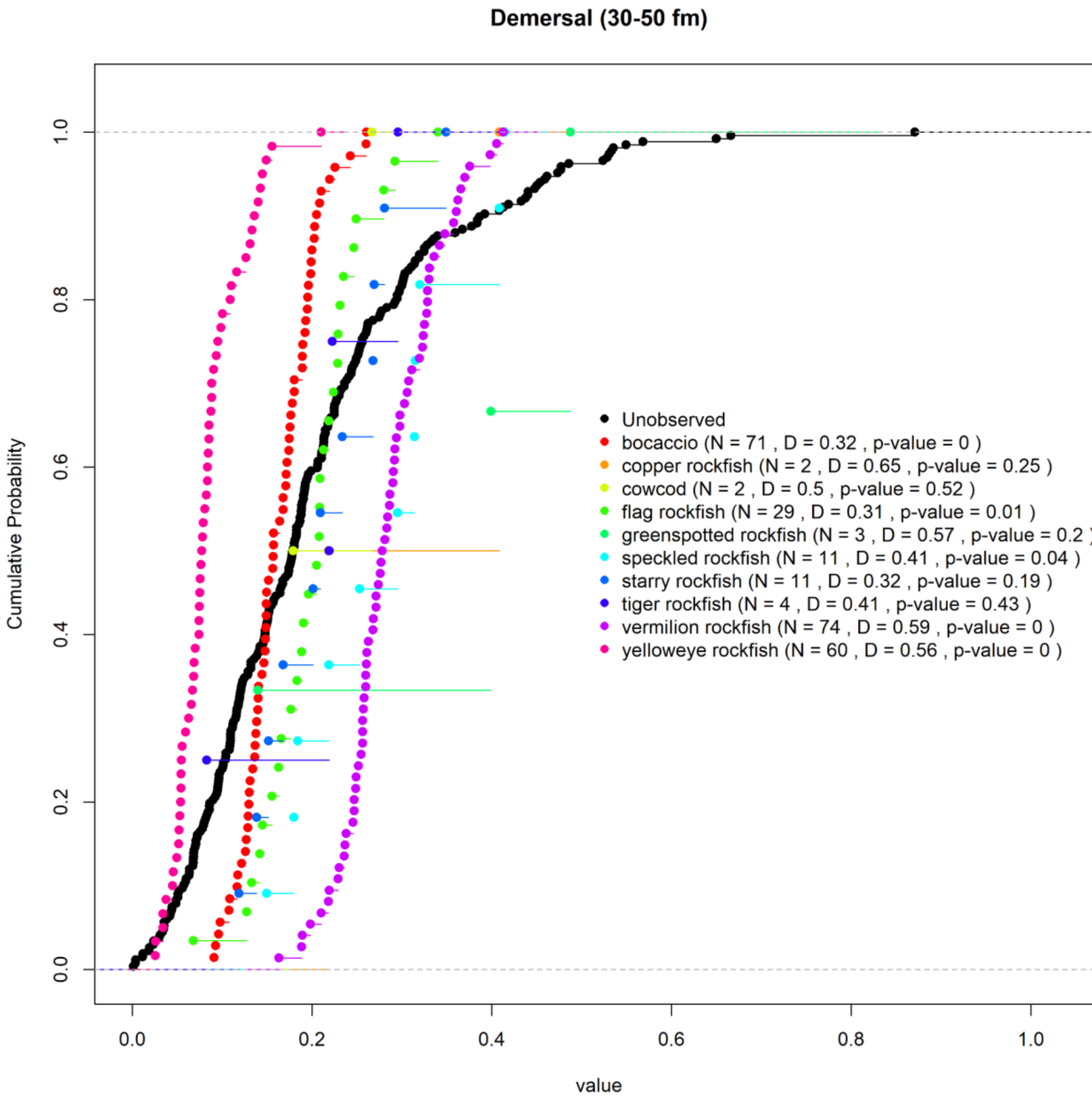

Figure 6. The cumulative distributions for each demersal species compared with the unobserved species cumulative distribution for the 30-50 fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

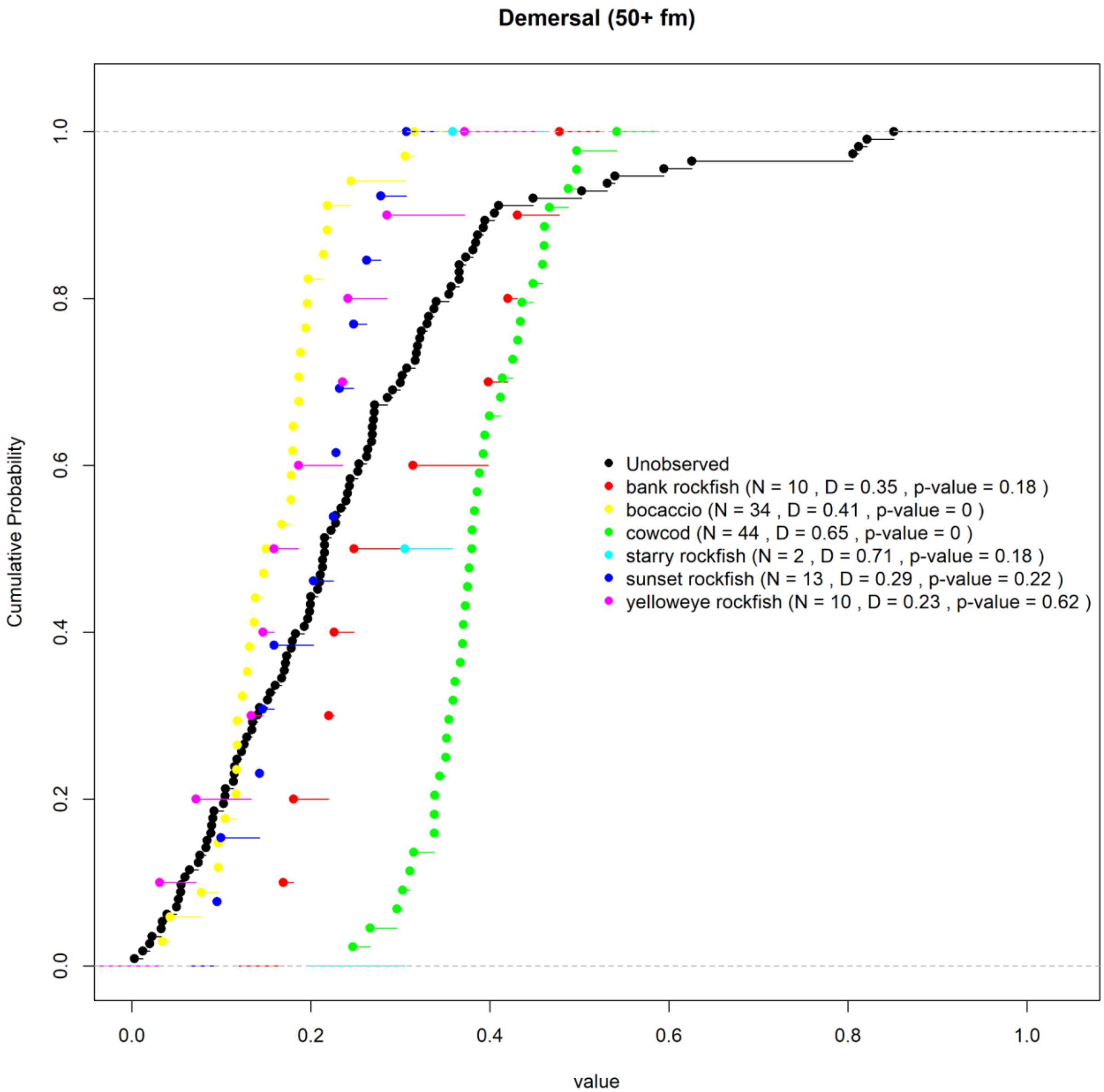

Figure 7. The cumulative distributions for each demersal species compared with the unobserved species cumulative distribution for the 50+ fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

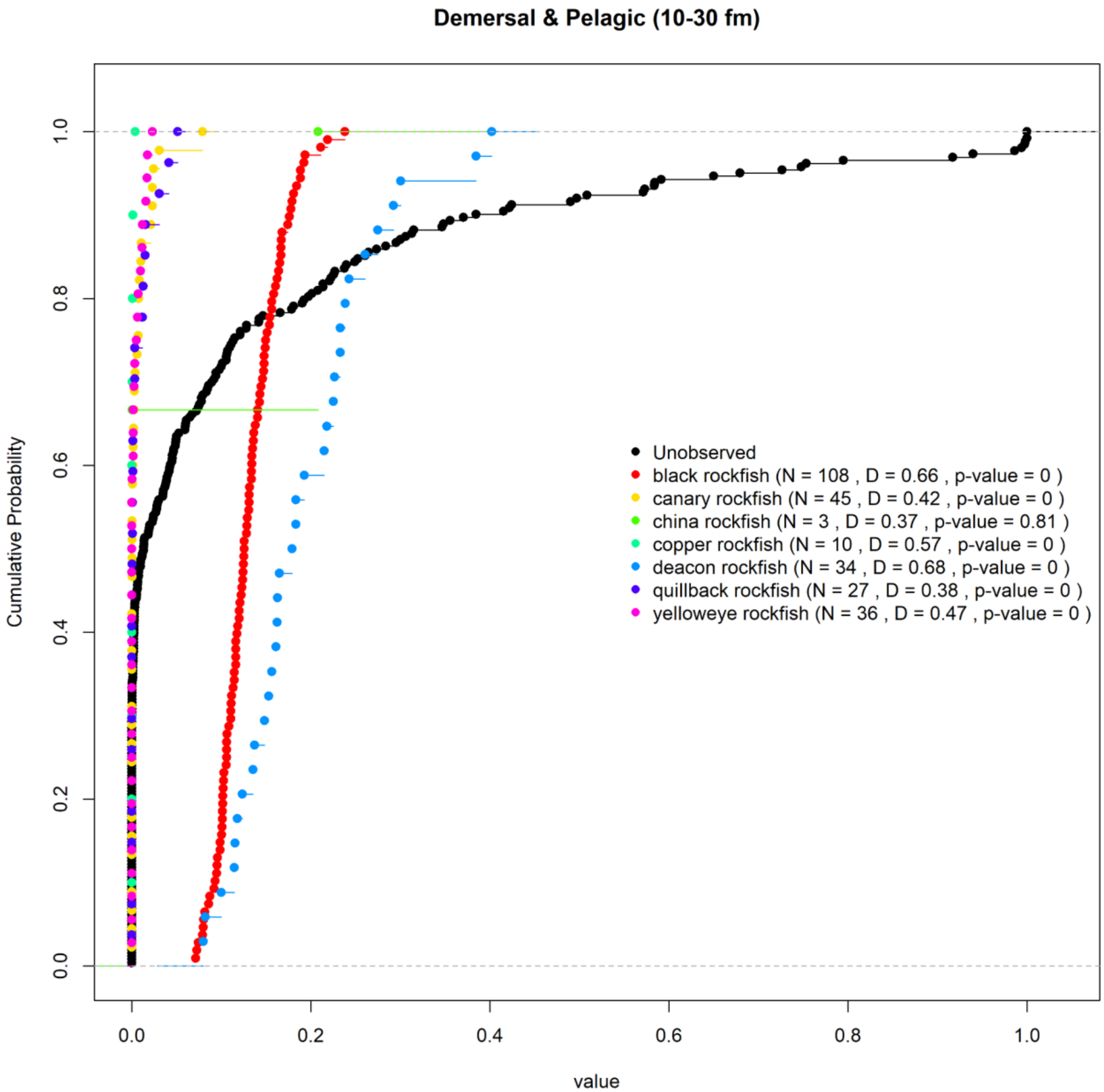

Figure 8. The cumulative distributions for demersal and pelagic species compared with the unobserved species cumulative distribution for the 10-30 fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

