Estimating Yield for Unassessed Species in the Pacific Coast Groundfish Fishery Management Plan

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Introduction

This report describes the results of applying two methods for estimating sustainable yields from unassessed stocks in the Pacific Coast Groundfish Fisheries Management Plan (FMP). Overfishing limits (OFLs) for these stocks are currently derived from a variety of methods, including adjustments to average catch (Restrepo et al., 1998) or survey biomass (Rogers, 1996). Two new methodologies for determining yields from data-poor stocks were evaluated at a joint meeting of the PFMC Scientific and Statistical Committee's (SSC) Groundfish Subcommittee and the Groundfish Management Team (GMT), held January 26-28, 2010, in Seattle, WA. Yield estimates from Depletion-Corrected Average Catch (MacCall, 2009) and Depletion-Based Stock Reduction Analysis (Dick and MacCall, in prep.), were compared to 31 stock assessments of species in the groundfish FMP. The SSC Groundfish Subcommittee endorsed application of DCAC and DB-SRA to unassessed stocks in the groundfish FMP. This report summarizes the results of applying both methods to 35 unassessed stocks in the groundfish FMP.

DCAC and DB-SRA estimate yield by incorporating catch history information and distributions describing our uncertainty about life history parameters and stock status. As such, neither method is a substitute for a traditional stock assessment, but both provide information that can be used to inform decisions regarding sustainable yield.

Depletion-Corrected Average Catch (DCAC)

DCAC (MacCall, 2009) is an estimate of sustainable yield for data-poor stocks of uncertain status. DCAC adjusts historical average catch to account for one-time "windfall" catches that are the result of stock depletion, producing an estimate of yield that was likely to be sustainable over the same time period. Advantages of the DCAC approach to determining sustainable yield for data-poor stocks include: 1) minimal data requirements, 2) biologically-based adjustment to catch-based yield proxies with transparent assumptions about relative changes in abundance, and 3) simple to compute.

DCAC, as described by MacCall (2009), incorporates uncertainty in natural mortality (M), the ratio F_{MSY}/M, and relative change in abundance (Δ) by using Monte Carlo simulation. We also account for uncertainty in the ratio of B_{MSY} to unfished biomass (K), setting the expected value of this ratio to 0.4 for rockfishes (genera *Sebastes* and *Sebastolobus*) and roundfishes. For flatfishes we set the expected value to 0.25 following target biomass proxies recently adopted by the Pacific Fishery Management Council. We assume an expected value of 0.8 for the ratio F_{MSY}/M, as suggested for demersal species in the northeastern Pacific by Walters and Martell (2004). Parameters of these distributions are provided in Table 1.

For each species we sum catches from the first year in which catches increased dramatically through 1999, after which yield for many species declines due to implementation of significant management measures off the U.S. west coast. Final DCAC distributions were calculated as

$$DCAC = \frac{\sum C_t}{n + \frac{\Delta}{\left(\frac{B_{MSY}}{K}\right)\left(\frac{F_{MSY}}{M}\right)(M)}} \qquad (1)$$

where *n* is the length of the catch time series in years, and C_t is the catch in year t.

Depletion-Based Stock Reduction Analysis (DB-SRA)

DB-SRA (Dick and MacCall, in prep.; draft MS submitted to SSC Groundfish Committee 1/22/10) extends DCAC by 1) restoring the temporal link between production and biomass and 2) evaluating and integrating alternative hypotheses regarding changes in abundance during the historical catch period. This method combines DCAC's distributional assumptions regarding life history characteristics and stock status with the dynamic models and simulation approach of stochastic stock reduction analysis (Walters et al., 2006).

In DB-SRA, draws from the input distributions are used to fully specify a delay-difference production model of the form

$$B_t = B_{t-1} + P(B_{t-a}) - C_{t-1} \quad (2)$$

where *B* is biomass, *P* is latent production based on a preceding biomass, *C* is catch, and *a* is age at reproductive maturity. For a given time series of catch, the methods solves for unfished biomass using each draw from the input distributions, producing distributions of biomass and production trajectories, unfished biomass, maximum sustainable yield, and other management reference points. Biologically credible trajectories (e.g. those with non-negative biomass) are retained, from which distributions of OFL over time are calculated.

Development of bias correction distributions using stock assessment comparisons and productivity-susceptibility analysis (PSA)

The comparison of yield estimates from DB-SRA to recent stock assessments (Dick and MacCall, in prep.) assumed that unassessed stocks are, on average, at 40% of their unfished biomass. Results suggest that life history characteristics affect the direction and magnitude of bias in DB-SRA results relative to the age-structured stock assessment models. It is possible to use distributions of relative OFL (the ratio of OFL from DB-SRA to the stock assessment's point estimates) as empirical bias-correction distributions for unassessed stocks. This requires that the assumptions used in the stock assessment comparison regarding stock status remain consistent with the assumptions used for unassessed stocks.

Results from the stock assessment comparison (Dick and MacCall, in prep.) suggest that life history characteristics affect the direction and magnitude of bias in DB-SRA results relative to previous stock assessment models. However, many unassessed stocks in the FMP are data-poor, making comparisons difficult. The recent productivity-susceptibility analysis (PSA) for west-coast groundfish (agenda item E.2.b) provides guidance with respect to life history characteristics as well as the relative influence of fisheries on data-poor stocks. Susceptibility to fisheries may change over time, so we focused our comparisons on productivity scores alone. Flatfish species are typically productive stocks and were treated separately from rockfish and roundfish. Among non-flatfish species, we define "low productivity" stocks as those with scores from the PSA below the median score (1.365), and the remaining species are combined into a high-productivity category (Table 2). Using the results of the stock assessment comparison, we estimated life-history based bias correction distributions for three groups: flatfish, low-productivity non-flatfish, and high-productivity non-flatfish (Figure 1). Drawing random samples from the ratio of each unassessed species' OFL distribution (from DB-SRA) to the appropriate bias-correction distribution provides a distribution of OFL for each unassessed stock.

Data Sources

Life history data

Observed maximum age was used to inform natural morality (M). We used Hoenig's (1983) method for estimating total mortality as the expectation of the distribution for M. If fishing mortality is large relative to natural mortality, this assumption may overestimate the productivity of stocks. Sources and estimates of maximum age and age at maturity for each species are provided in Table 3. Species-specific productivity parameters (e.g. F_{MSY} / M and B_{MSY} / K) used in DCAC and DB-SRA are in Table 1. Whenever possible, estimates of maximum age and age at maturity were taken from sources based on stocks in U.S. waters off the west-coast.

Age at maturity information was not available for some rockfish species (flag, pink, and shortraker). For these species, we approximated age at maturity using the product of maximum age and the mean of the ratio of age at maturity to maximum age across all rockfish species (0.14).

Historical Catch Reconstructions

Commercial fisheries

DB-SRA results in this report are based on estimates of landings by species and year, aggregated across other strata (e.g. area and gear type). When available, estimates of discard (described below) have been applied to landings data so yield estimates could be treated as total mortality (landings plus discard mortality). For ongoing data sources we project landings in 2010 using the average of landings in 2008-2009. Therefore, forecasted estimates of OFLs in 2011 are based on the assumption that catches in 2010 will not differ greatly from the previous two years.

The CALCOM database was queried for California's commercial landings estimates from 1969 – 2009 (SQL code provided in Appendix A). Since multiple species are often landed within a single market category, it is necessary to "expand" landings estimates from fish tickets using species composition data obtained by port samplers. CALCOM is the source of this expansion for California's landings, and generates estimates of species compositions by year, quarter, market category, gear group, port complex, and live/nonlive fishery. These compositions are applied to fish ticket data, and the resulting "expanded" species compositions are uploaded to PacFIN on a monthly basis. A final annual expansion is also uploaded to PacFIN when the landing receipts for that year have been submitted.

We queried CALCOM, rather than PacFIN, for estimates of California's commercial landings because 1) CALCOM is the original source of California's landings estimates, 2) a final expansion of the 2008 landings for California was completed in CALCOM but final species compositions had not yet been uploaded to PacFIN for that year, and 3) a preliminary expansion for 2009 was completed for this analysis because final landing receipts were not yet available. At the time of writing this report, final landings estimates for the fourth quarter of 2009 were not available. We estimate fourth quarter landings in 2009 by species using a ratio of statewide landings in quarters 1-3 from 2007 and 2008 to landings in quarter 4 of those same years. We apply that ratio to the first three quarters of 2009 to obtain estimates of fourth-quarter 2009 landings. To estimate OFL in 2011, we project 2010 landings using the average landings, by species, over the years 2008 and 2009.

Pacific Fisheries Information Network (PacFIN) database was the primary source of commercial landings data from Oregon and Washington. Oregon landings from 1987-2009 and Washington landings from 1981-2009 were queried from the PacFIN database (see Appendix A). Landings in nominal codes in PacFIN were pooled with corresponding market categories (e.g. nominal category VRM1 was added to category VRML). ODFW staff (M. Karnowski, pers. comm.) provided revised estimates of rockfish landings from 1981-1986 due to uncertainty regarding the source of species compositions previously applied to that time period. The revised Oregon rockfish estimates replaced PacFIN estimates of rockfish landings from 1981-86. Non-rockfish Oregon landings of groundfish species from 1981-1986 were based on the PacFIN query.

Historical estimates of commercial landings in California from 1916-1968 were available from the CALCOM database. A description of these estimates is given by Ralston et al. (2009). We adopt their reconstruction without modification. Historical rockfish landings from the Oregon trawl fishery were estimated by NMFS and ODFW staff (V. Gertseva, pers. comm.) as part of Oregon's commercial catch reconstruction effort. These landings represent the majority of commercial catch, because the trawl fishery dominated Oregon landings from the early 1940s through the mid-1960s (Figure 2). Even in the late 1960s and '70s, the trawl fishery typically accounted for greater than 70% of total landings. Although the Oregon trawl fishery prior to 1942 was minor relative to other gear types, the total landings during this time period were small relative to total historical removals (Figure 2). Efforts to estimate historical catch (pre-1981) of non-rockfish species are underway and should be available in the near future (V. Gertseva, pers. comm.).

Washington Department of Fish and Wildlife (WDFW) is in the process of preparing historical catch reconstructions of Washington landings (T. Tsou and G. Lippert, pers. comm.). WDFW provided numerous data sets and background documents that will be considered during the state's reconstruction efforts. It was not possible to develop a detailed catch reconstruction from these sources in time for this analysis. We used readily available data sources to reconstruct a time series of catch (described below). We consider this reconstruction to be a placeholder until a more thorough reconstruction is completed.

Tagart (1985) reports on trawl-caught rockfish by year, species, PMFC area, and reporting agency (CDFG, ODFW, WDFW, and DFO Canada) for the years 1963-1980. The number of species broken out in the early years of the report (8 species reported in 1963 plus one category for unidentified rockfish) is less than in later years. We calculated species compositions from the 1969-1976 data (prior to the widow rockfish fishery) and applied them to aggregated rockfish landings from 1963-1968.

A comparison of total rockfish landings from the Tagart (1985) data and the commercial rockfish landings in the PMFC Data Series (areas 2D, 3A, 3B, and 3C) showed strong agreement between the two sources (Table 4). We estimated the fraction of rockfish landed in Washington and originating in U.S. waters by PMFC area using the Tagart data over the years 1963-1967 (Table 5). The estimated fractions of Washington rockfish landings of U.S. origin were 1.9% for area 3A, 85.2% for area 3B, and

43.9% for area 3C. We applied the area-specific fractions to the total rockfish landings by area from the PMFC Data Series, generating estimates of Washington rockfish landings from U.S. waters for the period 1956-1962. Finally, we applied the 1969-1976 species composition data from Tagart (1985) to estimate rockfish landings by species from 1956-1962 (Table 6). Landings may be over- or under-estimated for a given species if the composition of catch changed dramatically between the periods 1956-1962 and 1969-1976.

Pacific Fisherman yearbooks provide a record of total rockfish landings in Washington from the 1930s to 1956 (I. Stewart, pers. comm.). Their reported catch is partitioned into POP and other rockfish categories after 1952. Stewart (2007) found this source to be similar to Fish and Wildlife statistics from the same time period, with the exception of one year (1945) in which the Pacific Fisherman data estimated 7,300 mt and the Fish and Wildlife data showed 11,552 mt. We retained the estimate from the Pacific Fisherman yearbooks. These data include landings originating from Canadian waters, so it is necessary to identify the fraction of catch originating in U.S. waters. Alverson (1957) reports the fraction of landed rockfish that originated from U.S. waters during 1953 (14.9% for other rockfish and 9.7% for POP). We applied these proportions to the Pacific Fisherman estimates (using the average proportion in years reporting only total rockfish) to get Washington landings from U.S. waters. We then applied the 1969-1976 species composition data from Tagart (1985) (Table 7) to estimate rockfish landings by species from 1942-1955, as these composition data are the best available information at this time (Table 8). As with the PFMC Data Series, this application of the Tagart composition data makes a strong assumption that rockfish species compositions do not vary over time.

In summary, estimates of total rockfish for years prior to 1981 are derived from a total of 3 sources: Pacific Fisherman yearbooks, PMFC Data Series Reports, and Tagart (1985). After adjusting each source to remove catches from outside U.S. waters, the scale of total rockfish does not change dramatically between sources (Figure 8).

Recreational fisheries

Recreational landings and discard estimates were obtained from RecFIN for the period 1980-2009. A time series of recreational catch in California was provided by CDFG (J. Budrick, pers. comm.) that incorporated estimates of discard mortality. These estimates are derived from the combined weights of catch types A and B1, plus 42% (7% for non-rockfish spp.) of the number of B2 fish multiplied by average weights of discarded fish from 2004-2009, by species. Recreational landings and discard estimates for Oregon and Washington are based on reported values from RecFIN (weights of A+B1 fish). We interpolate catch for the years 1990-1992 (unavailable in RecFIN) as a linear trend between the average catch taken over the 3-year periods bracketing the missing time period (87-89 and 93-95).

Estimates of recreational rockfish catch in Washington's coastal waters prior to 1980 were not readily available. Washington Sport Catch Reports from 1975-1980 report rockfish landings, but show that the majority of sport-caught rockfish were not recorded to species (c.f. Nye et al., 1975). Recreational catch in Oregon and Washington prior to 1980 is not included in our reconstructions. Ralston et al. (2009) prepared historical recreational catch reconstructions of rockfish mortality (landings + discard) in California for the period 1928-1980. We use these estimates without modification. Due to irregularities in RecFIN's reported reported recreational catch in 1980 (Ralston et al., 2009), we replaced 1980

RecFIN estimates of rockfish mortality with the estimates from California's historical recreational catch reconstruction.