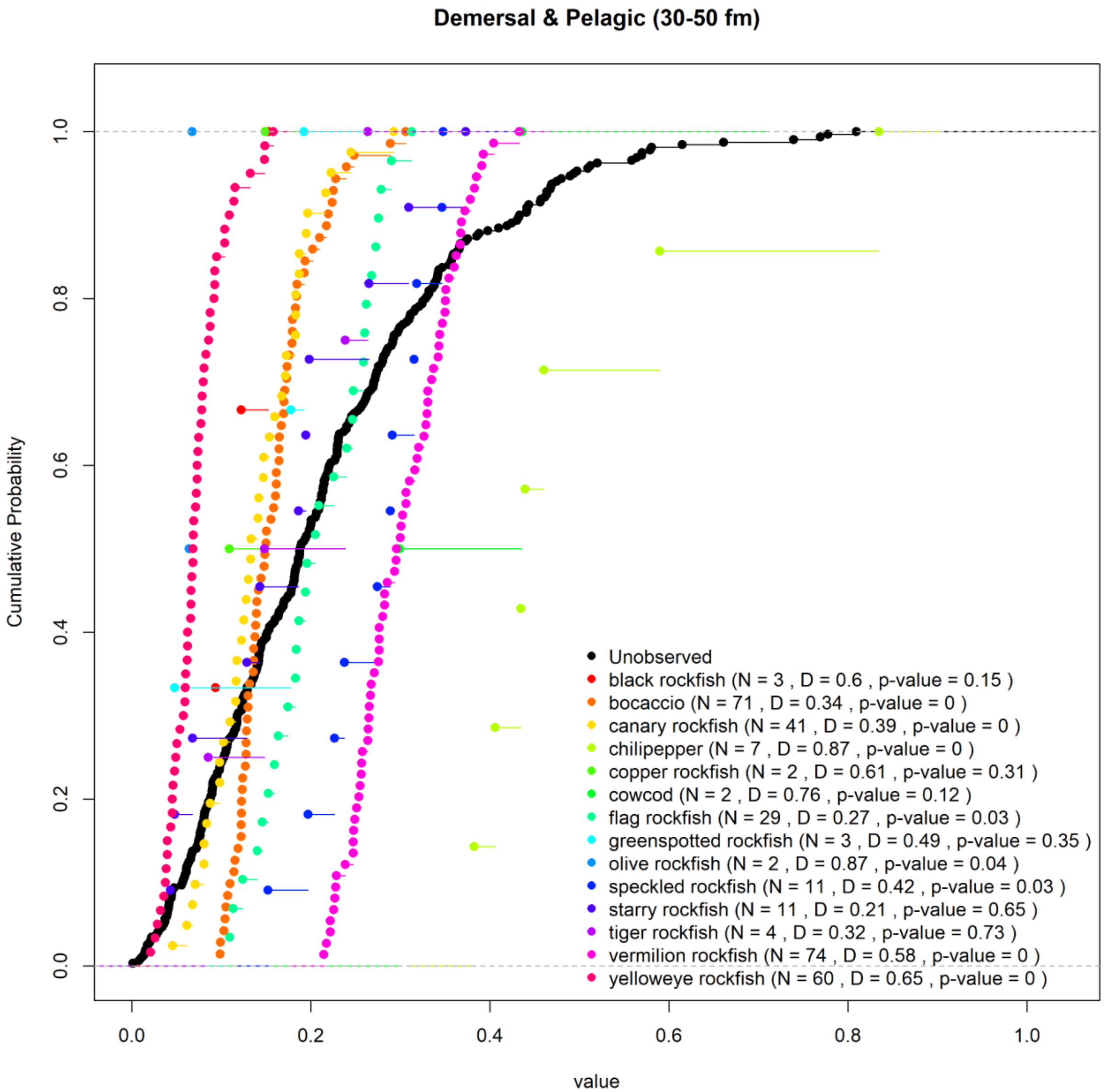

Figure 9. The cumulative distributions for each demersal and pelagic species compared with the unobserved species cumulative distribution for the 30-50 fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

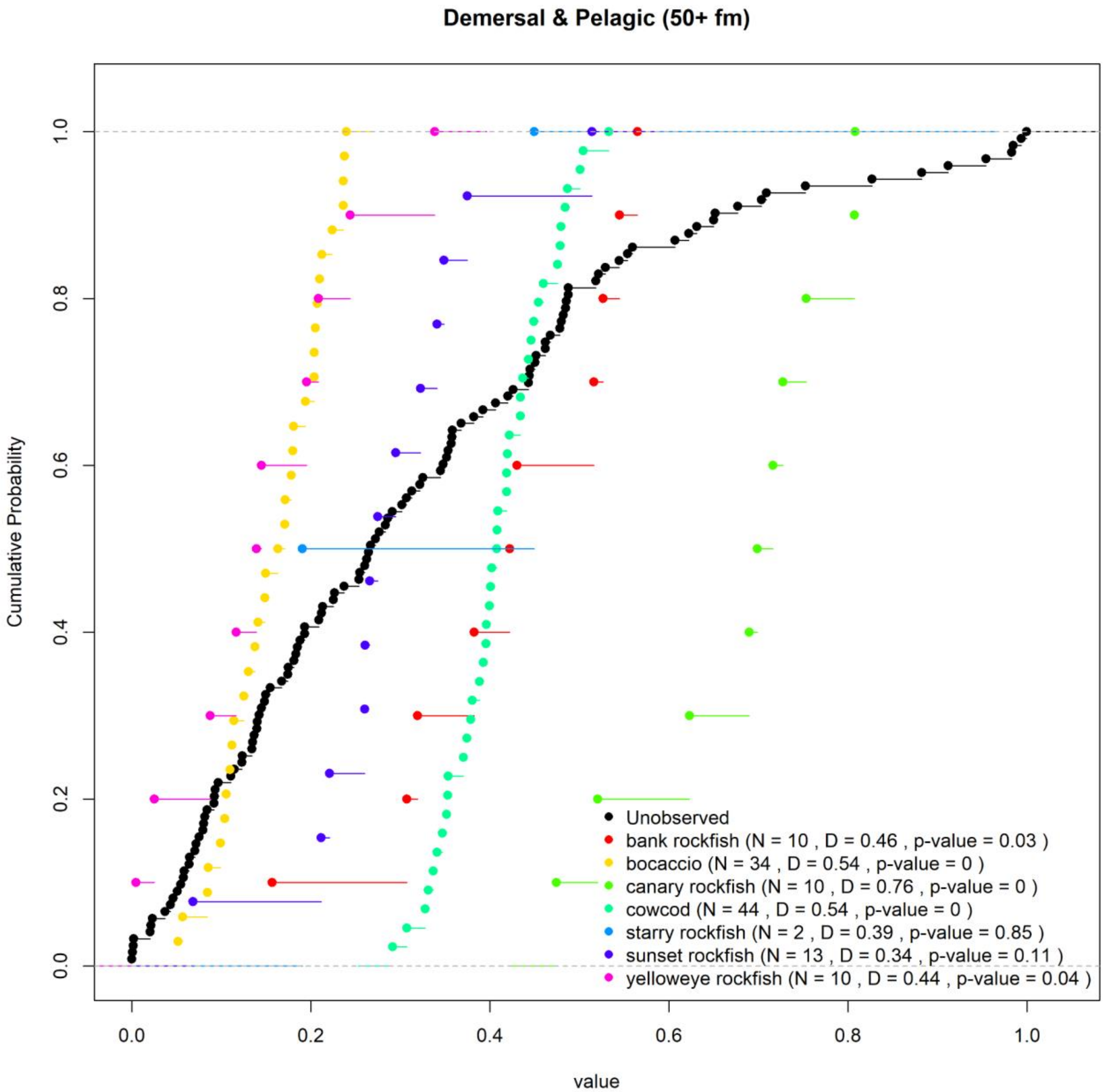

Figure 10. The cumulative distributions for each demersal and pelagic species compared with the unobserved species cumulative distribution for the 50+ fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