Estimated bycatch of groundfish species from the at-sea whiting fleet is available for the years 1991-2009 from the NORPAC database. We queried NORPAC for estimates of total weight by species, area, and year (Appendix A). Annual estimates of total bycatch by species from this fishery were included in our catch reconstructions without modification. Rogers (2003) provides estimates of rockfish catch by foreign vessels occurring off the West Coast of the United States (U.S.) from 1965-76.

When possible, catch reconstruction for some species were augmented with readily available information, including catch reconstructions available in the literature. Due to the availability of historical rockfish reconstructions from California and Oregon, most of this additional data was compiled for non-rockfish species. The following species accounts describe these sources in greater detail.

Spiny dogfish

A reconstruction of historical catches in U.S. coastal waters was completed by Taylor (2008) for landings prior to 1980 and the PacFIN database from 1981-2006. Data since 2006 was obtained from CALCOM, PacFIN, and NORPAC databases.

Kelp greenling

An assessment of the kelp greenling substock in Oregon was adopted in 2005. An assessment of the California substock was also completed, but the stock assessment review (STAR) panel rejected the California model for issues not related to the catch time series.(PFMC, 2005). Cope and MacCall (2005) completed a reconstruction of California landings back to 1916, and we apply DB-SRA to their catch estimates. Discard and associated mortality are assumed to be negligible because of the desirability of this species and its lack of an air bladder.

Rex Sole

Cleaver (1951) reported rex sole landings for 1942-49 in Oregon, noting "The peak landing in 1943 of 569,737 pounds represents a heavy demand for food fish, while the peak of 223,667 pounds in 1949 represents an increasing demand for mink food." Smith (1956) provided Oregon landings from 1950-53, and also reported the composition of the growing mink food landings, noting that 53% of the mink food landings was a mixture of arrowtooth flounder, Bellingham (butter) sole, and rex sole. We assume that 20% of total mink food landings were rex sole during this time period. This assumption is consistent with an increase in landings that matches reported landings of over 1000 mt in 1956 (fish caught for both animal food and human consumption, per the PMFC Data Series) (Figure 3). CA landing receipt data matched Data Series landings from Areas 1A-1C very well (Figure 4), and were used without modification. PMFC Data Series landings for areas 2A-3B are therefore interpreted as landings by other agencies (ODFW, WDFW, DFO) from these areas (Figure 5).

Rock Sole

The PMFC Data Series reports catch of rock sole as early as 1956. Historical CA landings were taken from landing receipts. We approximate landings in Oregon and Washington using Data Series reports from areas 2A-3B (Figure 6). Visual inspection of WDFW Data Reports showed that the majority of rock sole landings from area 3C originated in what are now Canadian waters (WA state statistical areas 7-11). Alverson (1955) reported on the 1954 trawl fishery and noted that almost all rock sole landed in Washington were caught in the Hecate Strait, Goose Island, and Cape Scott fishing grounds. Cleaver (1951) reports that rock sole were not an important component of the Oregon trawl fishery, with landings recorded in only 2 years between 1942 and 1949.

Sand Sole

Sand sole landings were not differentiated from the unspecified rockfish category in the PFMC Data Series. This species was consistently reported in WDFW Data Reports and Progress Reports since 1963, and these were used to reconstruct sand sole landings in Washington from U.S. Coastal Waters (PMFC areas 2C, 3A, and 3B) (Figure 7). Landings in area 3C were rare and relatively small. Statewide sand sole landings averaged 29 tons per year from 1951-1954. It is unclear how much was caught in inland versus coastal waters. In 1963 and 1964, 90% of sand sole caught in U.S. waters were from Puget Sound (Pattie, 1973). Cleaver (1951) refers to sand sole as a minor component of the Oregon trawl fishery prior to 1950, noting that this species was often landed with petrale sole.

Pacific Sanddab

Pacific sanddabs were historically landed as unspecified flatfish. While early markets existed in California, this species was generally discarded or landed for animal food in Oregon and Washington. In California the unspecified sanddab market category is greater than 96% Pacific sanddab (Pearson et al., 2008). Following Pearson et al., we combined the unspecified sanddab market category (SDAB) in CALCOM with the Pacific sanddab market category (PDAB). We also assume that all Washington and Oregon landings in the unspecified sanddab market category (category UDAB in PacFIN) are Pacific sanddab. Historical landings may be underestimated if sanddab were landed in any of the ‘unspecified’ or ‘other’ flatfish market categories.

Discard assumption

Two data sources were consulted for information on discard in the commercial fisheries. Trawl reports from the West Coast Groundfish Observer Program in 2007 and 2008 were used to estimate discard for several species and species groups. Estimates were based on the ratio of discarded catch to retained catch (total catch minus discarded catch). When species-specific rates were not supplied, ratios were developed using aggregated categories (e.g. shelf rockfish). An analysis of data from Pikitch et al. (1988) was supplied by D. Erickson (ODFW) for the mid-1980s. We developed a matrix of discard ratios (discard / retained) by species and year using these two data sources. Discard ratios in years between sources was assigned using linear interpolation. We assume that discard ratios from the earliest source remain constant for all previous years (Table 9). A 50% discard mortality rate was applied to all species as a placeholder value until more detailed information can be developed.

Discard in recreational fisheries from 1980 to the present is based on RecFIN (B1 fish for Oregon and Washington, and as described above for California).

Results

Depletion-Corrected Average Catch (DCAC)

Distributions of DCAC for the 35 unassessed groundfish species are based on 10,000 independent draws from each distribution (Table 10; Figure 9). This quantity represents a yield that is likely to have been sustainable during the time period over which the catch was aggregated. Reductions from average catch are based on life history characteristics of the species and the assumed distribution of current status (Equation 1).

Depletion-Based Stock Reduction Analysis (DB-SRA)

For each unassessed stock, we summarize the DB-SRA results in a figure with four panels (Figures 10-44). The panels include 1) time series of catch and assumed commercial discard by data source, 2) time series of the bias-corrected distribution of OFL, 3) probability that catch exceeded the OFL over time, and 4) the bias-corrected distribution of forecasted OFL in 2011. Summary statistics of OFL in 2011 are also provided (Table 11), with the fraction of retained runs reported as Table 12.

The results of both DB-SRA and DCAC are conditional on the assumed status of the stock. Application of the bias correction distributions to the DB-SRA estimates of OFL is an attempt to correct for potential bias, taking into account differences in productivity characteristics among stocks. For any species, the OFL and the probability that catch exceeded the OFL in any given year are both conditional on the assumed distribution of current stock status and the assumed bias-correction distribution.

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Tables

Table 1. Input parameters for Depletion-Corrected Average Catch and Depletion-Based Stock Reduction Analysis

Species Group	Common Name	Species Code	Maximum Age	Natural Mortality	Age at Maturity	DCAC start yr.	DCAC end year	Std. Dev. of ln(M)	FMSY/ M	Std. Dev. Of FMSY / M
Elasmobranch	Leopard shark	LSRK	25	0.191	10	1976	1999	0.4	0.8	0.2
Elasmobranch	Spiny dogfish	DSRK	80	0.054	35	1938	1999	0.4	0.8	0.2
Flatfish	Pacific sanddab	PDAB	11	0.465	2	1981	1999	0.4	0.8	0.2
Flatfish	Rex sole	REX	24	0.2	5	1941	1999	0.4	0.8	0.2
Flatfish	Rock sole	RSOL	22	0.219	5	1965	1999	0.4	0.8	0.2
Flatfish	Sand sole	SSOL	10	0.516	2	1941	1999	0.4	0.8	0.2
Rockfish	Aurora rockfish	ARRA	75	0.058	5	1970	1999	0.4	0.8	0.2
Rockfish	Black-and-Yellow Rockfish	BYEL	30	0.157	4	1947	1999	0.4	0.8	0.2
Rockfish	Brown Rockfish	BRWN	34	0.137	4	1945	1999	0.4	0.8	0.2
Rockfish	China Rockfish	CHNA	79	0.055	5	1916	1999	0.4	0.8	0.2
Rockfish	Copper Rockfish	COPP	50	0.09	6	1945	1999	0.4	0.8	0.2
Rockfish	Flag Rockfish	FLAG	38	0.121	5	1916	1999	0.4	0.8	0.2
Rockfish	Grass Rockfish	GRAS	23	0.209	4	1947	1999	0.4	0.8	0.2
Rockfish	Greenblotched Rockfish	GBLC	50	0.09	10	1916	1999	0.4	0.8	0.2
Rockfish	Greenspotted Rockfish	GSPT	51	0.088	10	1916	1999	0.4	0.8	0.2
Rockfish	Kelp Rockfish	KLPR	25	0.191	4	1945	1999	0.4	0.8	0.2
Rockfish	Olive Rockfish	OLVE	30	0.157	5	1942	1999	0.4	0.8	0.2
Rockfish	Pink Rockfish	PNKR	66	0.067	9	1941	1999	0.4	0.8	0.2
Rockfish	Quillback Rockfish	QLBK	76	0.057	9	1941	1999	0.4	0.8	0.2
Rockfish	Redbanded Rockfish	RDBD	106	0.04	4	1941	1999	0.4	0.8	0.2
Rockfish	Redstripe Rockfish	REDS	55	0.081	7	1965	1999	0.4	0.8	0.2
Rockfish	Rosethorn Rockfish	RSTN	87	0.049	10	1950	1999	0.4	0.8	0.2
Rockfish	Rosy Rockfish	ROSY	18	0.273	4	1931	1999	0.4	0.8	0.2
Rockfish	Rougheye Rockfish	REYE	170	0.024	20	1963	1999	0.4	0.8	0.2
Rockfish	Sharpchin Rockfish	SHRP	58	0.077	6	1963	1999	0.4	0.8	0.2
Rockfish	Shortraker Rockfish	SRKR	157	0.026	22	1970	1999	0.4	0.8	0.2
Rockfish	Silvergray Rockfish	SLGR	82	0.053	9	1963	1999	0.4	0.8	0.2
Rockfish	Speckled Rockfish	SPKL	37	0.125	4	1941	1999	0.4	0.8	0.2
Rockfish	Starry Rockfish	STAR	32	0.146	7	1916	1999	0.4	0.8	0.2
Rockfish	Stripetail Rockfish	STRK	38	0.121	4	1941	1999	0.4	0.8	0.2
Rockfish	Swordspine Rockfish	SWSP	43	0.106	3	1950	1999	0.4	0.8	0.2
Rockfish	Treefish	TREE	25	0.191	5	1946	1999	0.4	0.8	0.2
Rockfish	Vermillion Rockfish	VRML	60	0.074	5	1921	1999	0.4	0.8	0.2
Rockfish	Yellowmouth Rockfish	YMTH	99	0.043	6	1963	1999	0.4	0.8	0.2
Roundfish	Kelp greenling (CA)	KLPG_CA	25	0.191	4	1916	1999	0.4	0.8	0.2

Table 1. (Continued) Input parameters for Depletion-Corrected Average Catch and Depletion-Based Stock Reduction Analysis

Species Group	Common Name	Species Code	Delta	SD(Delta)	Delta Lower Bound	Delta Upper Bound	BMSY / B0	SD (BMSY/B0)	BMSY / B0 Lower Bound	BMSY / B0 Upper Bound
Elasmobranch	Leopard shark	LSRK	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Elasmobranch	Spiny dogfish	DSRK	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Flatfish	Pacific sanddab	PDAB	0.6	0.1	0.01	0.99	0.25	0.05	0.05	0.95
Flatfish	Rex sole	REX	0.6	0.1	0.01	0.99	0.25	0.05	0.05	0.95
Flatfish	Rock sole	RSOL	0.6	0.1	0.01	0.99	0.25	0.05	0.05	0.95
Flatfish	Sand sole	SSOL	0.6	0.1	0.01	0.99	0.25	0.05	0.05	0.95
Rockfish	Aurora rockfish	ARRA	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Black-and-Yellow Rockfish	BYEL	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Brown Rockfish	BRWN	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	China Rockfish	CHNA	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Copper Rockfish	COPP	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Flag Rockfish	FLAG	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Grass Rockfish	GRAS	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Greenblotched Rockfish	GBLC	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Greenspotted Rockfish	GSPT	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Kelp Rockfish	KLPR	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Olive Rockfish	OLVE	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Pink Rockfish	PNKR	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Quillback Rockfish	QLBK	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Redbanded Rockfish	RDBD	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Redstripe Rockfish	REDS	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Rosethorn Rockfish	RSTN	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Rosy Rockfish	ROSY	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Rougheye Rockfish	REYE	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Sharpchin Rockfish	SHRP	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Shortraker Rockfish	SRKR	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Silvergray Rockfish	SLGR	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Speckled Rockfish	SPKL	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Starry Rockfish	STAR	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Stripetail Rockfish	STRK	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Swordspine Rockfish	SWSP	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Treefish	TREE	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Vermillion Rockfish	VRML	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Rockfish	Yellowmouth Rockfish	YMTH	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95
Roundfish	Kelp greenling (CA)	KLPG_CA	0.6	0.1	0.01	0.99	0.4	0.05	0.05	0.95

Table 2. Productivity scores from productivity-susceptibility analysis (Agenda item E.2.b). See text for category descriptions. In each category, species with available stock assessments (bold text) were used to generate empirical bias correction distributions applied to OFL distributions for unassessed stocks.

Low-productivity Rockfish and Roundfish

Species	P score
Cowcod	1.06
Spiny dogfish	1.11
Soupfin shark	1.11
Rougheye rockfish	1.17
Blackspotted rockfish	1.17
Rosethorn rockfish	1.19
California skate	1.21
Yelloweye rockfish	1.22
Bronzespotted rockfish	1.22
Blackgill rockfish	1.22
Vermilion rockfish	1.22
Silvergrey rockfish	1.22
Shortraker rockfish	1.22
Starry rockfish	1.25
Tiger rockfish	1.25
Bank rockfish	1.25
Leopard shark	1.26
Canary rockfish	1.28
Bocaccio	1.28
Greenblotched rockfish	1.28
Redbanded rockfish	1.28
Dusky rockfish	1.28
Greenstriped rockfish	1.28
Splitnose rockfish	1.28
Quillback rockfish	1.31
Redstripe rockfish	1.31
Widow rockfish	1.31
Harlequin rockfish	1.31
Pinkrose rockfish	1.31
China rockfish	1.33
Aurora rockfish	1.33
Speckled rockfish	1.33
Pink rockfish	1.33
Flag rockfish	1.33
Black rockfish	1.33
Swordspine rockfish	1.33
Yellowtail rockfish	1.33
Shortspine thornyhead	1.33
Copper rockfish	1.36
Sharpchin rockfish	1.36
Honeycomb rockfish	1.36

High-productivity Rockfish and Roundfish

Species	P score
Big skate	1.37
Darkblotched rockfish	1.39
Chameleon rockfish	1.39
Blue rockfish	1.39
Greenspotted rockfish	1.39
Pacific rattail/grenadier	1.39
Stripetail rockfish	1.39
Pacific ocean perch	1.44
Longspine thornyhead	1.47
Mexican rockfish	1.50
Longnose skate	1.53
Gopher rockfish	1.56
Brown rockfish	1.61
Yellowmouth rockfish	1.61
Grass rockfish	1.61
Rosy rockfish	1.61
Squarespot rockfish	1.61
Sablefish	1.61
Ratfish	1.63
Monkyface prickelback	1.67
Treefish rockfish	1.67
Olive rockfish	1.69
Finescale codling	1.72
Calico rockfish	1.75
Lingcod	1.75
Rock greenling	1.78
California sheephead	1.78
Freckled rockfish	1.78
Pygmy rockfish	1.78
Cabezon	1.78
Kelp greenling	1.83
Dwarf-red rockfish	1.83
California scorpionfish	1.83
Chilipepper	1.83
Black-and-yellow rockfish	1.89
Puget Sound rockfish	1.89
Kelp rockfish	1.94
Shortbelly rockfish	1.94
Pacific whiting	2.00
Halfbanded rockfish	2.00
Pacifc cod	2.11

Flatfish

Species	P score
Petrale sole	1.70
Dover sole	1.80
Rock sole	1.95
Arrowtooth flounder	1.95
Rex sole	2.05
Starry flounder	2.15
English sole	2.25
Flathead sole	2.30
Sand sole	2.35
Pacific sanddab	2.40
Curlfin sole	2.45
Butter sole	2.45

Table 3. Maximum age and age at 50% maturity estimates with source information.

Common Name	Scientific Name	Group	Max. Age	Hoenig Z	Amat	Source for maximum age	Source for age at maturity
Aurora rockfish	Sebastes aurora	Rockfish	75	0.058	5	Love et al. 2002	Love et al. 2002
Brown Rockfish	Sebastes auriculatus	Rockfish	34	0.137	4	Love et al. 2002	Love et al. 2002
Black-and-Yellow Rockfish	Sebastes chrysomelas	Rockfish	30	0.157	4	Love et al. 2002	Love et al. 2002
China Rockfish	Sebastes nebulosus	Rockfish	79	0.055	5	Love et al. 2002	Love et al. 2002
Copper Rockfish	Sebastes caurinus	Rockfish	50	0.090	6	Love et al. 2002	Love et al. 2002
Spiny dogfish	Squalus acanthias	Elasmobranch	80	0.054	35	McFarlane and King 2003	McFarlane and King 2003
Flag Rockfish	Sebastes rubrivinctus	Rockfish	38	0.121	5	Love et al. 2002	0.14*max age
Greenblotched Rockfish	Sebastes rosenblatti	Rockfish	50	0.090	10	Love et al. 2002	Love et al. 2002
Grass Rockfish	Sebastes rastrelliger	Rockfish	23	0.209	4	Love and Johnson 1998	Love and Johnson 1998
Greenspotted Rockfish	Sebastes chlorostictus	Rockfish	51	0.088	10	Benet et al. 2009	Benet et al. 2009
Kelp greenling (CA)	Hexagrammos decagrammus	Roundfish	25	0.191	4	Cope and MacCall 2005	Cope and MacCall 2005
Kelp Rockfish	Sebastes atrovirens	Rockfish	25	0.191	4	Love et al. 2002	Love et al. 2002
Leopard shark	Triakis semifasciata	Elasmobranch	25	0.191	10	Smith et al., 2003	Kusher et al., 1992
Olive Rockfish	Sebastes serranoides	Rockfish	30	0.157	5	Love et al. 2002	Love et al. 2002
Pacific sanddab	Citharichthys sordidus	Flatfish	11	0.465	2	Love 1996	Rackowski and Pikitch 1989
Pink Rockfish	Sebastes eos	Rockfish	66	0.067	9	Love et al. 2002	0.14*max age
Quillback Rockfish	Sebastes maliger	Rockfish	76	0.057	9	Yamanaka and Kronlund 1997	Love et al. 2002
Redbanded Rockfish	Sebastes babcocki	Rockfish	106	0.040	4	Love et al. 2002	Love et al. 2002
Redstripe Rockfish	Sebastes proriger	Rockfish	55	0.081	7	Love et al. 2002	Shaw 1999
Rex sole	Glyptocephalus zachirus	Flatfish	24	0.200	5	Hosie and Horton 1977	Hosie and Horton 1977
Rougheye Rockfish	Sebastes aleutianus	Rockfish	170	0.024	20	Munk 2001	Love et al. 2002
Rosy Rockfish	Sebastes rosaceus	Rockfish	18	0.273	4	Tenera Environmental Services 2000	Love et al. 2002
Rock sole	Lepidopsetta bilineata	Flatfish	22	0.219	5	Fishbase.org	Fargo and Wilderbuer 2000
Rosethorn Rockfish	Sebastes helvomaculatus	Rockfish	87	0.049	10	Love et al. 2002	Shaw 1999
Sharpchin Rockfish	Sebastes zacentrus	Rockfish	58	0.077	6	Love et al. 2002	Shaw 1999
Silvergray Rockfish	Sebastes brevispinis	Rockfish	82	0.053	9	Love et al. 2002	Stanley and Kronlund 2005
Speckled Rockfish	Sebastes ovalis	Rockfish	37	0.125	4	Love et al. 2002	Love et al. 2002
Shortraker Rockfish	Sebastes borealis	Rockfish	157	0.026	22	Love et al. 2002	0.14*max age
Sand sole	Psettichthys melanostictus	Flatfish	10	0.516	2	Pearson and McNally 2005	Pearson and McNally 2005
Starry Rockfish	Sebastes constellatus	Rockfish	32	0.146	7	Love et al. 2002	Love et al. 2002
Stripetail Rockfish	Sebastes saxicola	Rockfish	38	0.121	4	Love et al. 2002	Love et al. 2002
Swordspine Rockfish	Sebastes ensifer	Rockfish	43	0.106	3	Love et al. 2002	Love et al. 2002
Treefish	Sebastes serriceps	Rockfish	25	0.191	5	Colton and Larson 2007	Colton and Larson 2007
Vermillion Rockfish	Sebastes miniatus	Rockfish	60	0.074	5	Munk 2001	Love et al. 2002
Yellowmouth Rockfish	Sebastes reedi	Rockfish	99	0.043	6	Schnute (DFO Canada) 1999	Love et al. 2002

Table 4. Comparison of total rockfish trawl landings reported by Tagart (1985) and the PMFC Data Series (Lynde, 1986). Data are for all reporting agencies (ODFW, WDFW, and DFO Canada). Tagart PMFC areas limited to 3A (includes 2D), 3B, 3C-S, and 3C-N. PMFC Data Series areas include 2D, 3A, 3B, and 3C (includes 3C-S and 3C-N). Deviations from 1978 onward are likely due to the expansion of the widow rockfish fishery.

Year	PMFC Data Series	Tagart 1985	PMFC / Tagart
1963	6921.4	6922.7	1.00
1964	5618.2	5618.4	1.00
1965	6013.7	6028.8	1.00
1966	5326.1	5302.9	1.00
1967	2838.6	2827.6	1.00
1968	3364.8	3387.4	0.99
1969	3740.3	3739.4	1.00
1970	3699.1	3733.0	0.99
1971	3063.1	3064.9	1.00
1972	2459.8	2464.0	1.00
1973	1839.3	1836.7	1.00
1974	1626.1	1627.1	1.00
1975	2416.3	2416.1	1.00
1976	6141.2	6144.2	1.00
1977	8922.2	8919.6	1.00
1978	13947.1	13042.1	1.07
1979	15237.1	13405.4	1.14
1980	23337.4	21724.4	1.07

Table 5. Rockfish trawl landings (mt) by year, PMFC area and reporting agency (Tagart, 1985).

	3A		**3B**			**3C-N**		**3C-S**		
YEAR	**ODFW**	**WDF**	**DFO**	**ODFW**	**WDF**	**DFO**	**WDF**	**DFO**	**ODFW**	**WDF**
1963	2722.0	48.6	1.4	119.0	975.3	13.5	2051.5	0.1	3.0	988.3
1964	2324.0	78.1	2.5	429.0	980.0	46.1	833.6	6.7	39.0	879.4
1965	1983.0	24.7		37.0	699.9	25.8	1978.9	4.4	91.0	1184.1
1966	1910.0	7.0		25.0	797.1		873.1		116.0	1574.7
1967	1493.0	48.4	0.3	38.0	290.0	18.4	434.5		8.0	497.0
1968	1087.0	8.6	1.6	163.0	1416.3	17.4	114.2	0.3	4.0	575.0
1969	1007.0	18.0	0.1	94.0	1662.6	28.7	214.1		24.0	690.9
1970	812.0	22.4	2.9	70.0	692.3	357.5	727.3	2.0	456.0	590.6
1971	620.0	153.7	11.2	116.0	646.8	295.3	272.9	17.6	244.0	687.4
1972	927.0	232.2		141.0	413.2	113.2	202.1	0.7	7.0	427.6
1973	942.0	50.1		29.0	296.8	47.5	124.1	0.5	13.0	333.7
1974	778.0	187.1		27.0	233.8	70.7	90.3		1.0	239.2
1975	850.0	302.3		23.0	670.0	43.8	166.2			360.8
1976	1665.0	1644.1		5.0	695.6	177.2	693.3	7.8		1256.2
1977	1853.0	2158.1	6.2		1677.4	196.1	278.0	305.2		2445.6
1978	2989.1	5225.5			1924.4	165.8	197.9	0.7		2538.7
1979	3344.0	5441.1			2098.0	205.6	26.6	45.8		2244.3
1980	8194.8	9629.9		6.4	1765.3	443.6	37.1			1647.3

Table 6. Washington rockfish landings from U.S. waters, 1956-1962, by PMFC area. Estimates are based on PMFC Data Series landings (areas 3A, 3B, and 3C) from all reporting agencies multiplied by catch-weighted fractions of Washington landings by PMFC area (1963-1967).

YEAR	3A	3B	3C	Total
1956	19.3	918.6	469.6	1407.5
1957	38.8	572.5	531.8	1143.1
1958	36.5	814.8	449.1	1300.4
1959	24.2	749.2	709.5	1482.9
1960	31.4	977.3	784.4	1793.1
1961	37.1	1102.4	803.3	1942.9
1962	68.5	1009.7	1534.2	2612.4

Table 7. Species compositions derived from total weight of rockfish catch by species reported by Tagart (1985) for the years 1969-1976.

Species	Composition
S. aleutianus	0.1%
S. alutus	21.9%
S. babcocki	0.2%
S. brevispinis	0.8%
S. crameri	1.9%
S. diploproa	0.7%
S. elongatus	0.0%
S. entomelas	0.7%
S. flavidus	45.4%
S. helvomaculatus	0.0%
S. maliger	0.0%
S. melanops	0.6%
S. paucispinis	0.2%
S. pinniger	21.8%
S. proriger	0.1%
S. reedi	0.4%
S. ruberrimus	0.0%
S. zacentrus	0.2%
Sb. alascanus	0.0%
Unidentified	4.7%

Table 8. Washington landings of rockfish (mt) from Pacific Fisherman yearbooks (I. Stewart, NMFS, pers. comm.). Alverson (1957) reported the fraction of Washington rockfish catch from U.S. waters in 1953, separately for POP and the "other rockfish" categories. Prior to 1952 the average fraction for the two categories is applied.

	WA Rockfish Landings Source: Pacific Fisherman				Estimated
Year	Rockfish - trawl	POP	Total	Assumed fraction of catch from U.S. waters	WA rockfish landings from U.S. waters
1942	469.2		469.2	0.123	57.7
1943	2025.2		2025.2	0.123	249.1
1944	2327.9		2327.9	0.123	286.3
1945	7300.0		7300.0	0.123	897.9
1946	4578.7		4578.7	0.123	563.2
1947	2732.7		2732.7	0.123	336.1
1948	4655.0		4655.0	0.123	572.6
1949	5720.0		5720.0	0.123	703.6
1950	5538.6		5538.6	0.123	681.2
1951	4508.5		4508.5	0.123	554.5
1952	5120.2	768.5	5888.7	(RF=0.149, POP=0.097)	837.5
1953	3165.7	1406.8	4572.5	(RF=0.149, POP=0.097)	608.2
1954	5832.1	2835.0	8667.1	(RF=0.149, POP=0.097)	1144.0
1955	4119.6	1587.0	5706.7	(RF=0.149, POP=0.097)	767.8

Table 9. Assumed discard ratios (discard / retained). See text for sources and details.