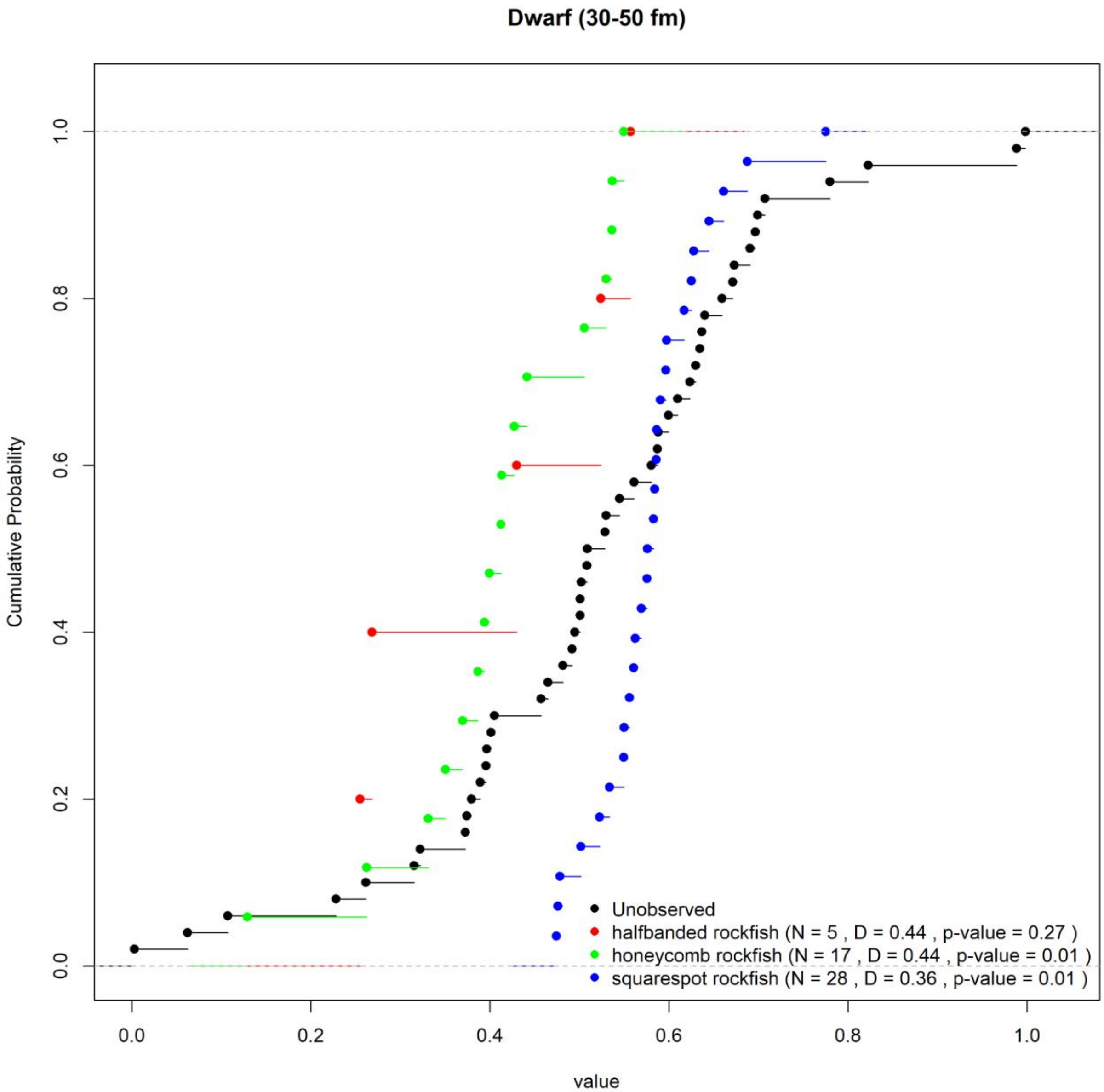

Figure 11. The cumulative distributions for dwarf species compared with the unobserved species cumulative distribution for the 30-50 fathom depth bin. The Kolmogorov-Smirnov statistical distance (D) and p-values were reported for each distribution.

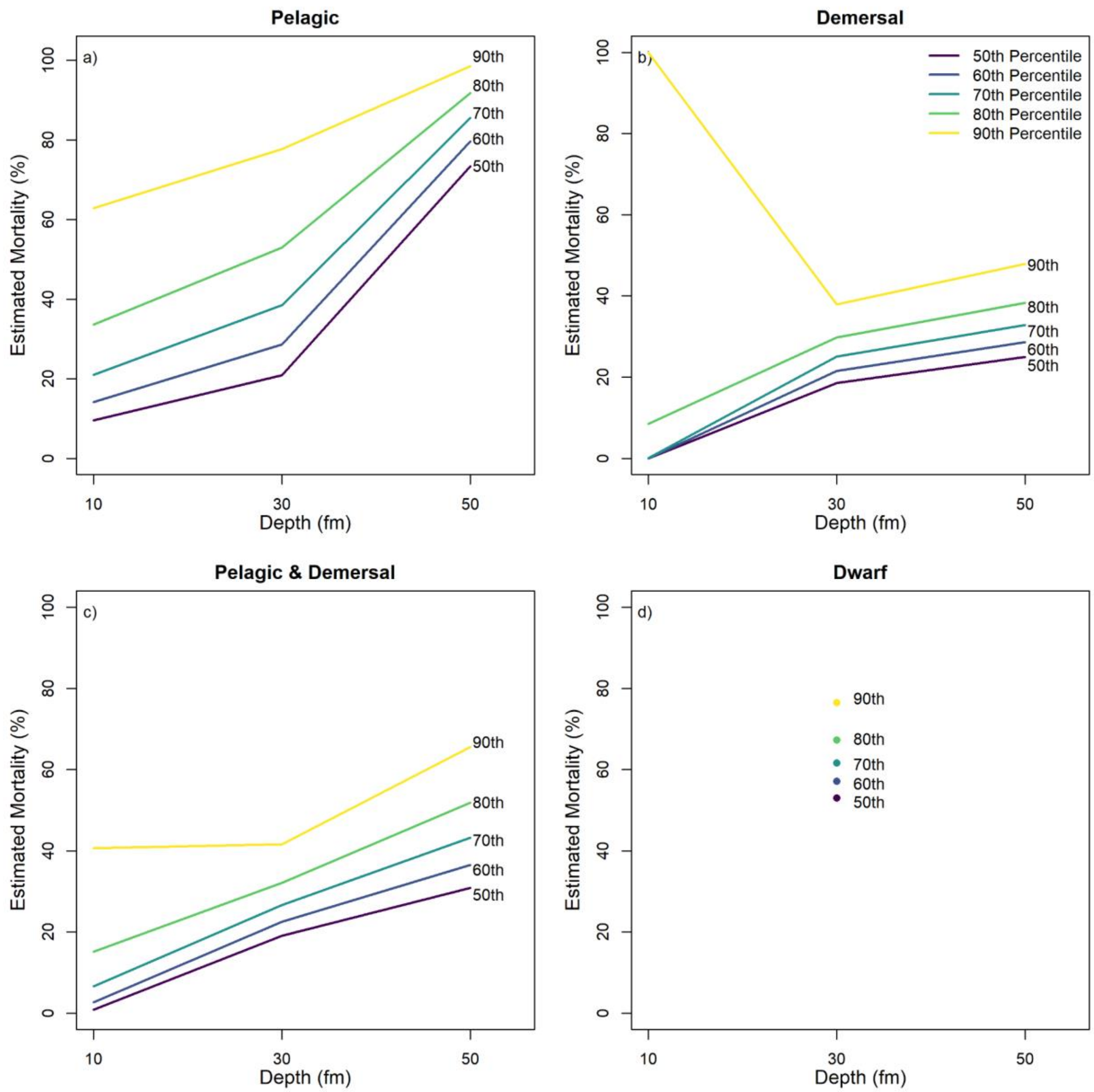

Figure 12. The estimated percent mortality by percentile ranging between 50th and 90th percentile across depth bins (fm) and by grouping.

Appendix

Figures: Pelagic Guild

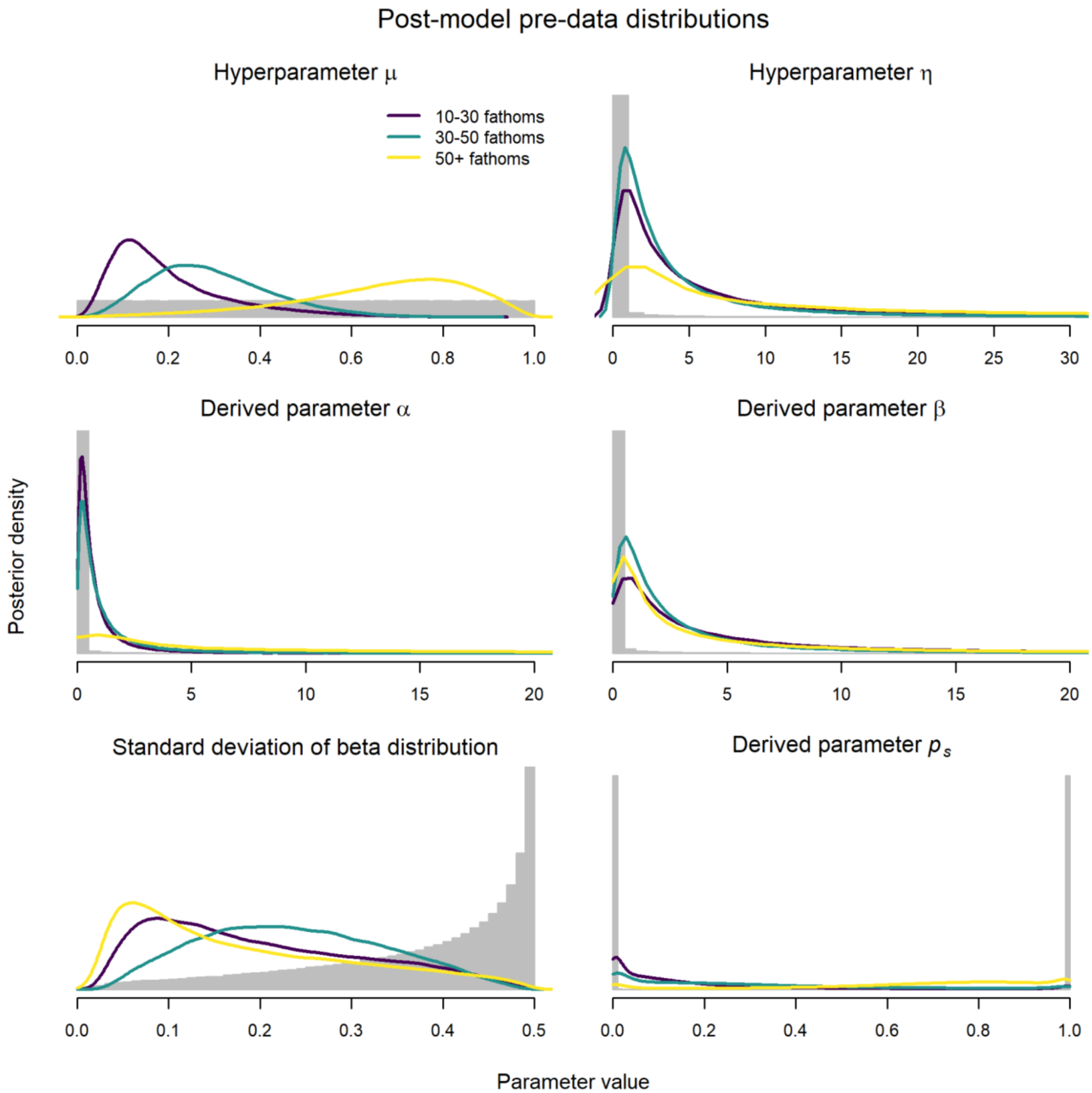

Figure A.1. Post-model pre-data distributions for quantities associated with the hierarchical model (grey) shown in comparison to the associated posterior distributions from three analyses with the data: 10-30 fathoms (purple), 30-50 fathoms (blue), and 50-100 fathoms (yellow) for the pelagic guild.