Species Code	Pikitch et al., 1988	WCGOP Trawl Reports	Comments
ARRA	0.393	0.983	slope rockfish rate
BRWN		0.113	
BYEL		0.130	nearshore rockfish rate
CHNA		0.130	nearshore rockfish rate
COPP		0.130	nearshore rockfish rate
DSRK		0.000	discard accounted for by Taylor (2008)
FLAG		0.447	shelf rockfish rate
GBLC		0.447	shelf rockfish rate
GRAS		0.130	nearshore rockfish rate
GSPT		0.010	
KLPG_CA		0.000	Cope and MacCall, 2005
KLPR		0.130	nearshore rockfish rate
LSRK		0.000	high survival
OLVE		0.130	nearshore rockfish rate
PDAB	3.165	1.156	unspecified flatfish rate
PNKR		0.983	slope rockfish rate
QLBK		0.130	nearshore rockfish rate
RDBD	0.112	0.983	slope rockfish rate
REDS	1.393	0.447	shelf rockfish rate
REX	0.559	0.174	
REYE	0.001	0.100	slope, retained
ROSY		0.447	shelf rockfish rate
RSOL	0.379	0.256	
RSTN	2.065	0.447	shelf rockfish rate
SHRP	2.219	0.983	slope rockfish rate
SLGR	0.019	0.447	shelf rockfish rate
SPKL		0.447	shelf rockfish rate
SRKR		0.100	slope, retained
SSOL	0.104	0.261	
STAR		0.447	shelf rockfish rate
STRK		0.447	shelf rockfish rate
SWSP		0.447	shelf rockfish rate
TREE		0.130	nearshore rockfish rate
VRML	0.007	0.050	shelf, but often retained
YMTH	0.008	0.983	slope rockfish rate

Table 10. DCAC distribution summary statistics based on 10,000 Monte Carlo simulations.

			quantiles				
Common Name	**Species Code**	**mean**	**2.50%**	**25%**	**50%**	**75%**	**97.50%**
Aurora rockfish	ARRA	32.2	13.9	24.6	31.8	39.5	52.9
Brown Rockfish	BRWN	116.8	78.6	107.2	119.5	129.4	140.9
Black-and-Yellow Rockfish	BYEL	12.5	8.7	11.5	12.8	13.7	14.9
China Rockfish	CHNA	17.0	10.0	14.9	17.3	19.3	22.1
Copper Rockfish	COPP	132.1	78.8	116.6	134.6	149.7	169.9
Spiny dogfish	DSRK	1471.9	770.0	1243.2	1500.2	1719.4	2059.1
Flag Rockfish	FLAG	20.8	14.9	19.5	21.2	22.6	24.1
Greenblotched Rockfish	GBLC	23.0	15.5	21.1	23.5	25.4	27.7
Grass Rockfish	GRAS	32.0	23.4	30.1	32.7	34.5	36.8
Greenspotted Rockfish	GSPT	103.6	69.9	95.3	105.8	114.2	124.8
Kelp greenling (CA)	KLPG_CA	52.4	41.3	50.1	53.2	55.6	58.1
Kelp Rockfish	KLPR	13.8	10.1	13.0	14.1	15.0	16.0
Leopard shark	LSRK	113.2	64.7	98.4	115.7	130.1	149.6
Olive Rockfish	OLVE	112.8	78.9	104.9	115.2	123.4	133.3
Pacific sanddab	PDAB	1275.5	759.6	1123.7	1301.9	1451.7	1651.5
Pink Rockfish	PNKR	2.1	1.1	1.8	2.1	2.4	2.9
Quillback Rockfish	QLBK	7.5	3.9	6.3	7.6	8.7	10.4
Redbanded Rockfish	RDBD	49.4	23.4	39.3	49.5	59.5	74.7
Redstripe Rockfish	REDS	262.8	127.6	216.4	266.0	312.4	378.2
Rex sole	REX	1181.7	776.9	1072.1	1208.2	1319.0	1442.6
Rougheye Rockfish	REYE	36.5	12.4	25.5	35.0	46.2	68.3
Rosy Rockfish	ROSY	19.4	15.9	18.7	19.7	20.4	21.2
Rock sole	RSOL	16.3	9.3	14.3	16.7	18.6	21.3
Rosethorn Rockfish	RSTN	12.7	5.8	10.3	12.8	15.2	19.0
Sharpchin Rockfish	SHRP	205.2	101.0	169.9	207.0	243.1	296.3
Silvergray Rockfish	SLGR	153.4	68.0	120.2	152.7	186.2	240.7
Speckled Rockfish	SPKL	29.1	19.3	26.7	29.8	32.3	35.3
Shortraker Rockfish	SRKR	16.0	5.4	10.8	15.1	20.2	31.7
Sand sole	SSOL	147.0	118.8	141.5	149.6	155.1	161.2
Starry Rockfish	STAR	39.0	29.0	36.9	39.8	42.0	44.4
Stripetail Rockfish	STRK	36.5	23.6	33.3	37.3	40.6	44.8
Swordspine Rockfish	SWSP	11.5	6.8	10.2	11.8	13.0	14.7
Treefish	TREE	6.3	4.6	5.9	6.4	6.8	7.3
Vermillion Rockfish	VRML	177.5	112.0	159.1	181.1	199.6	223.8
Yellowmouth Rockfish	YMTH	148.3	61.8	112.7	146.2	181.5	247.5

Table 11. OFL distribution summary statistics from DB-SRA for 2011.

Common Name	Mean	2.50%	25%	50%	75%	97.50%
Aurora rockfish	74.9	2.9	18.5	47.5	97.8	303.1
Brown Rockfish	278.1	42.4	118.3	201.2	333.5	1002.5
Black-and-Yellow Rockfish	37.8	5.6	15.8	27.0	45.7	138.7
China Rockfish	48.0	2.1	12.3	31.5	64.1	189.0
Copper Rockfish	271.6	12.8	74.6	187.0	368.1	1037.6
Spiny dogfish	3393.0	145.8	857.1	2229.8	4610.4	13328.6
Flag Rockfish	37.5	1.8	10.1	26.6	51.4	136.7
Greenblotched Rockfish	40.4	1.8	10.5	27.7	52.6	150.0
Grass Rockfish	75.2	12.1	32.6	55.3	91.8	273.3
Greenspotted Rockfish	306.9	45.3	124.4	217.5	372.8	1136.4
Kelp greenling (CA)	148.0	24.8	64.1	107.4	179.3	548.7
Kelp Rockfish	36.4	5.8	15.4	26.1	43.1	129.2
Leopard shark	245.4	10.8	66.3	164.6	331.5	944.9
Olive Rockfish	264.2	40.9	110.0	189.1	315.0	970.0
Pacific sanddab	6227.7	1123.1	2881.5	4966.9	8112.3	18939.7
Pink Rockfish	4.2	0.2	1.1	2.8	5.8	16.4
Quillback Rockfish	22.8	1.0	5.6	14.2	30.4	92.8
Redbanded Rockfish	86.7	3.8	22.8	57.8	118.6	335.3
Redstripe Rockfish	442.9	19.2	112.7	292.0	609.2	1761.2
Rex sole	5455.3	942.4	2498.0	4307.2	7068.7	16749.4
Rougheye Rockfish	96.3	3.0	20.7	53.8	120.2	429.7
Rosy Rockfish	54.4	9.0	23.7	38.9	65.3	194.9
Rock sole	86.1	14.0	38.7	66.1	111.0	273.4
Rosethorn Rockfish	25.9	1.1	6.6	16.9	35.2	102.4
Sharpchin Rockfish	375.9	16.5	99.5	251.8	509.3	1460.1
Silvergray Rockfish	278.7	11.6	70.9	181.3	376.9	1111.5
Speckled Rockfish	61.4	2.9	16.8	42.8	83.9	228.8
Shortraker Rockfish	39.3	1.2	8.0	20.9	47.6	184.8
Sand sole	939.7	170.6	437.1	756.4	1219.4	2777.9
Starry Rockfish	104.0	5.0	28.2	71.8	142.0	382.1
Stripetail Rockfish	77.1	12.3	32.5	55.9	92.7	278.2
Swordspine Rockfish	19.7	0.9	5.4	13.4	27.0	72.7
Treefish	18.6	2.9	7.8	13.4	22.1	69.9
Vermillion Rockfish	480.5	20.7	119.5	312.1	654.5	1896.0
Yellowmouth Rockfish	265.8	32.9	102.1	181.3	321.9	1052.9

Table 12. Percentage of runs retained by DB-SRA analysis

Species Code	Percent Retained
ARRA	100%
BRWN	86%
BYEL	99%
CHNA	100%
COPP	85%
DSRK	85%
FLAG	73%
GBLC	69%
GRAS	75%
GSPT	80%
KLPG_CA	67%
KLPR	75%
LSRK	55%
OLVE	48%
PDAB	88%
PNKR	78%
QLBK	100%
RDBD	99%
REDS	79%
REX	76%
REYE	100%
ROSY	35%
RSOL	94%
RSTN	97%
SHRP	85%
SLGR	91%
SPKL	69%
SRKR	100%
SSOL	43%
STAR	80%
STRK	63%
SWSP	23%
TREE	98%
VRML	99%
YMTH	95%

Table 13. Assumed catch in 2010 (the average of 2008-09 catch), median OFL in 2010, and the probability that the assumed 2010 catch exceeds the OFL. Probabilities > 50% are in bold italics.

	Assumed 2010 Catch (avg. of 2008-09 Catch)	**Median OFL, 2010**	**Probability that Assumed Catch Exceeds the 2010 OFL**
Aurora rockfish	28.7	46.4	37%
Brown Rockfish	80.9	194.1	13%
Black-and-Yellow Rockfish	22.2	26.8	40%
China Rockfish	33.4	32.0	***51%***
Copper Rockfish	65.0	179.0	23%
Spiny dogfish	839.2	2098.2	25%
Flag Rockfish	5.3	25.0	12%
Greenblotched Rockfish	0.7	26.0	0%
Grass Rockfish	24.1	53.4	16%
Greenspotted Rockfish	11.2	208.8	0%
Kelp greenling (CA)	13.7	101.4	0%
Kelp Rockfish	5.5	24.4	2%
Leopard shark	37.6	148.6	16%
Olive Rockfish	34.6	180.3	2%
Pacific sanddab	408.9	4546.2	0%
Pink Rockfish	0.0	2.7	0%
Quillback Rockfish	15.8	14.8	***52%***
Redbanded Rockfish	22.1	56.9	25%
Redstripe Rockfish	0.4	287.0	0%
Rex sole	595.1	4280.9	1%
Rougheye Rockfish	127.6	54.3	***76%***
Rosy Rockfish	6.0	37.3	1%
Rock sole	5.3	62.8	0%
Rosethorn Rockfish	0.2	17.0	0%
Sharpchin Rockfish	1.8	239.0	0%
Silvergray Rockfish	0.9	173.9	0%
Speckled Rockfish	5.1	40.9	6%
Shortraker Rockfish	18.0	21.9	44%
Sand sole	41.0	707.7	0%
Starry Rockfish	23.6	68.3	22%
Stripetail Rockfish	0.1	52.9	0%
Swordspine Rockfish	0.0	13.1	0%
Treefish	7.7	12.9	25%
Vermillion Rockfish	136.2	318.4	28%
Yellowmouth Rockfish	3.6	177.3	0%

Figures

Figure 1. Box-and-whisker plots of distributions of OFL relative to MSY_{SPR} (point estimate) from stock assessments, used for bias-correction of OFL distributions of unassessed species. Thick black lines = medians, box = inter-quartile ranges, whiskers = 2.5% and 97.5% quantiles, circles = means. Dotted line is unity. “All.spp” is the combination of relative distributions from 31 stock assessment comparisons. Productivity-based distributions represent flatfish species, non-flatfish high-productivity species, and non-flatfish low-productivity species.

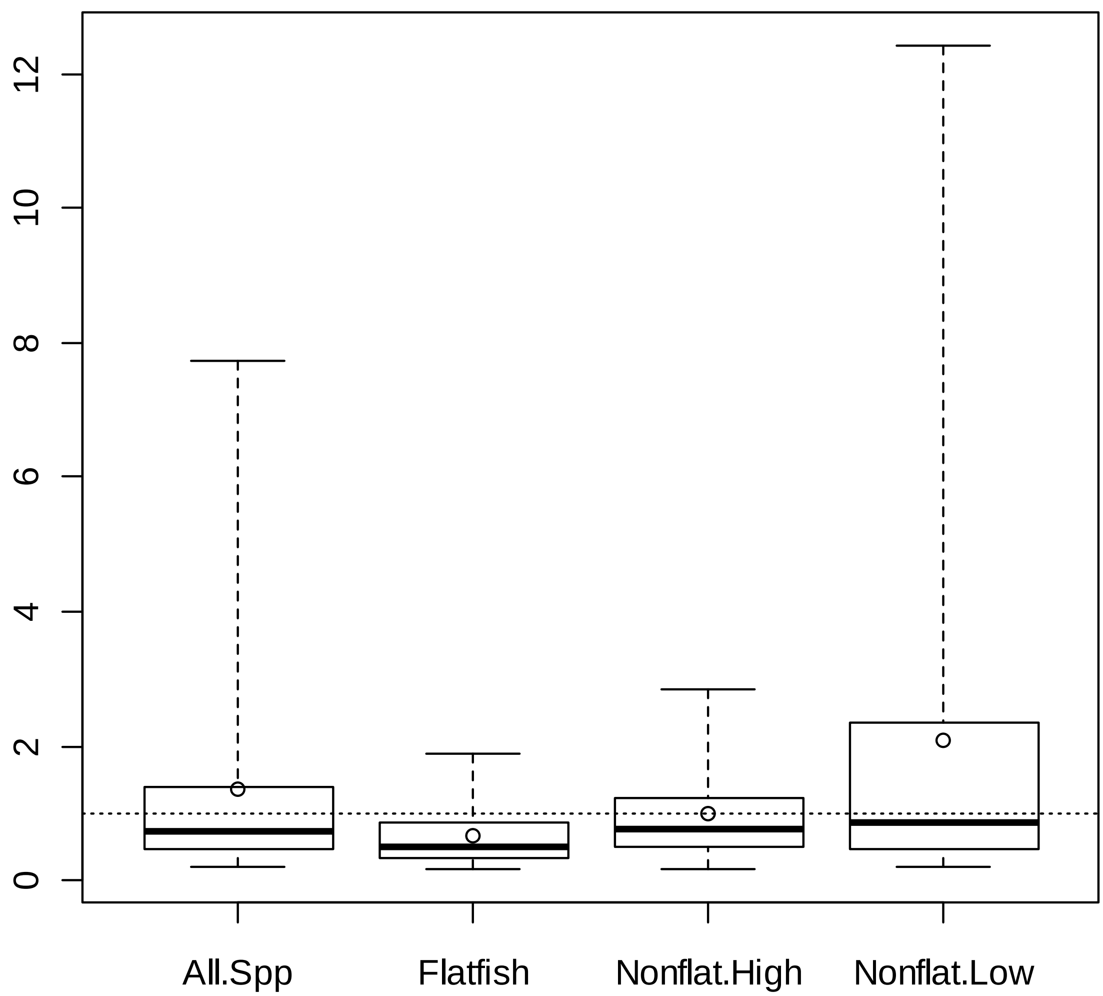


Figure 2. Oregon rockfish landings: trawl landings as a percentage of all gears (solid line) and cumulative percentage of landings from 1927-1980 (dotted line). Source: Oregon commercial catch reconstruction for rockfishes landed by trawl gears (V. Gertseva, pers. comm., February 2010).

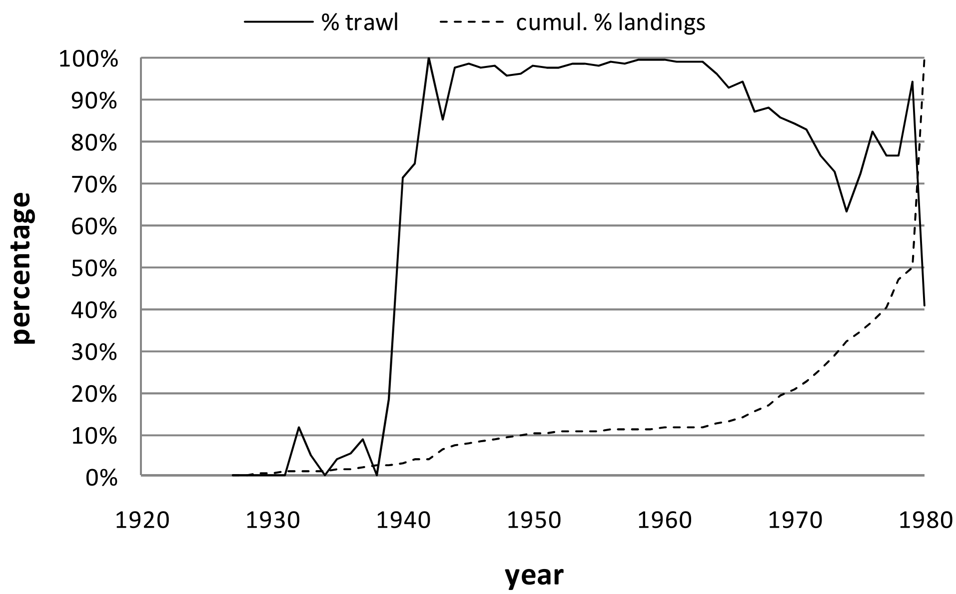


Figure 3. Estimated U.S. and Canadian landings of rex sole originating from PMFC areas 2A-3B, by use category (PMFC Data Series).