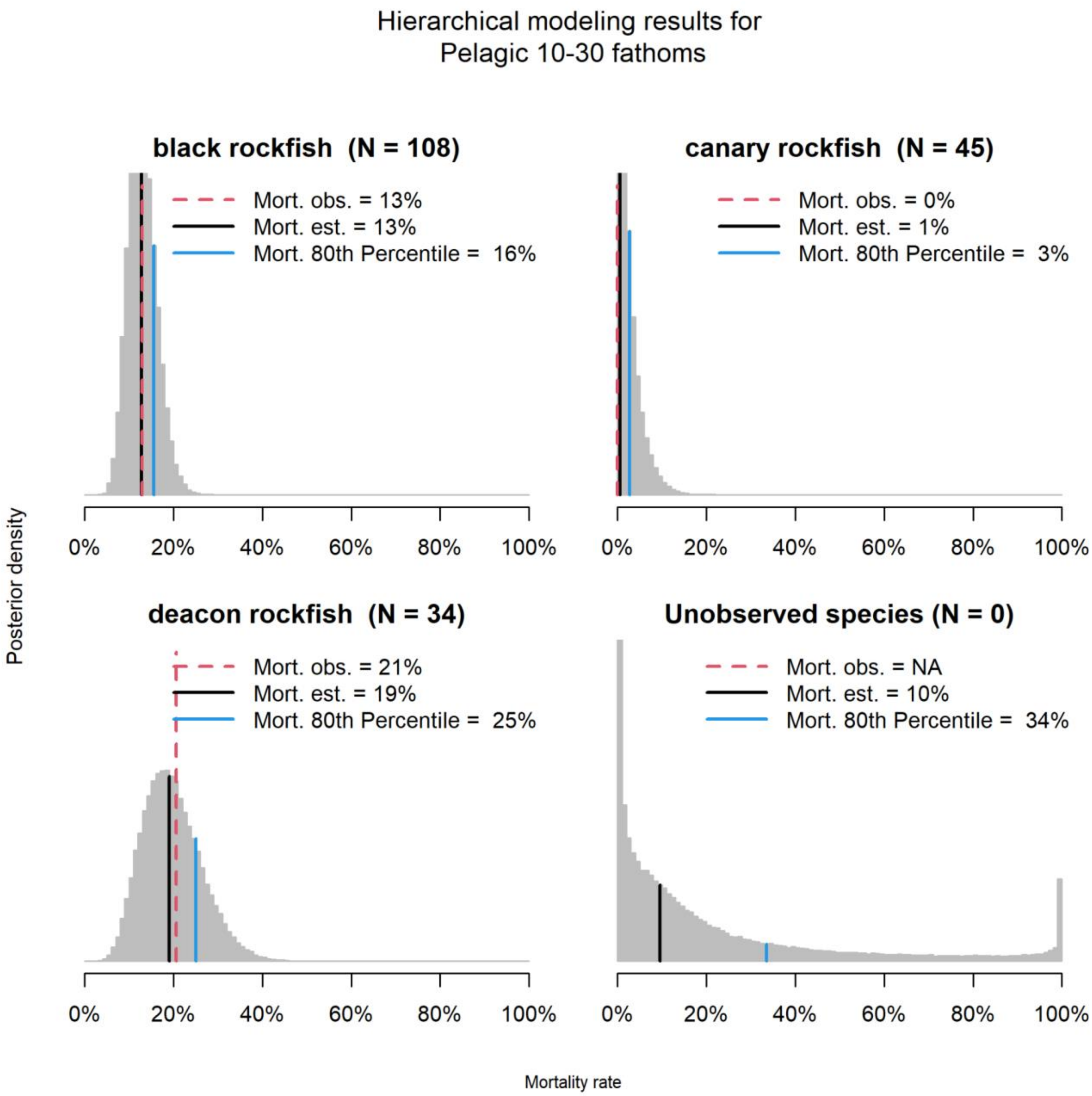

Figure A.2. Posterior predicted distributions of mortality estimates between 10-30 fathoms depth bin for the pelagic guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.

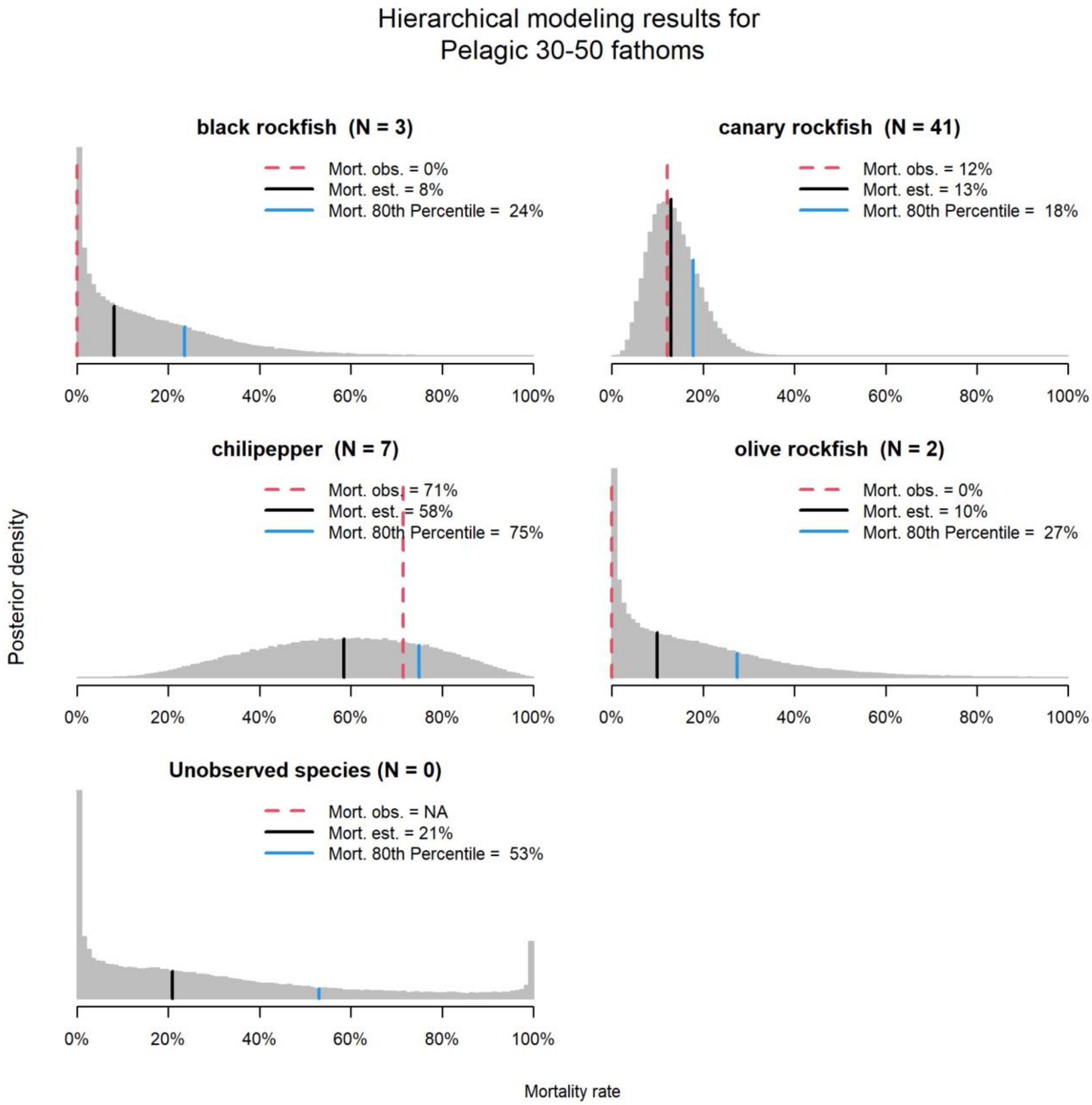

Figure A.3. Posterior predicted distributions of mortality estimates between 30-50 fathoms depth bin for the pelagic guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.