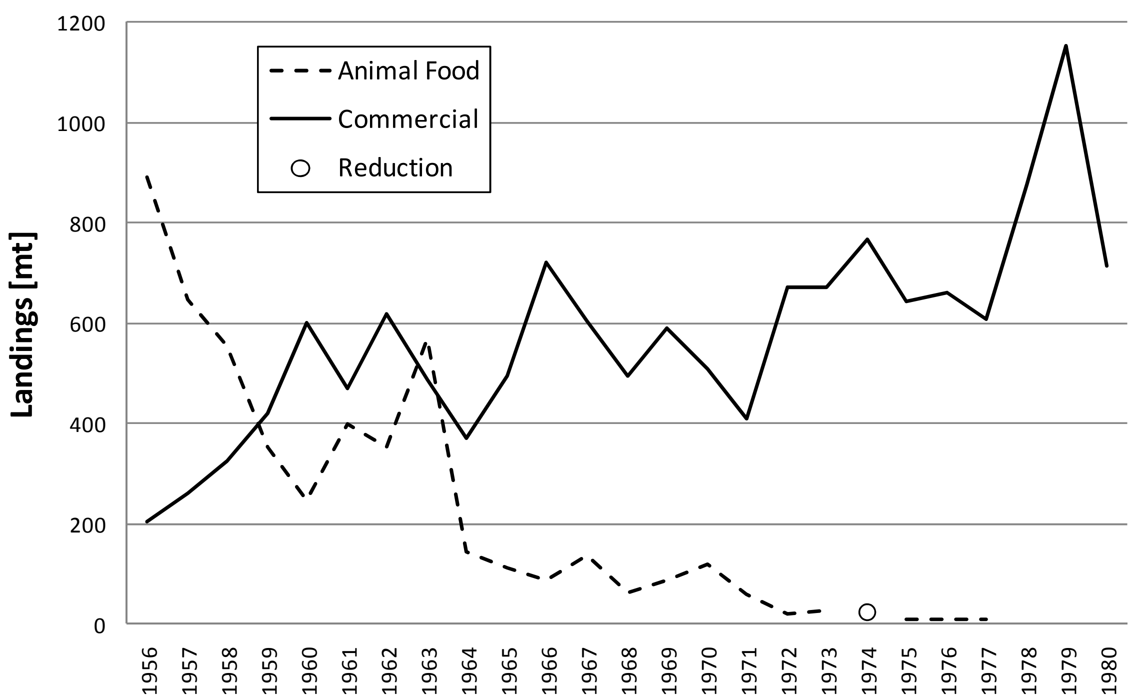


Figure 4. Comparison of landings (mt) reported as rex sole from California Landing Receipts and the Pacific Marine Fisheries Commission (PMFC) Data Series for PMFC areas 1A-1C, 1956-1968.

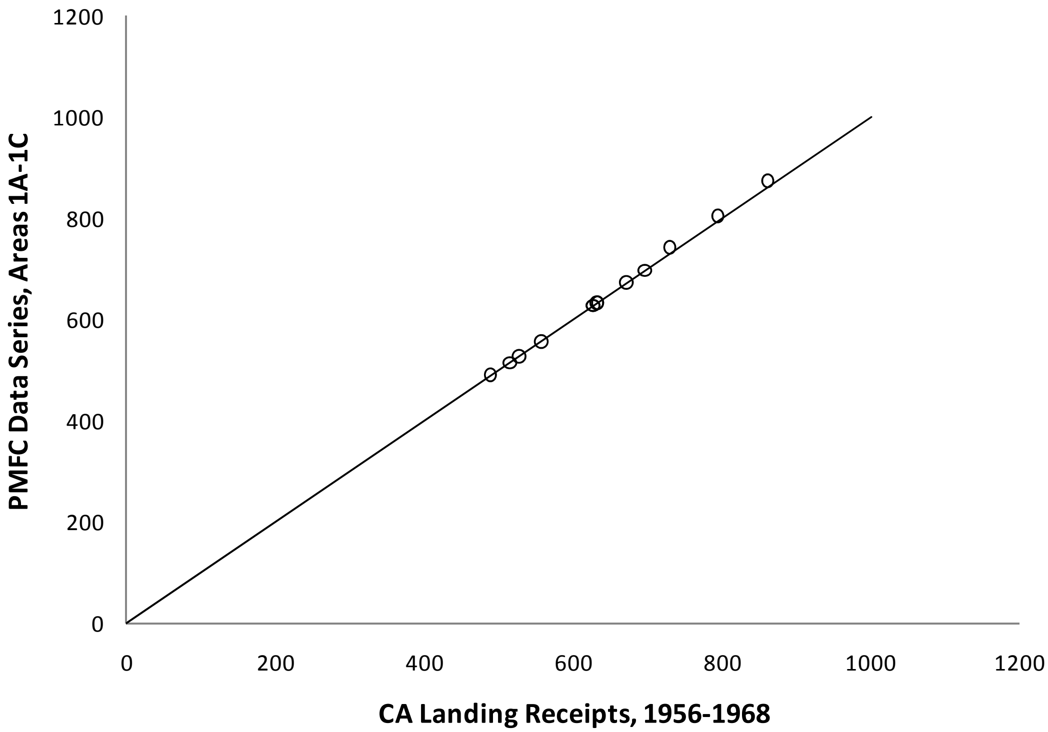


Figure 5. Estimated Oregon, Washington and Canadian landings of rex sole caught in U.S. waters, by PMFC area.

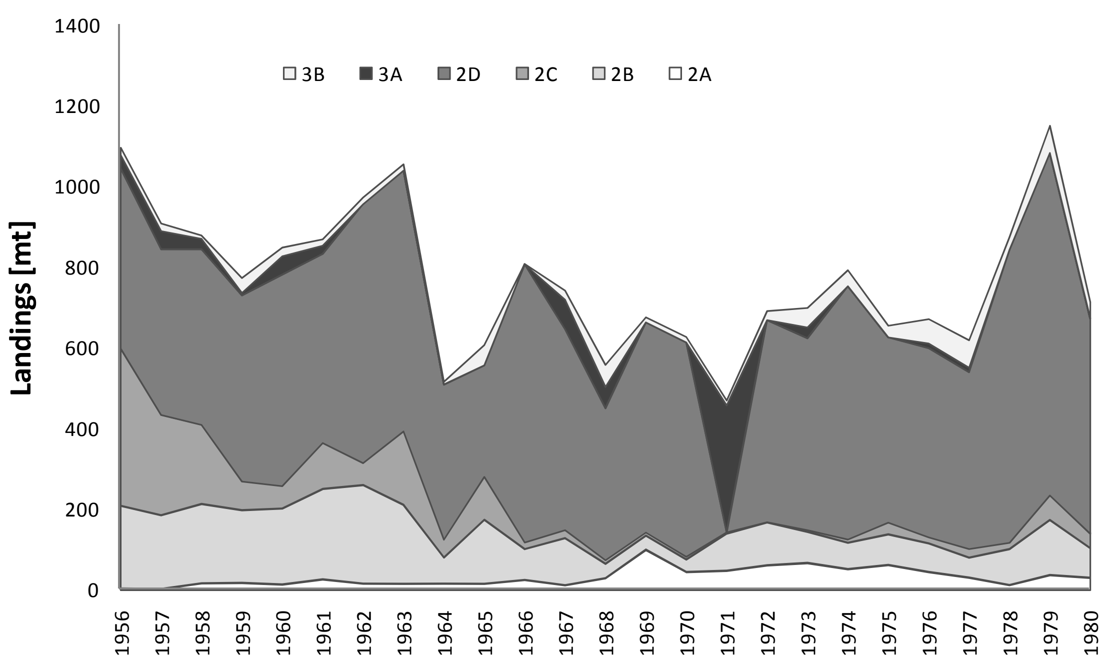


Figure 6. Estimated U.S. and Canadian landings of rock sole originating from PMFC areas 2A-3B (PMFC Data Series).

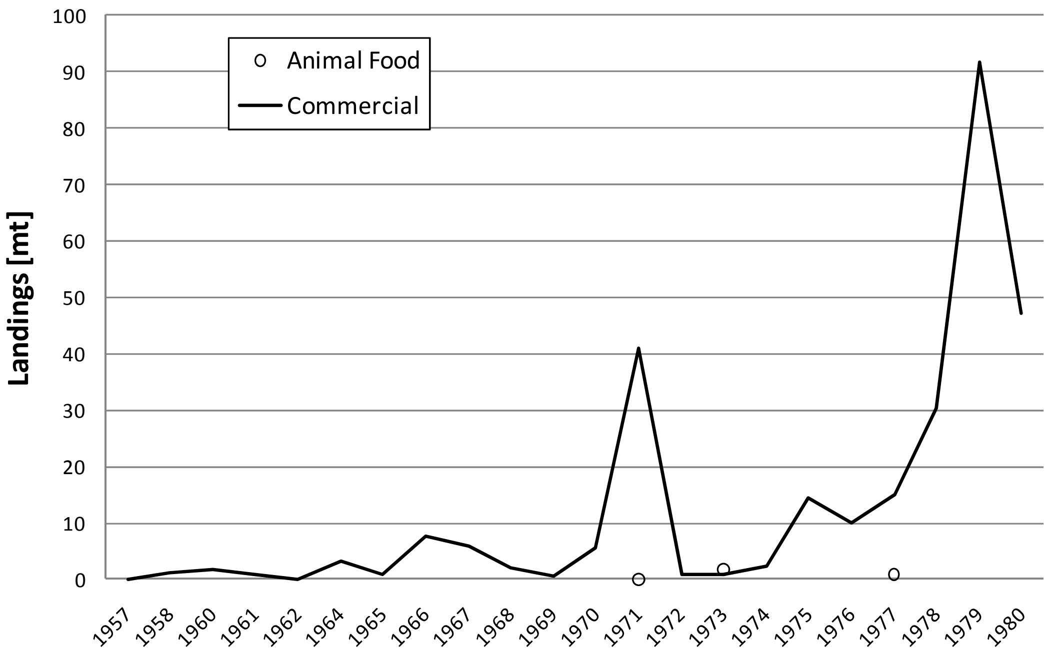


Figure 7. Estimated Washington landings of sand sole from PMFC areas 3A and 3B (Source: WDFW Data Reports and Progress Reports, 1963-1980).

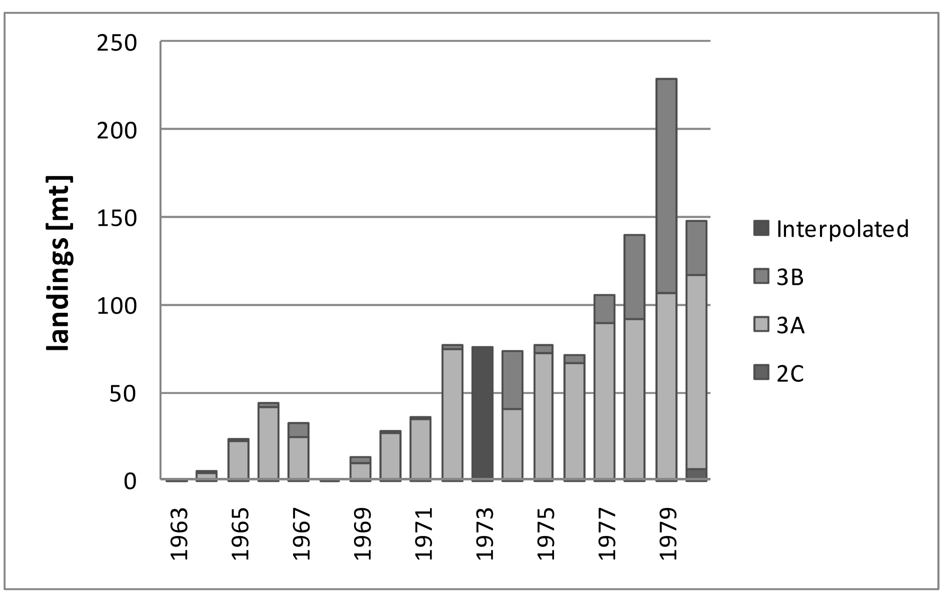


Figure 8. Estimated historical Washington landings of trawl-caught rockfish originating from U.S. waters. See text for description of methods and sources.

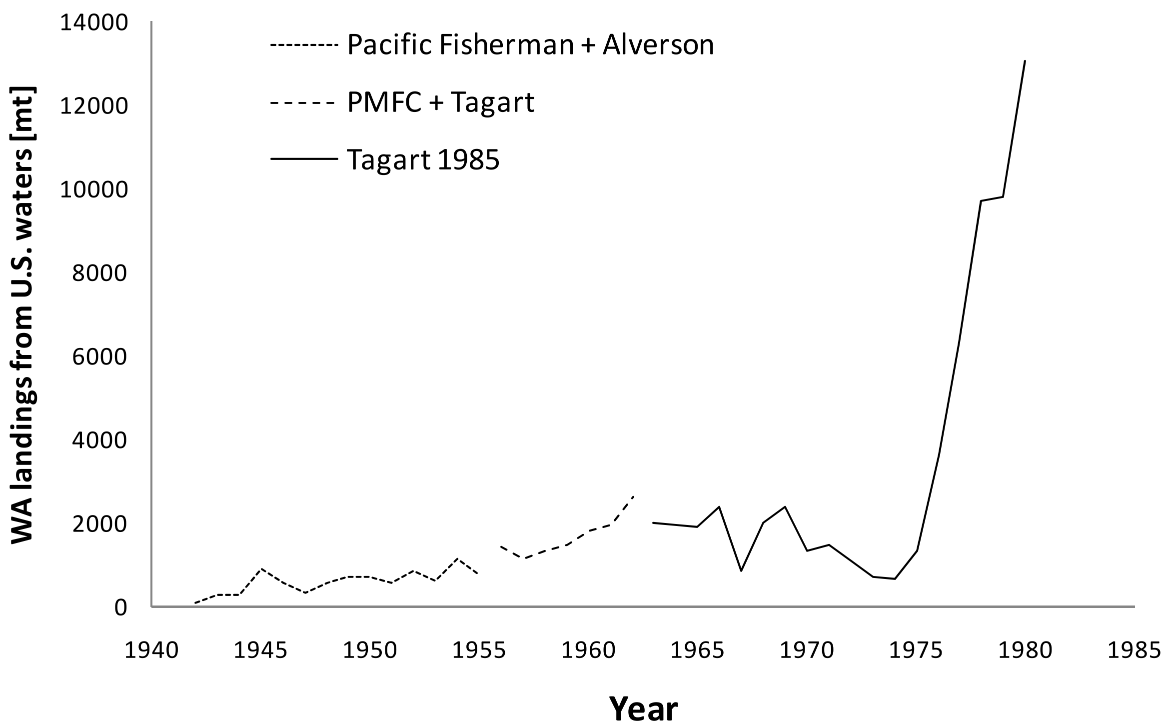


Figure 9. Distributions of DCAC [mt] for unassessed species in the Pacific Coast Groundfish FMP. Solid circles indicate median values.