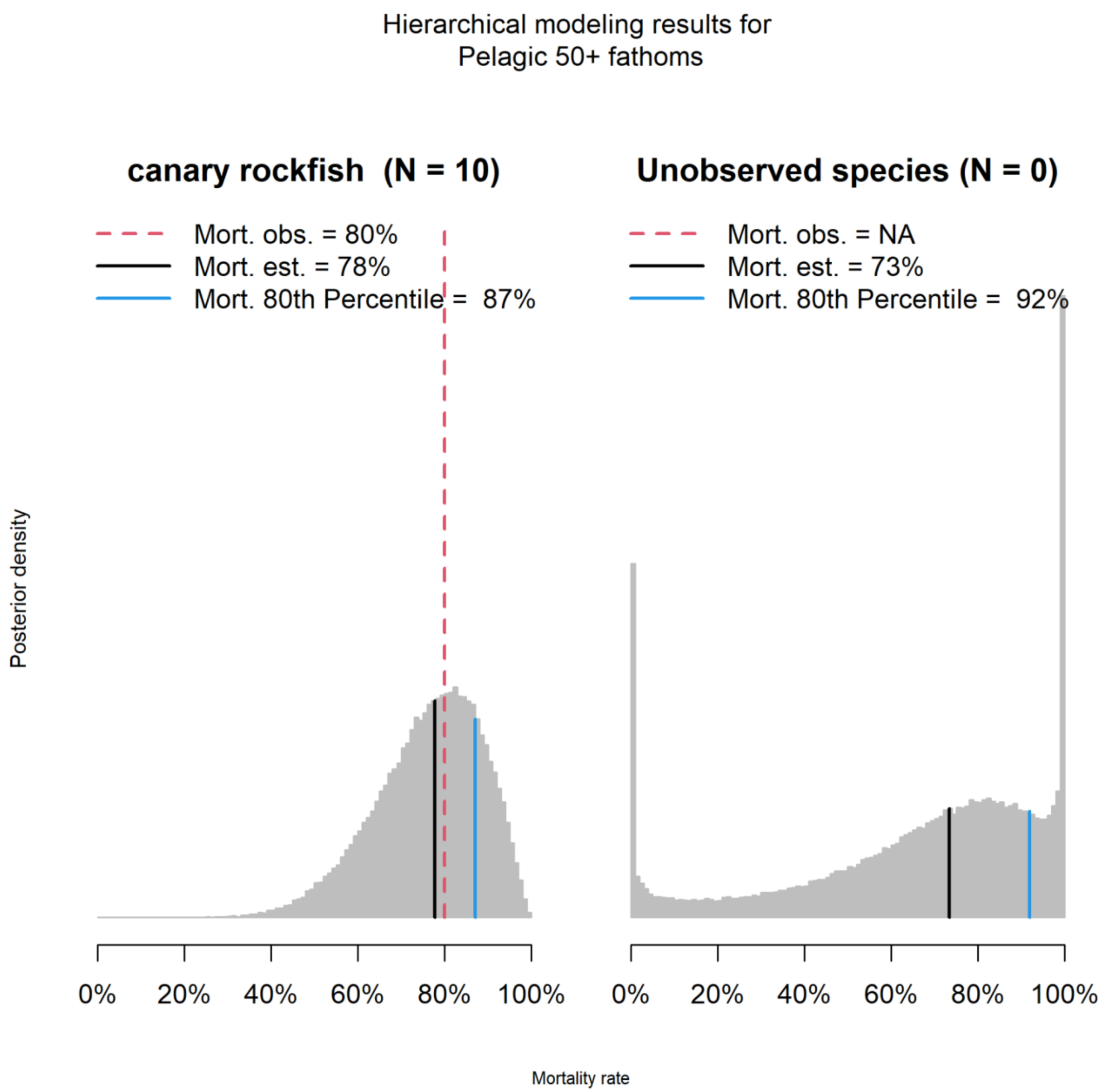

Figure A.4. Posterior predicted distributions of mortality estimates for 50-100 fathoms depth bin for the pelagic guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.

Figures: Demersal Guild

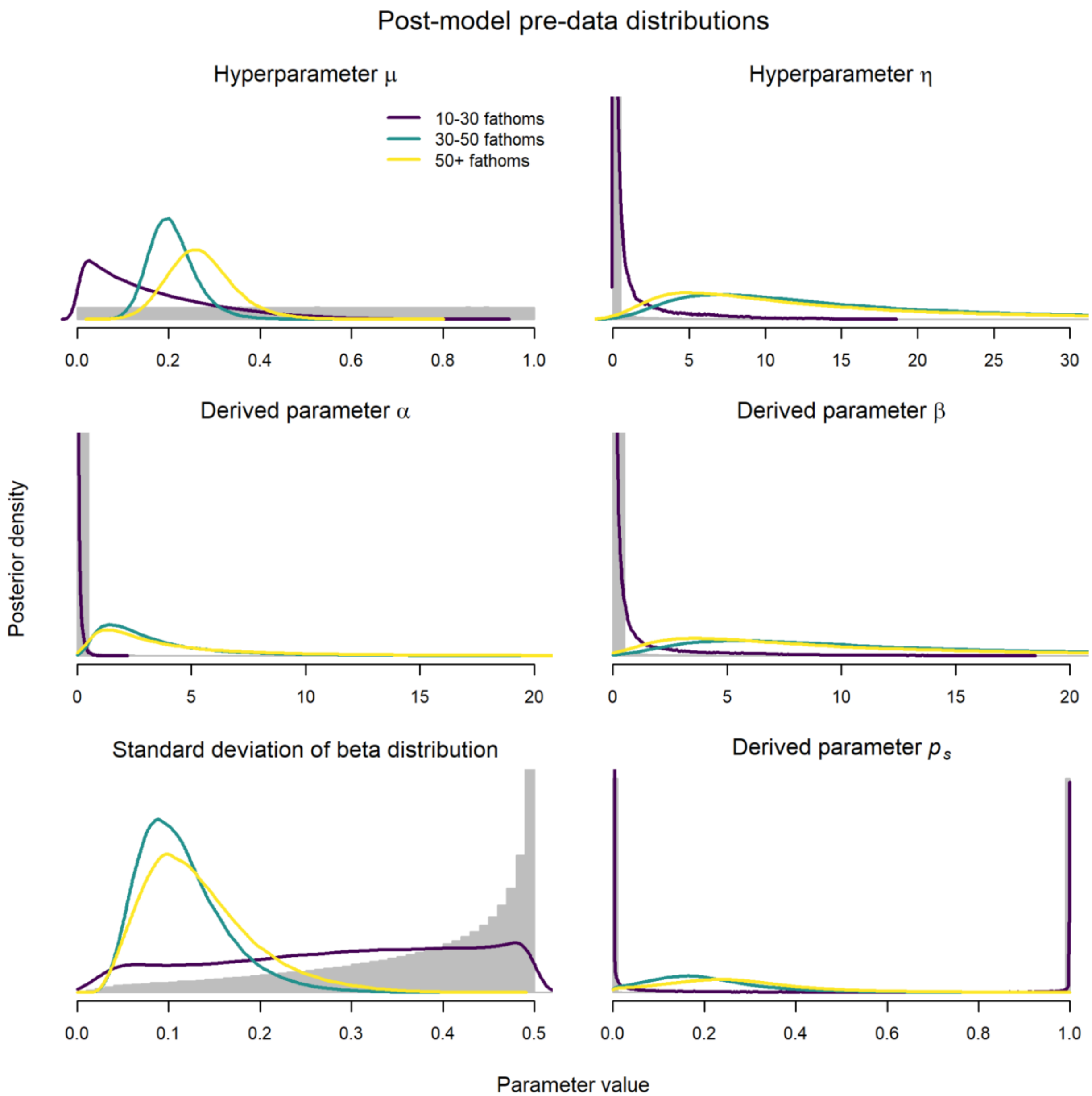

Figure A.5. Post-model pre-data distributions for quantities associated with the hierarchical model (grey) shown in comparison to the associated posterior distributions from three analyses with the data: 10-30 fathoms (purple), 30-50 fathoms (blue), and 50-100 fathoms (yellow) for the demersal guild.

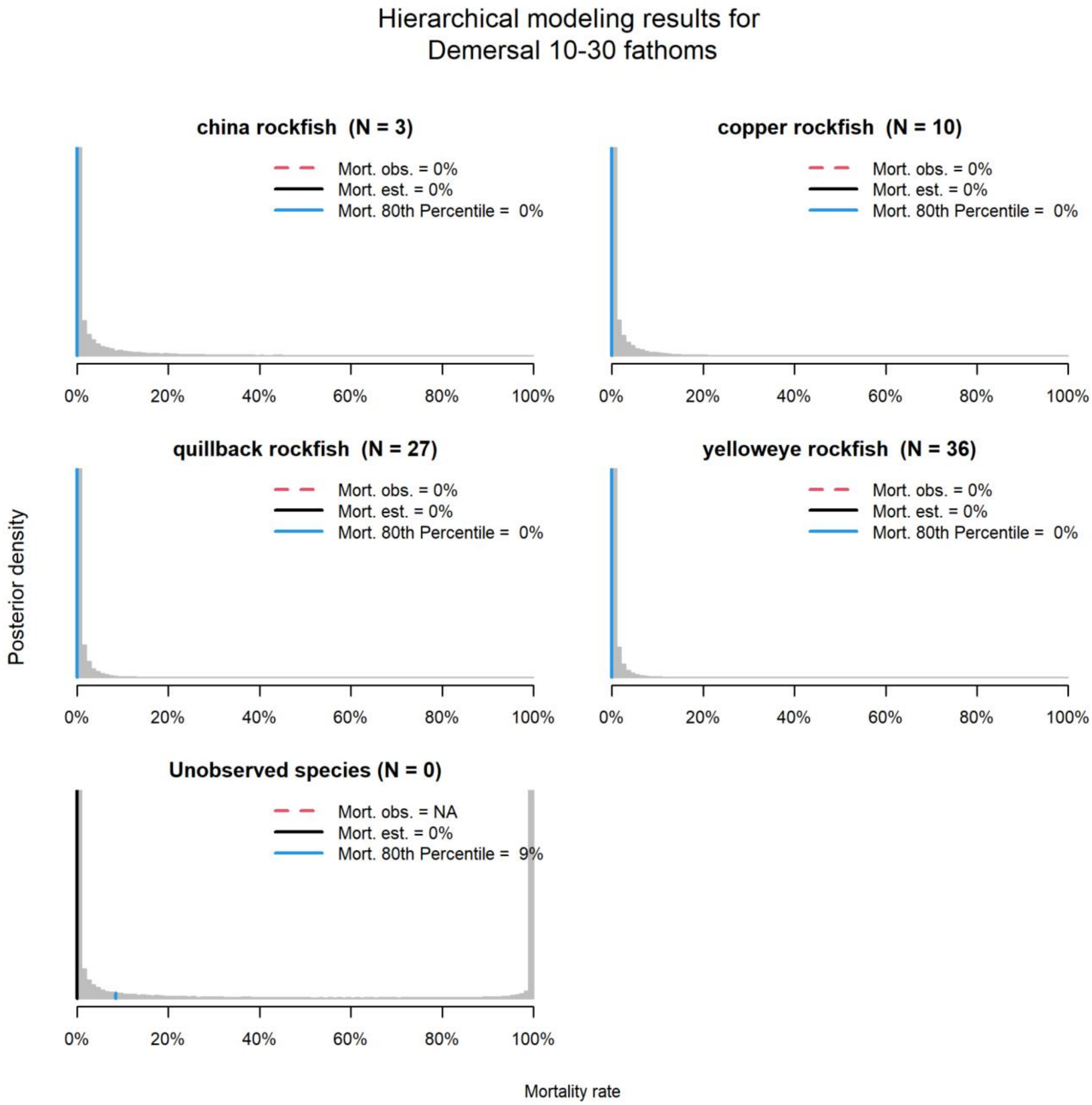

Figure A.6. Posterior predicted distributions of mortality estimates between 10-30 fathoms depth bin for the demersal guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.