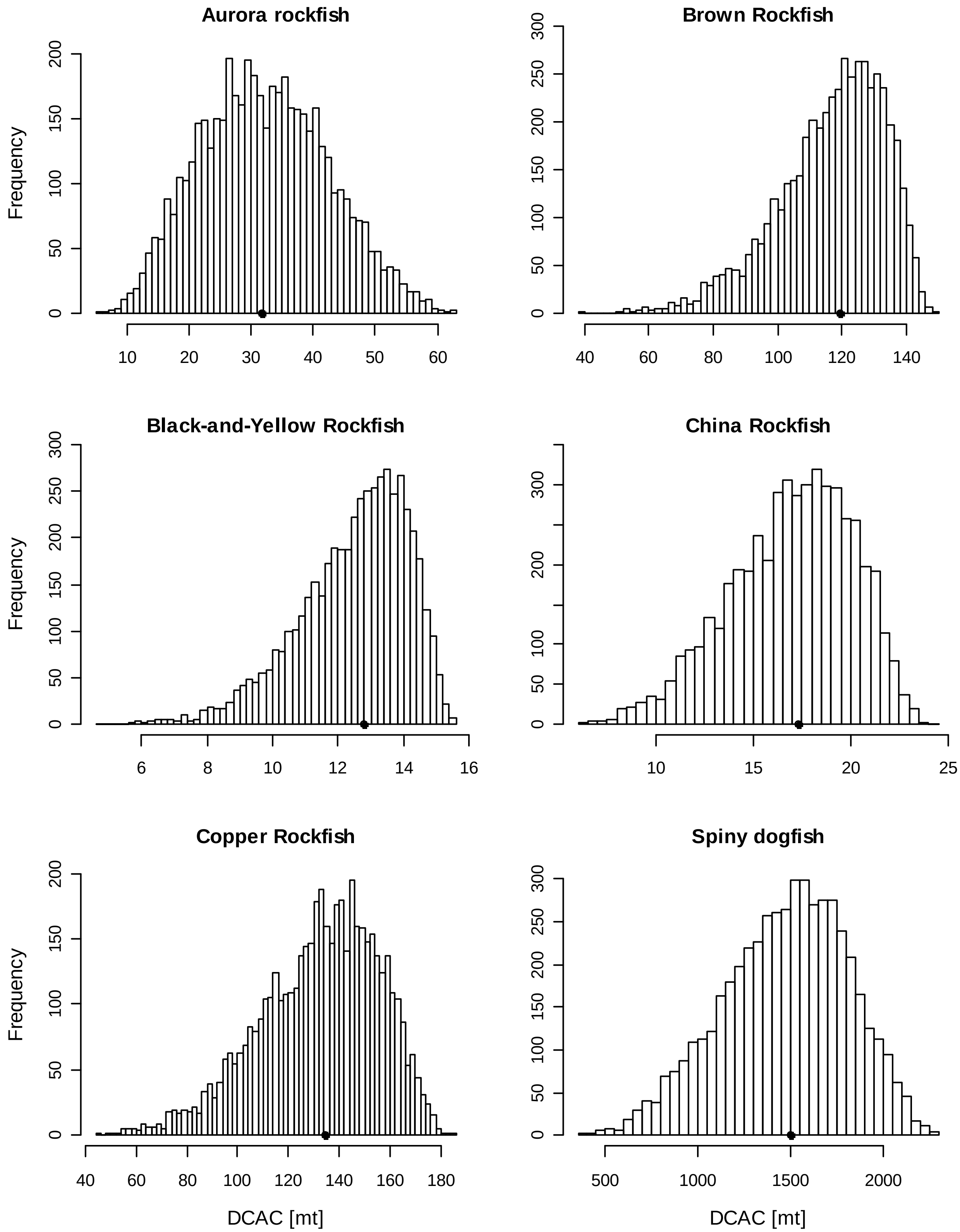


Figure 9 (Continued). Distributions of DCAC [mt] for unassessed species in the Pacific Coast Groundfish FMP. Solid circles indicate median values.

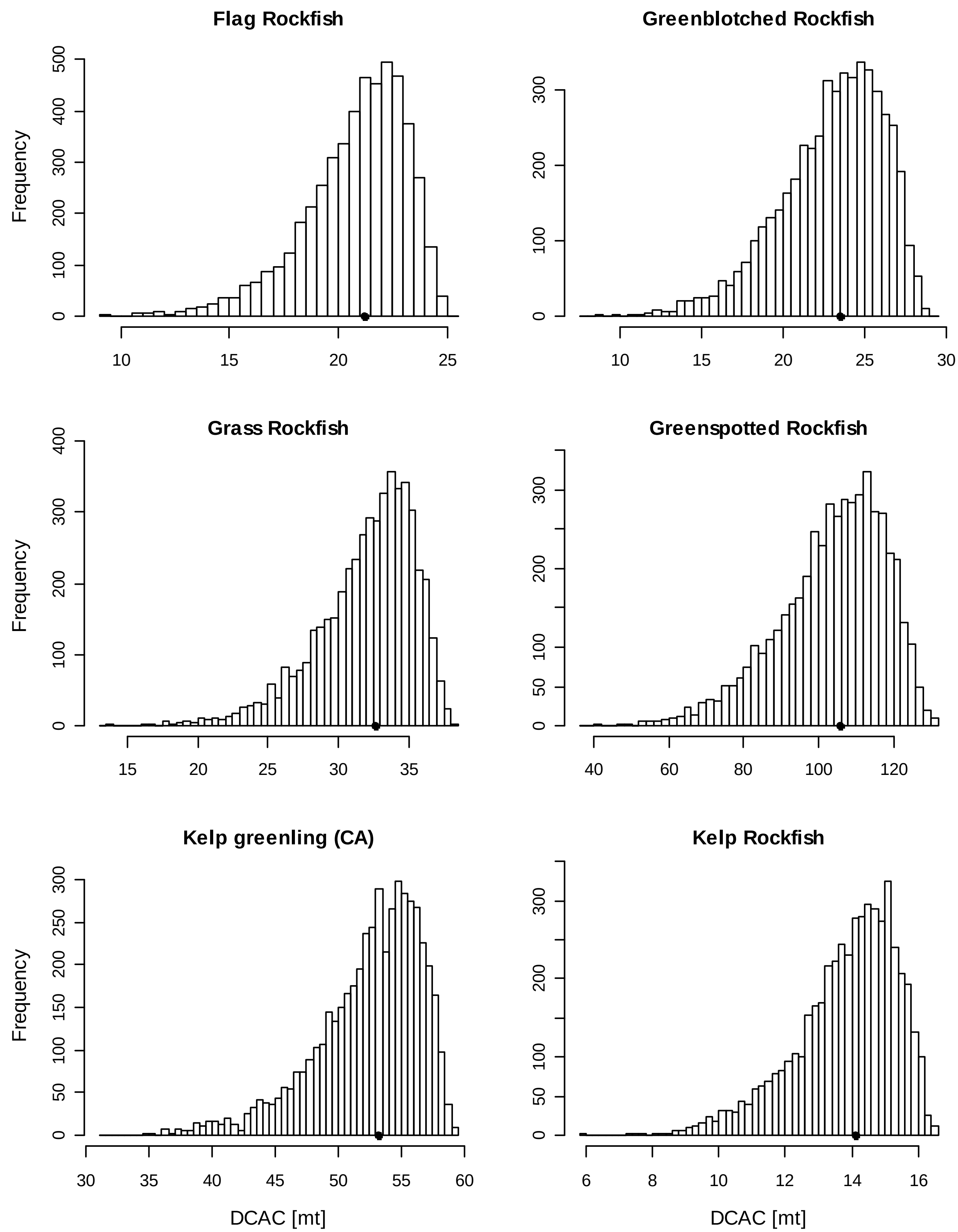


Figure 9 (Continued). Distributions of DCAC [mt] for unassessed species in the Pacific Coast Groundfish FMP. Solid circles indicate median values.

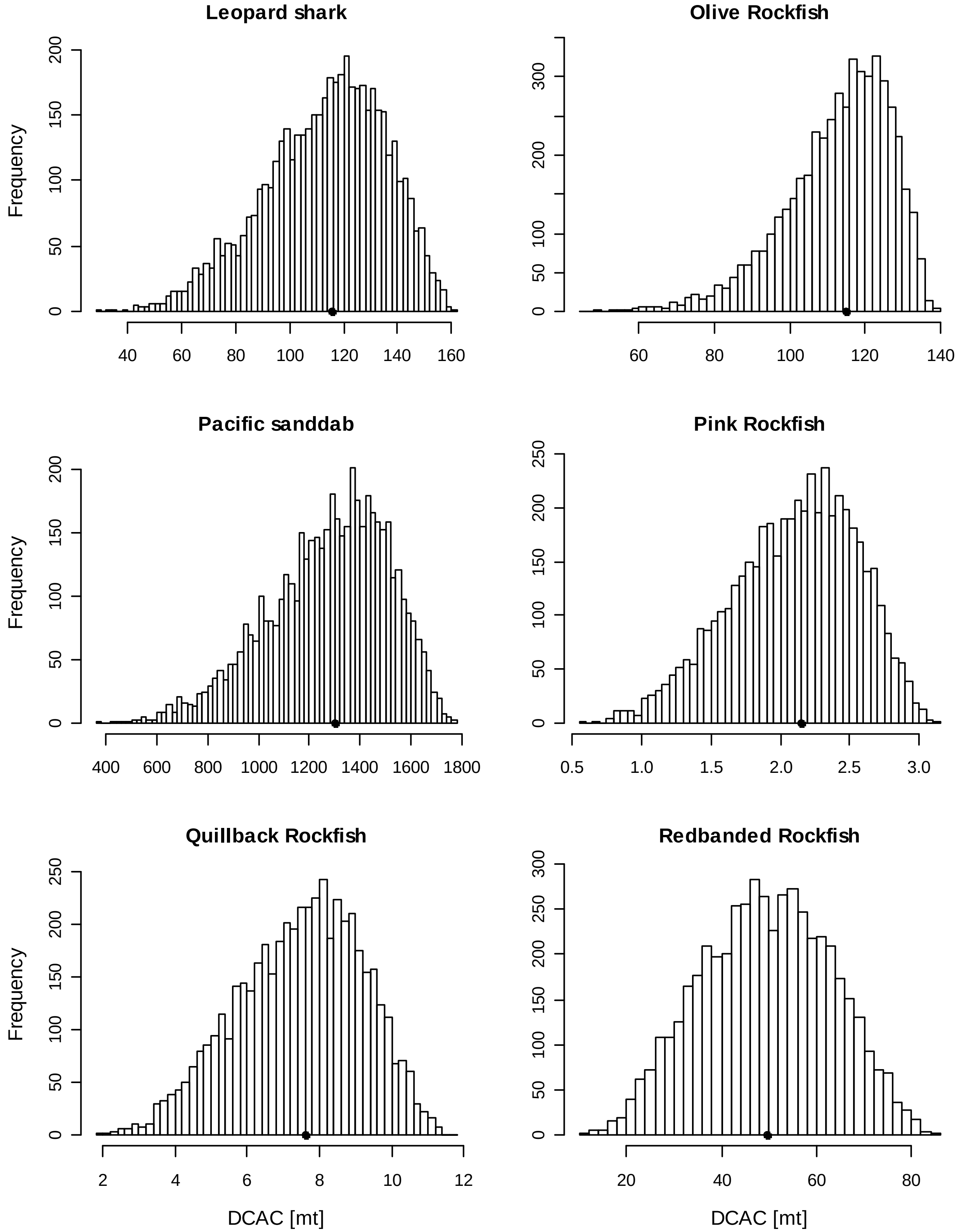


Figure 9 (Continued). Distributions of DCAC [mt] for unassessed species in the Pacific Coast Groundfish FMP. Solid circles indicate median values.