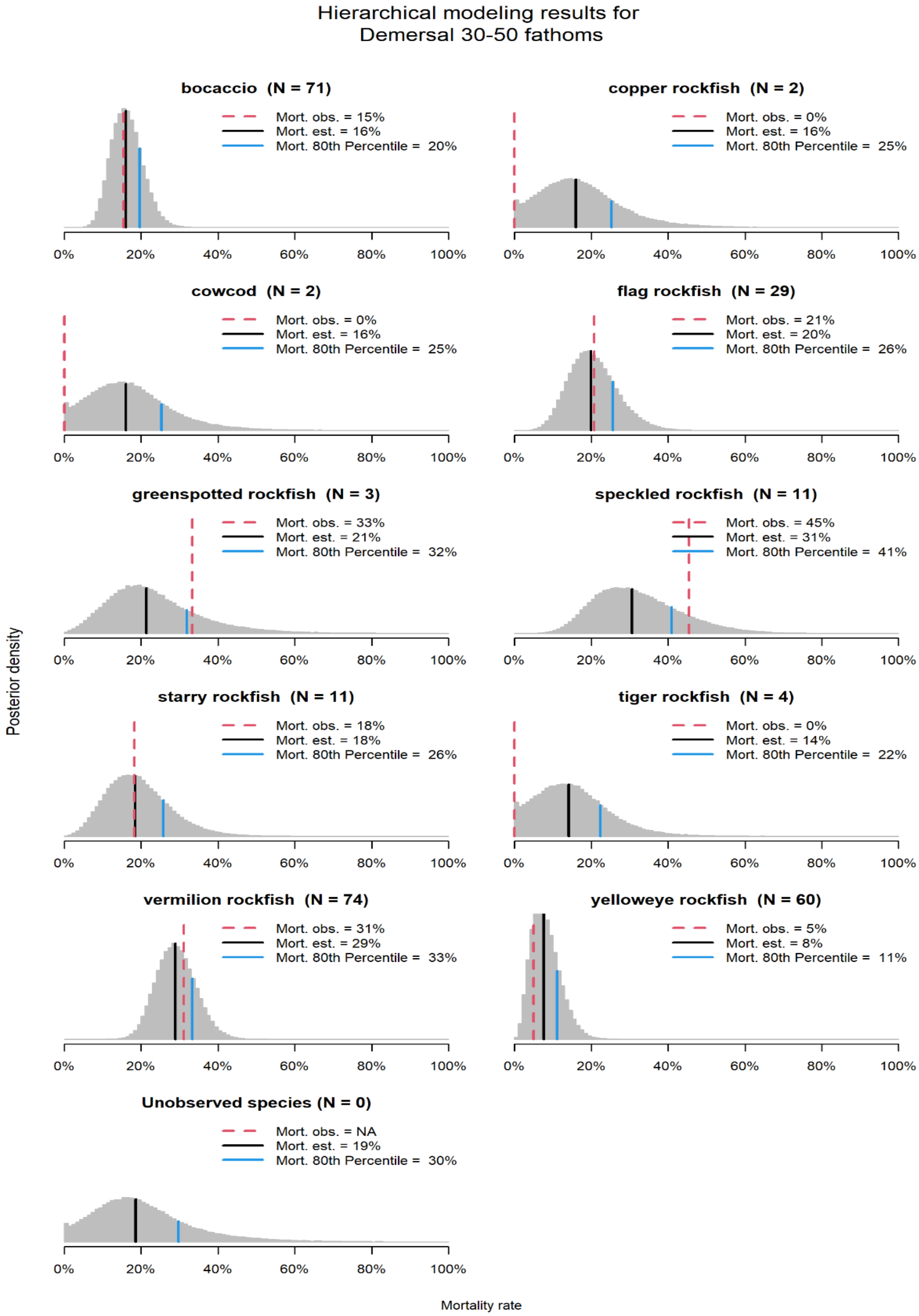

Figure A.7. Posterior predicted distributions of mortality estimates between 30-50 fathoms depth bin for the demersal guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.

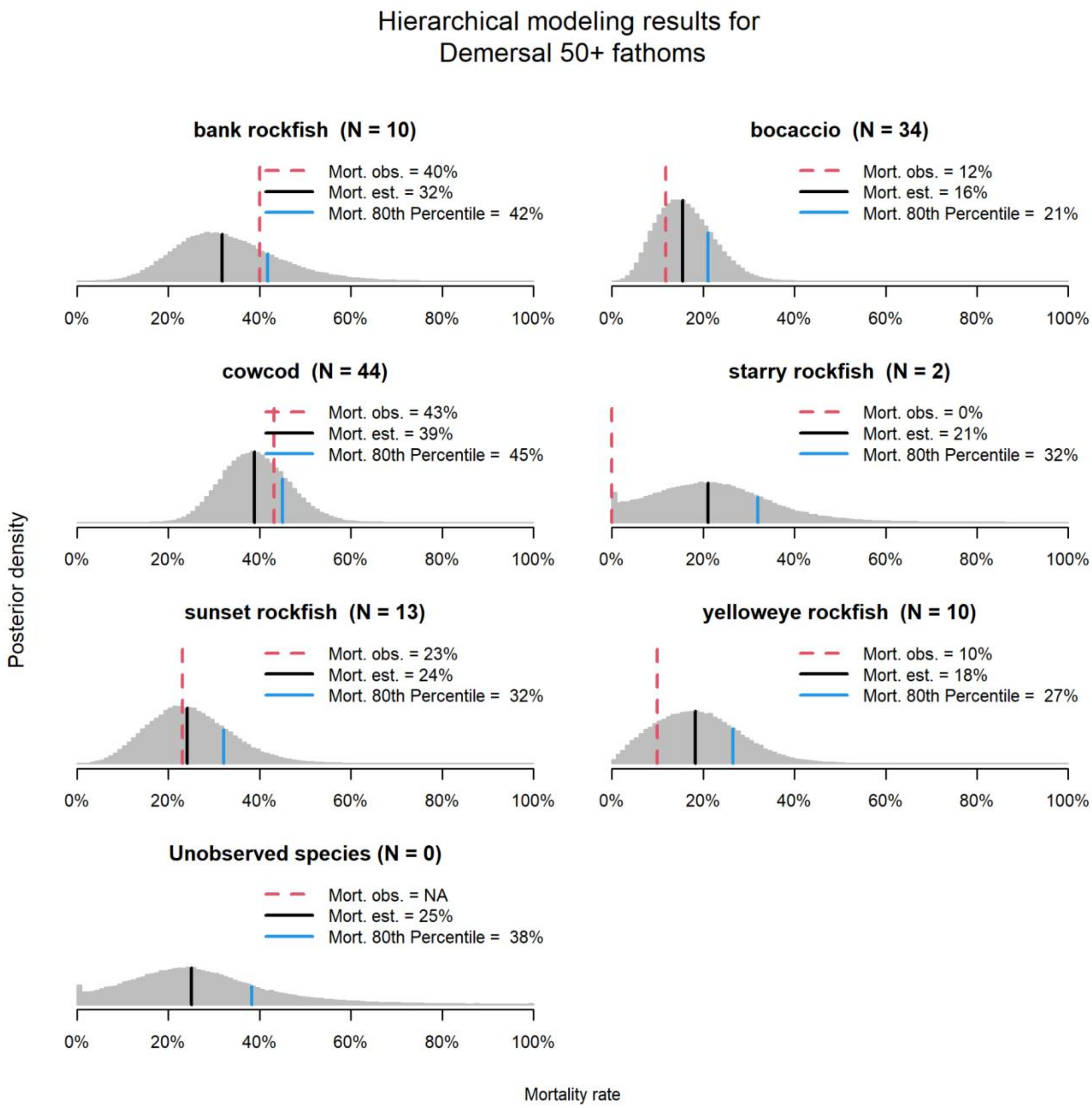

Figure A.8. Posterior predicted distributions of mortality estimates for 50-100 fathoms depth bin for the demersal guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.

Figures: Demersal and Pelagic Guild Combined

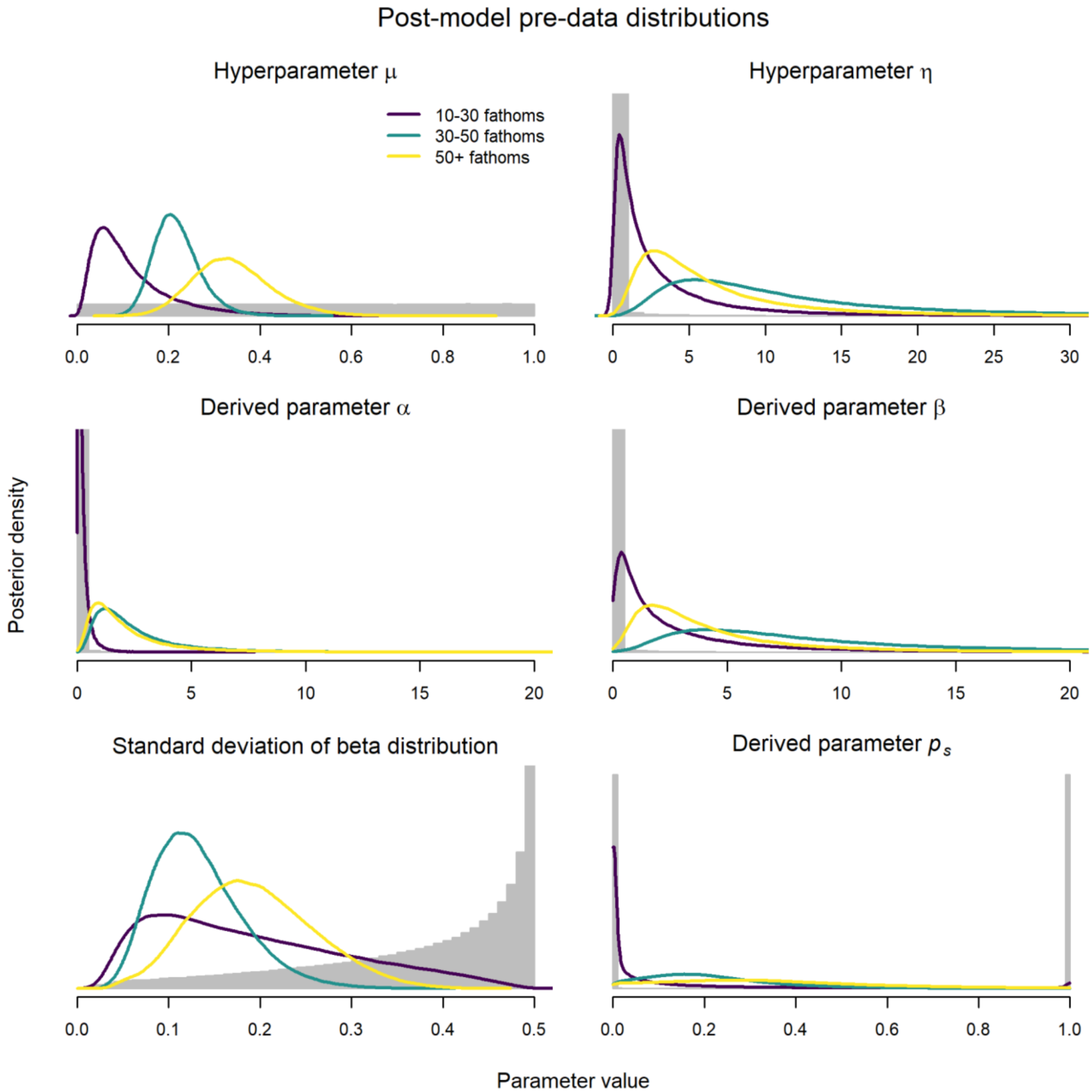

Figure A.9. Post-model pre-data distributions for quantities associated with the hierarchical model (grey) shown in comparison to the associated posterior distributions from three analyses with the data: 10-30 fathoms (purple), 30-50 fathoms (blue), and 50-100 fathoms (yellow) for the demersal guild.