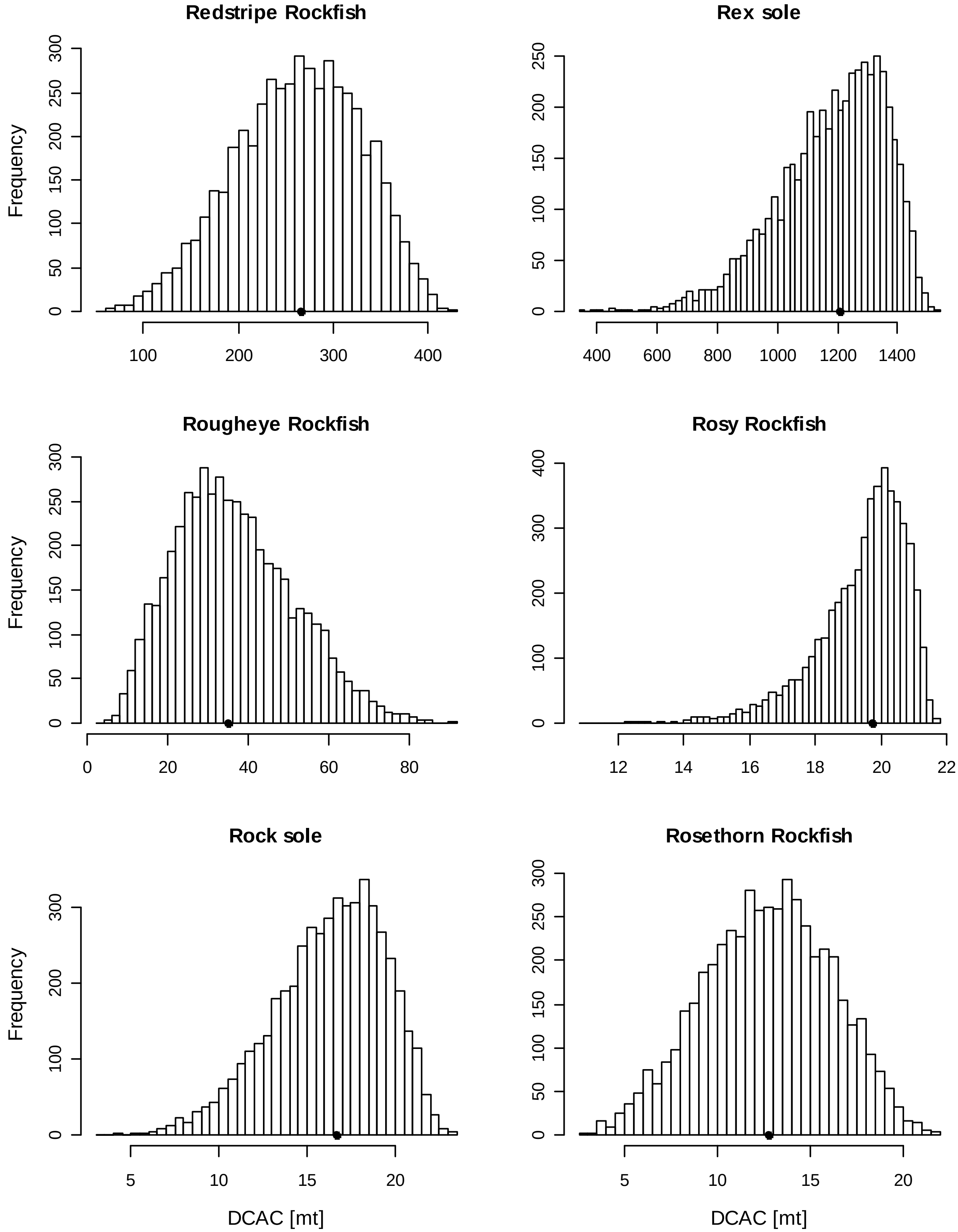


Figure 9 (Continued). Distributions of DCAC [mt] for unassessed species in the Pacific Coast Groundfish FMP. Solid circles indicate median values.

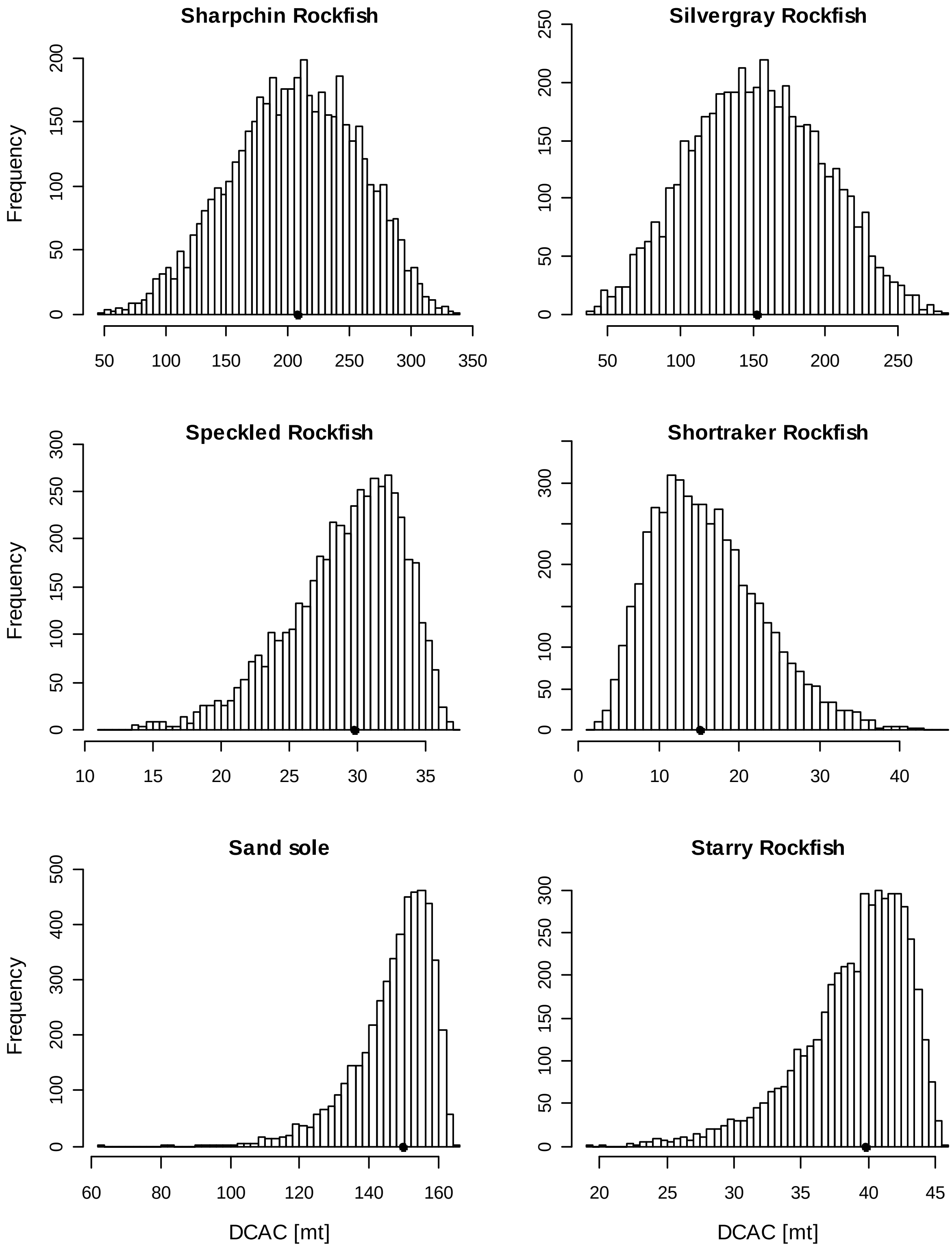


Figure 9 (Continued). Distributions of DCAC [mt] for unassessed species in the Pacific Coast Groundfish FMP. Solid circles indicate median values.

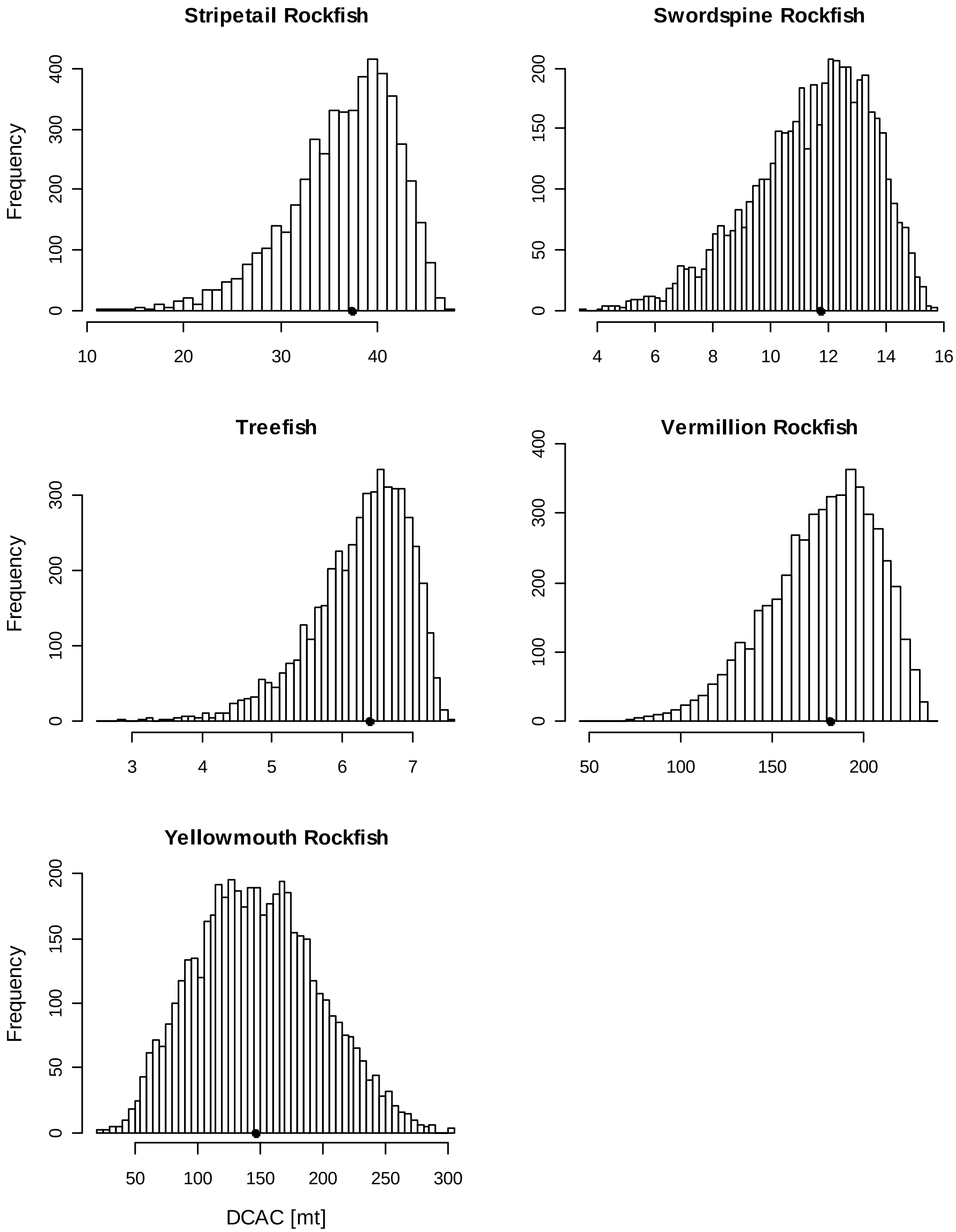


Figure 10. DB-SRA results for aurora rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

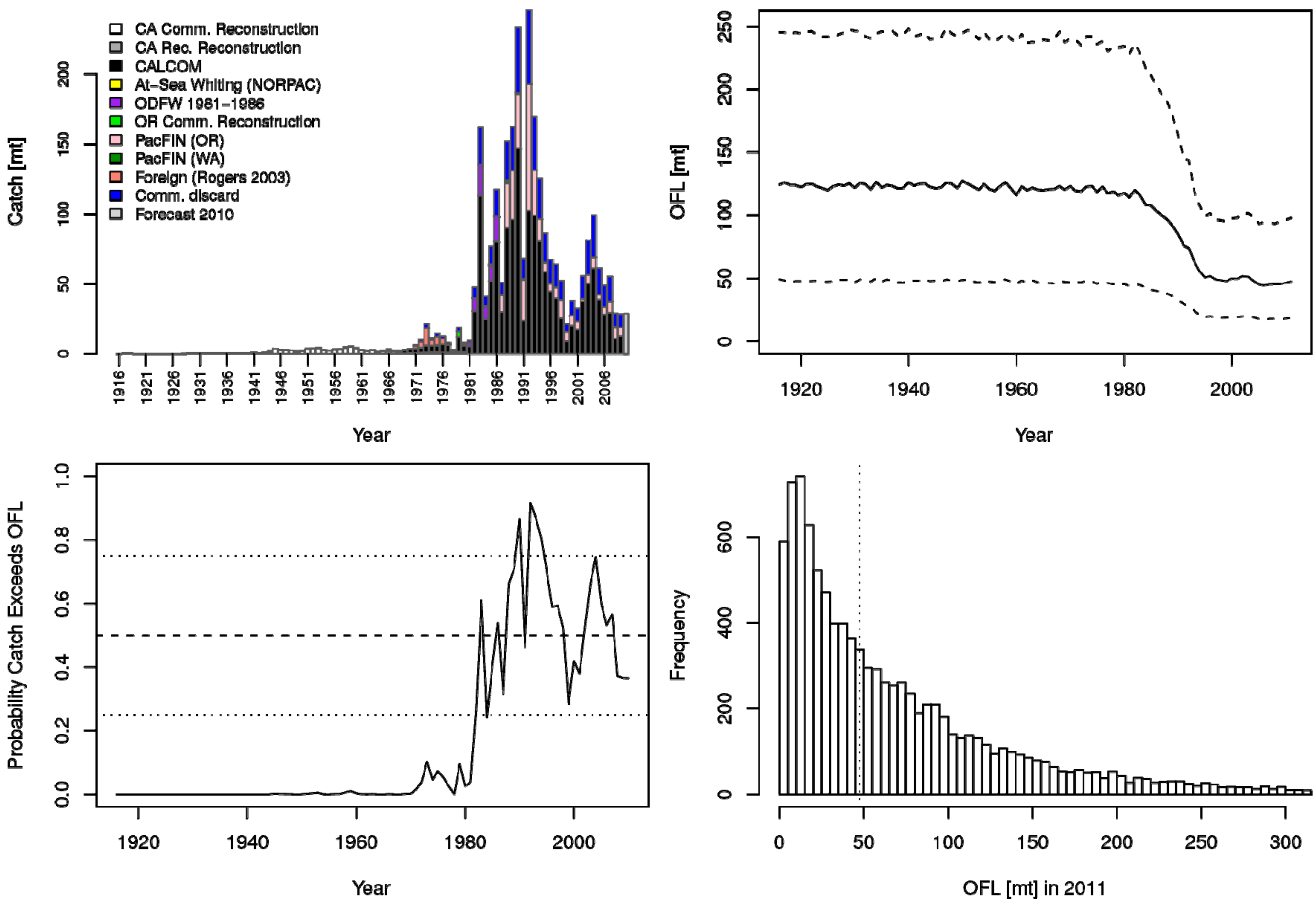


Figure 11. DB-SRA results for brown rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