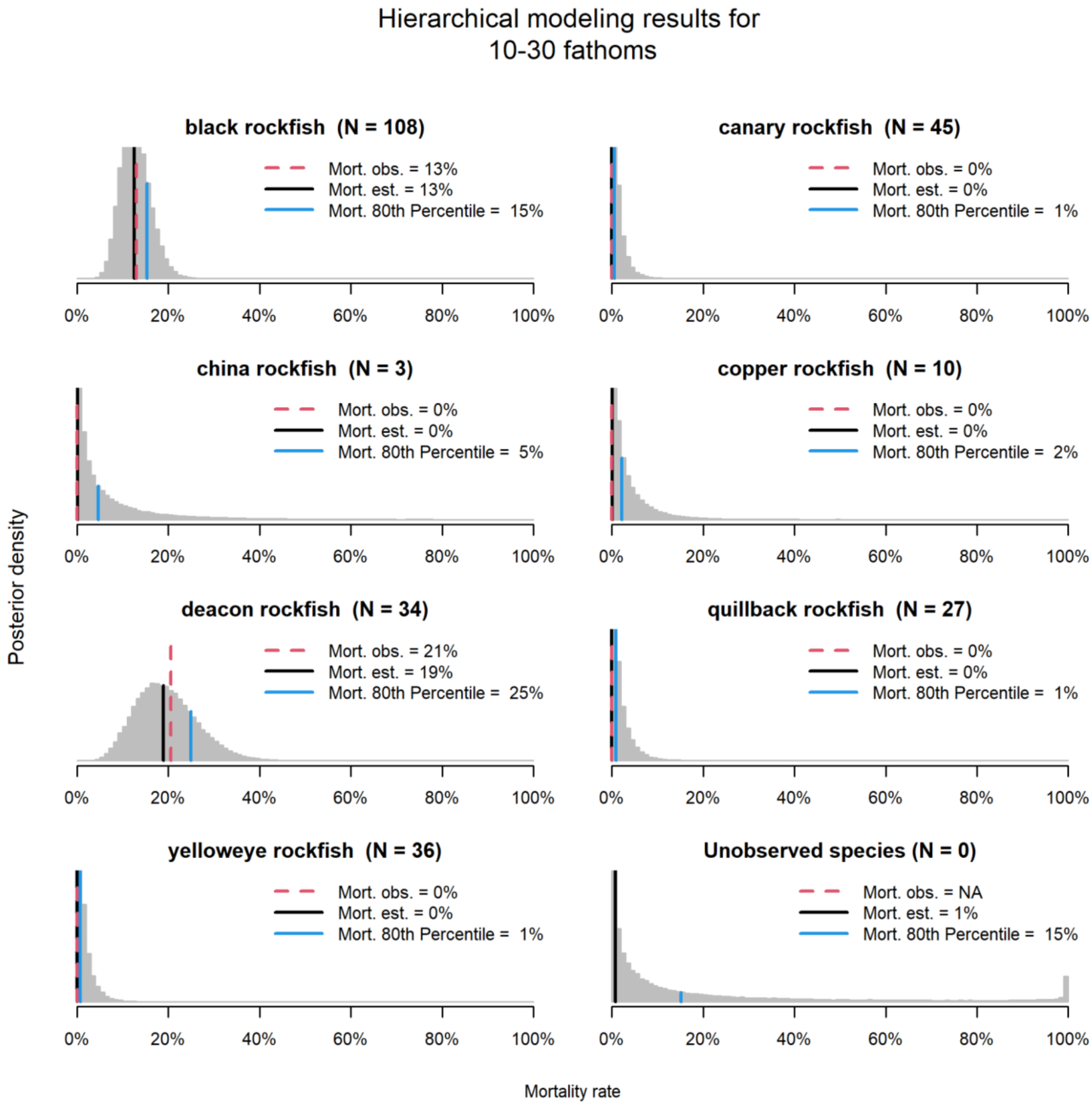

Figure A.10. Posterior predicted distributions of mortality estimates between 10-30 fathoms depth bin for the demersal guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.

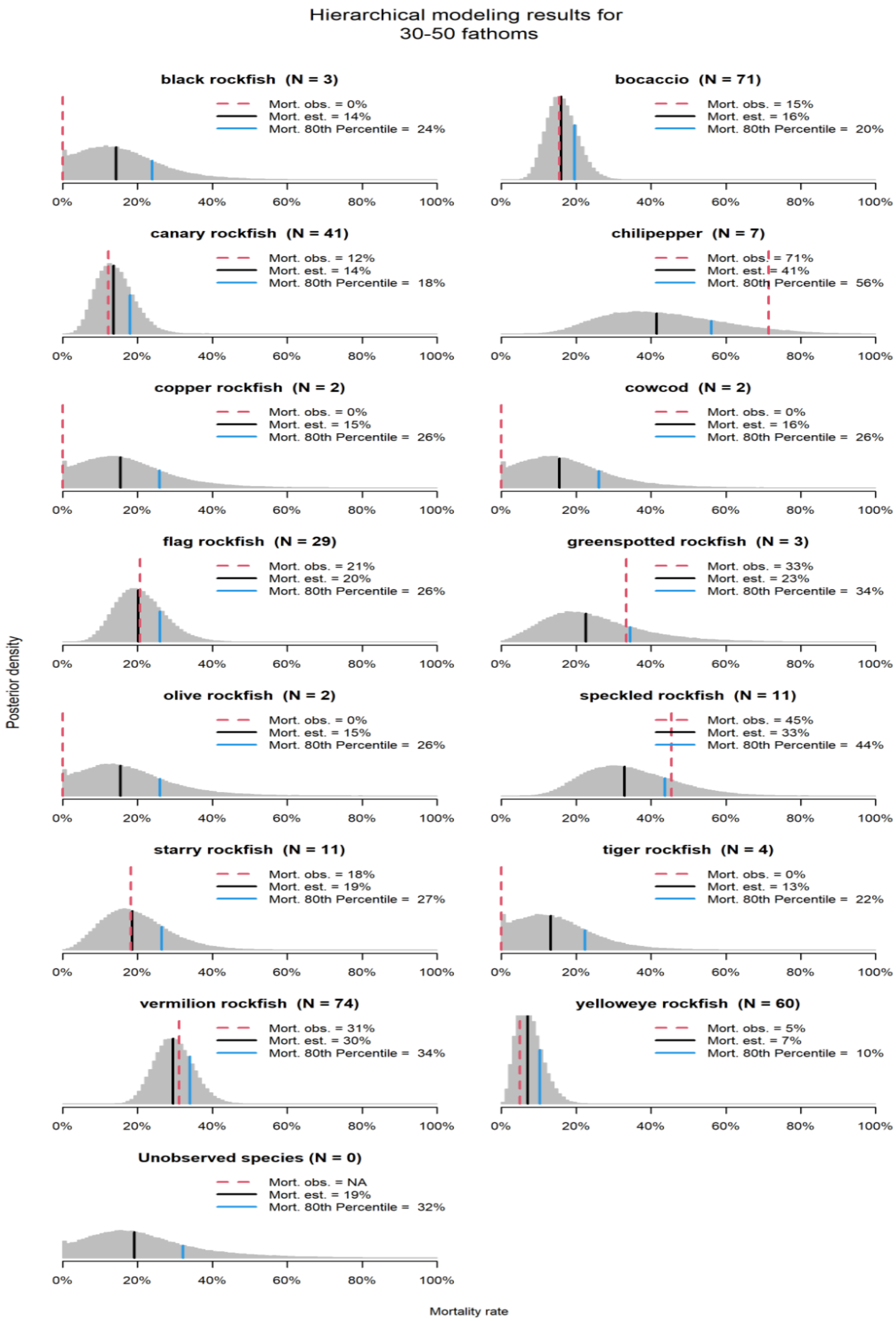

Figure A.11. Posterior predicted distributions of mortality estimates between 30-50 fathoms depth bin for the demersal guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.

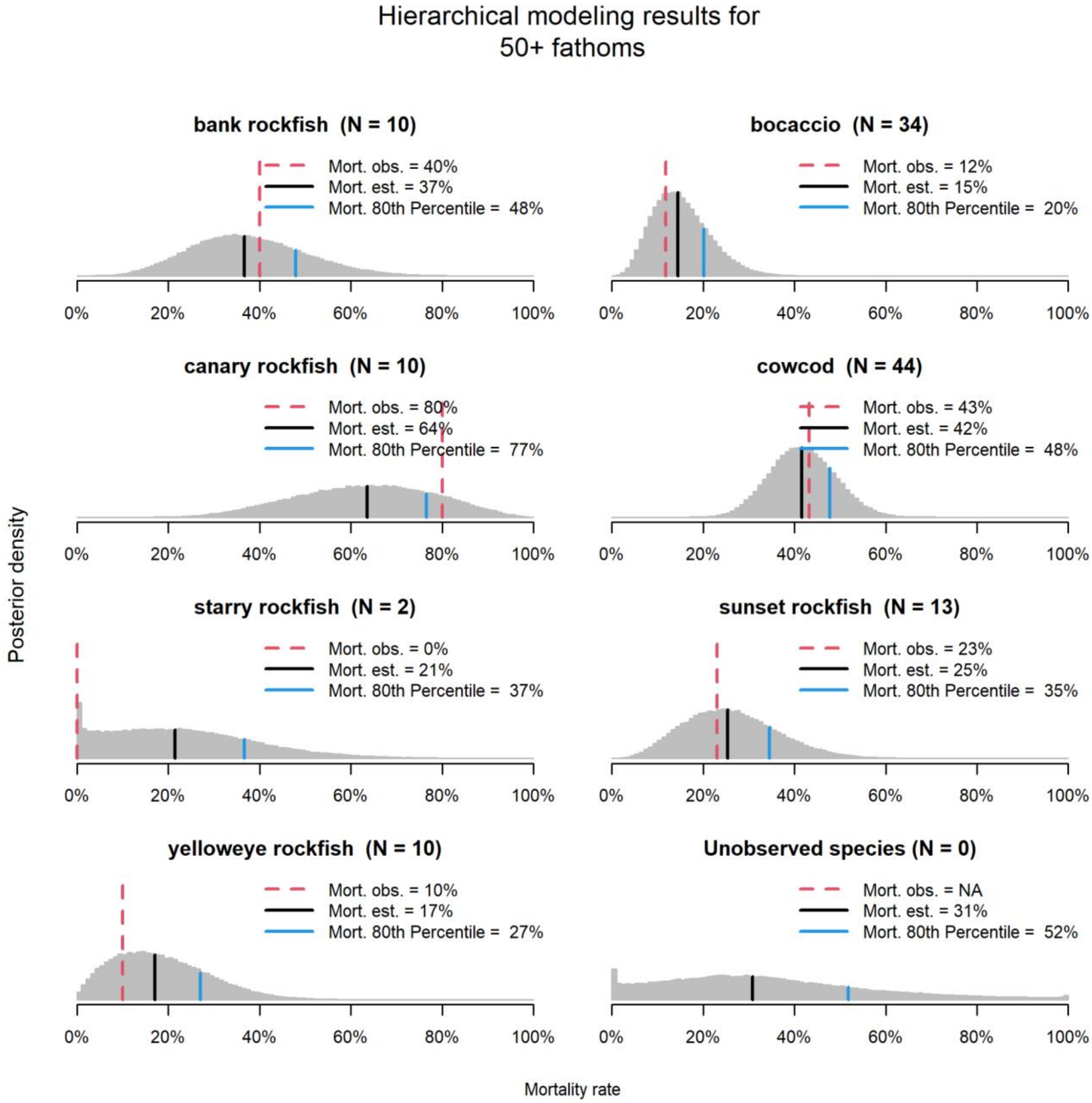

Figure A.12. Posterior predicted distributions of mortality estimates for 50-100 fathoms depth bin for the demersal guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.

Figures: Dwarf Guild

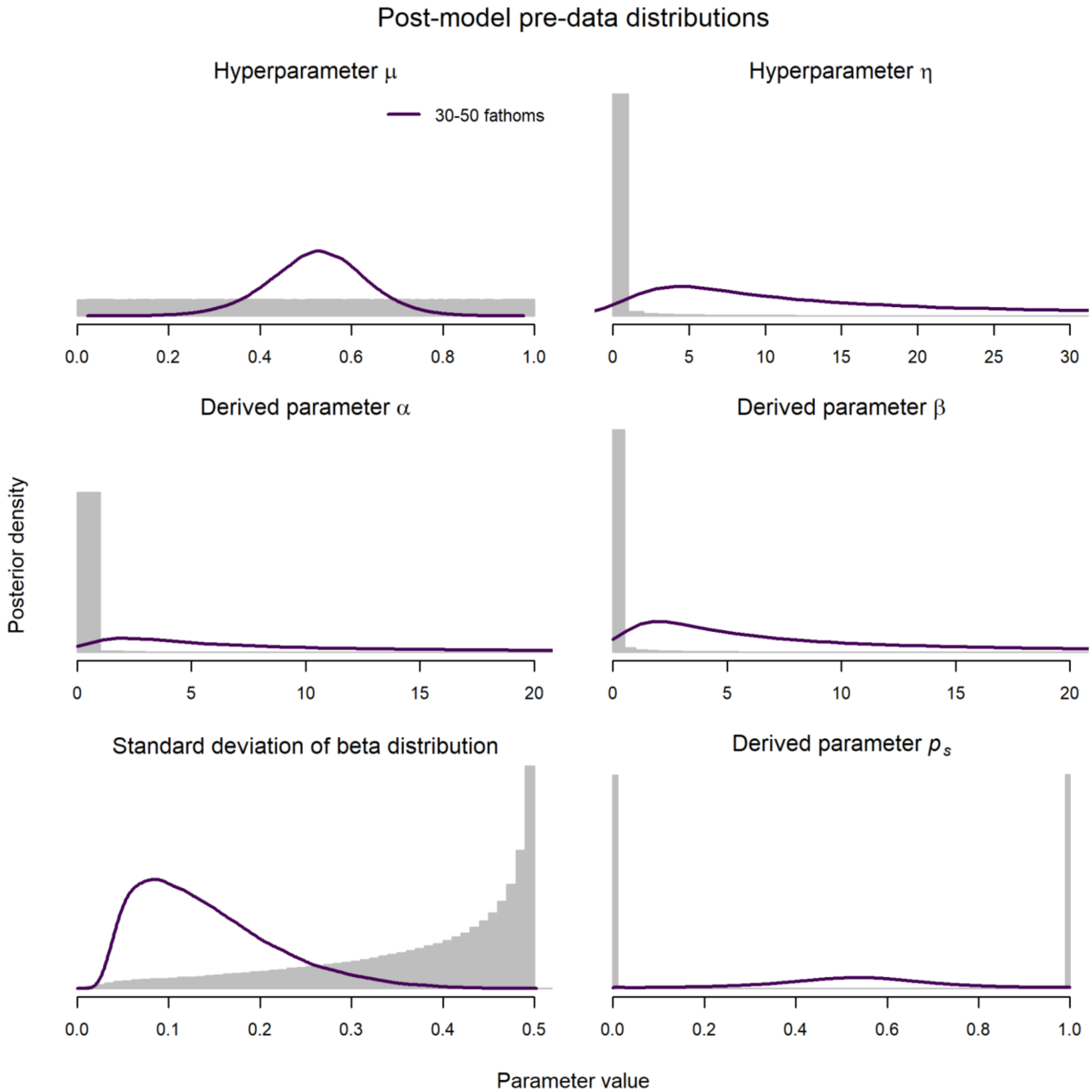

Figure A.13. Post-model pre-data distributions for quantities associated with the hierarchical model (grey) shown in comparison to the associated posterior distributions from three analyses with the data between 30-50 fathoms (blue) for the dwarf guild.

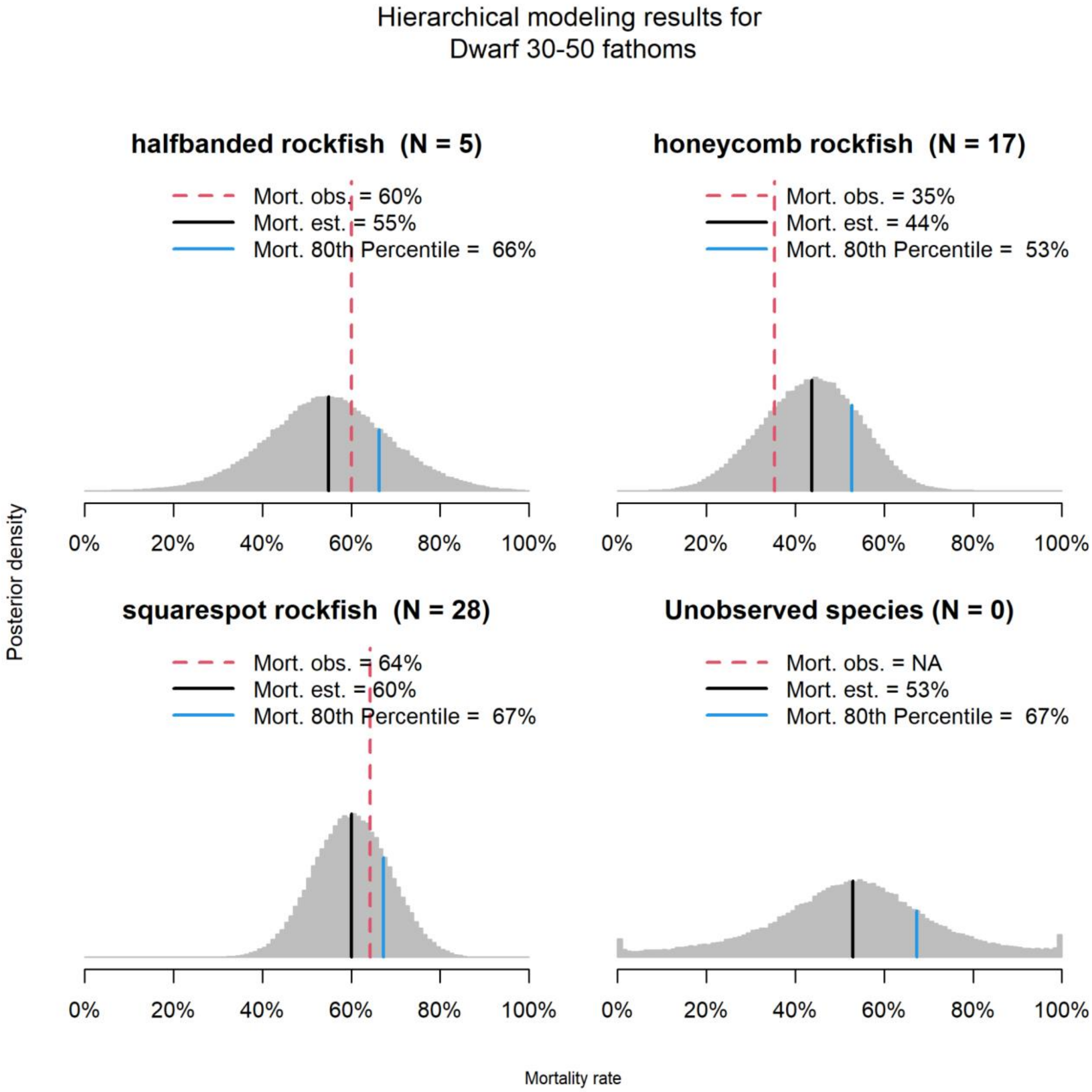

Figure A.14. Posterior predicted distributions of mortality estimates between 30-50 fathoms depth bin for the dwarf guild species from the hierarchical model. Median mortality estimates (50th percentile) are shown in the black line with the 80th percentile shown in blue. The observed mortality fraction is shown by the red line.