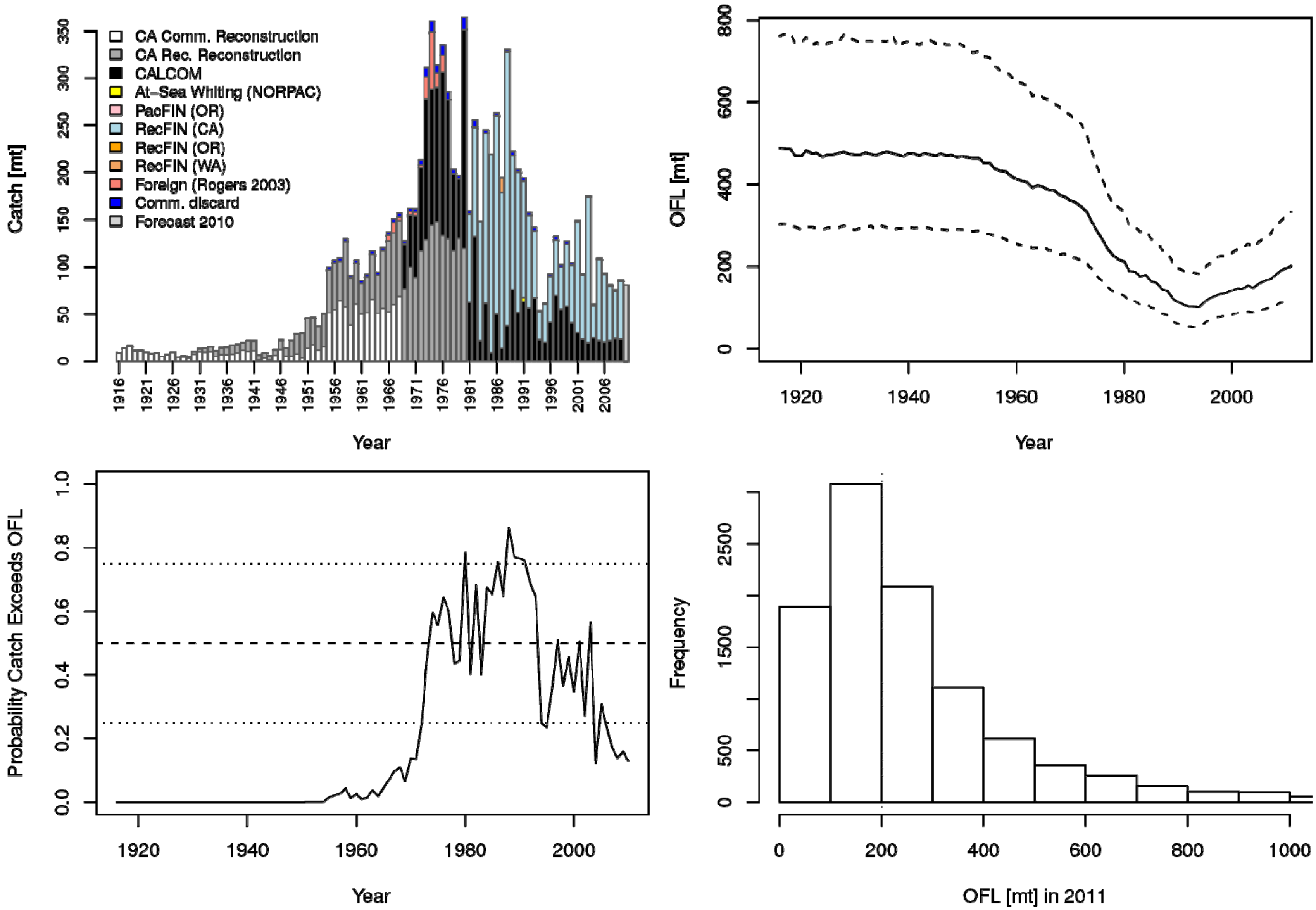


Figure 12. DB-SRA results for black-and-yellow rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

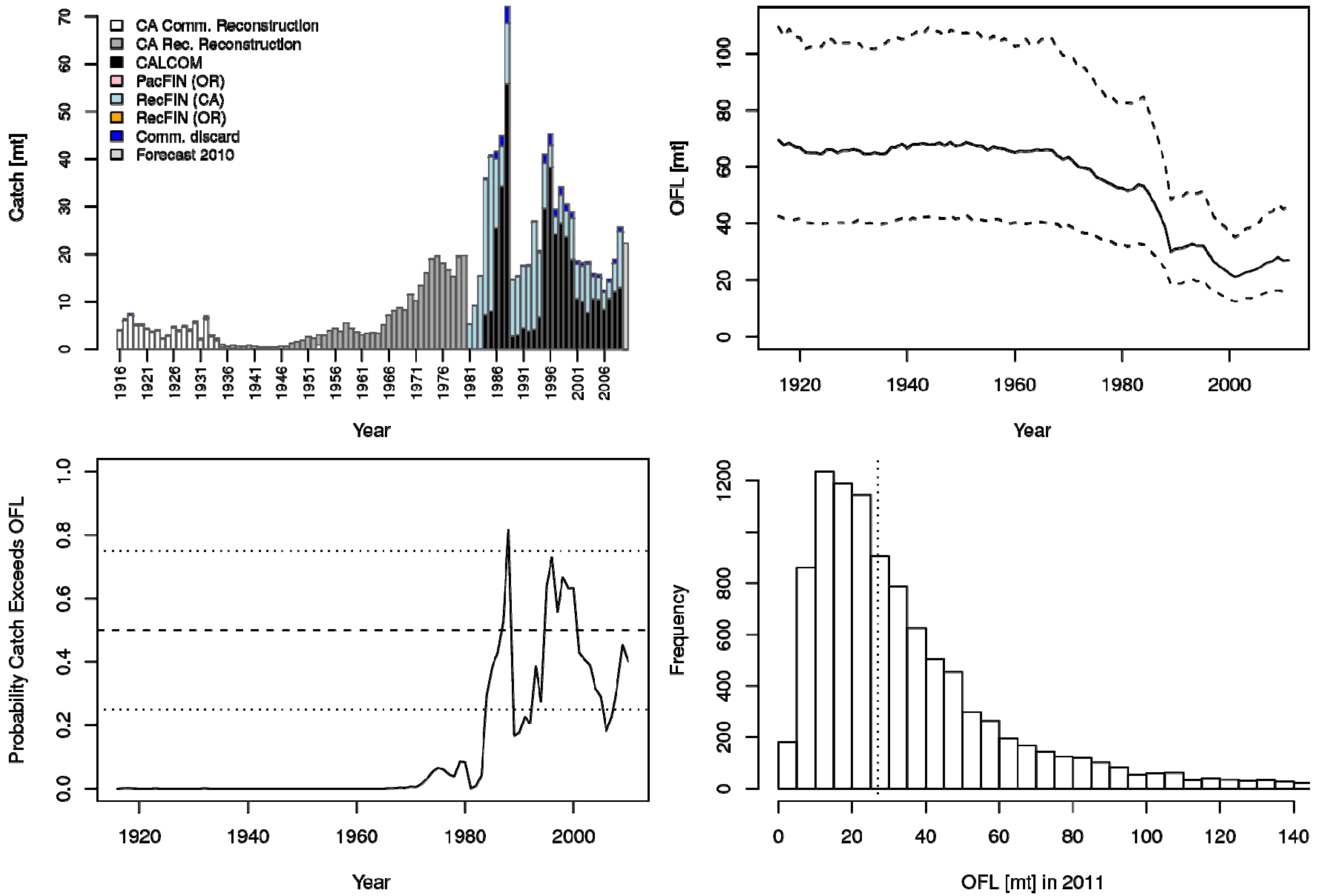


Figure 13. DB-SRA results for china rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

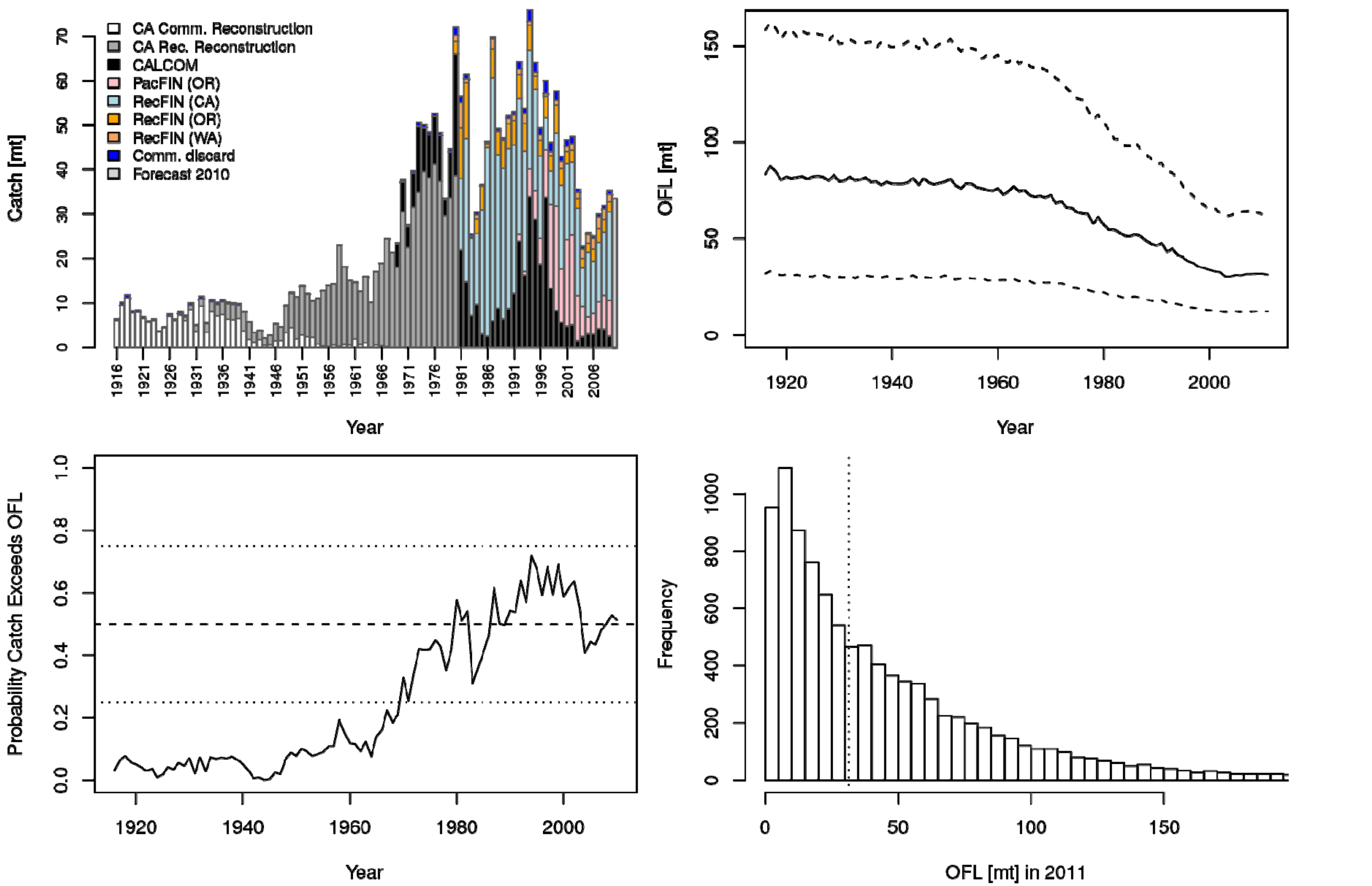


Figure 14. DB-SRA results for copper rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

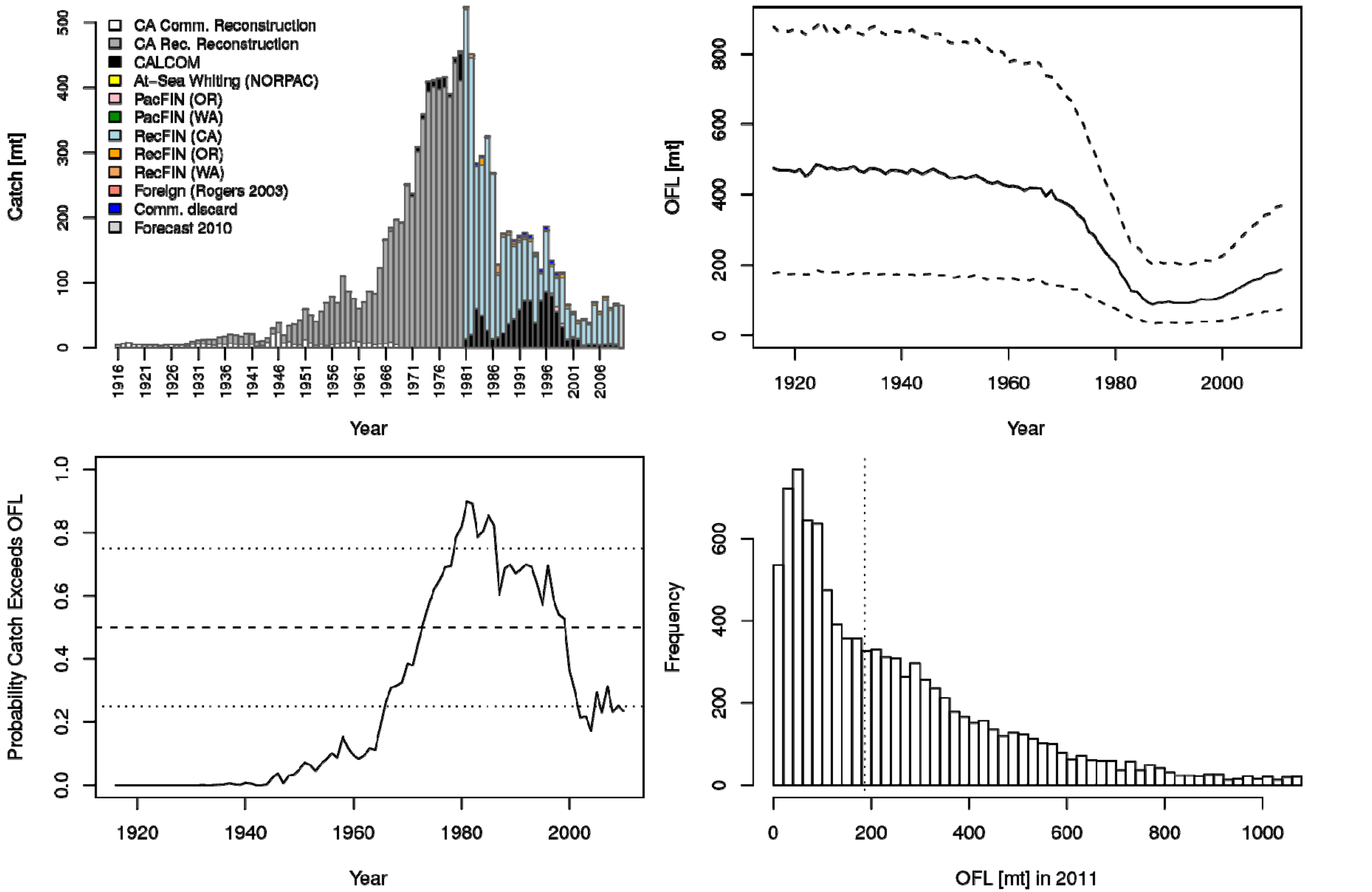


Figure 15. DB-SRA results for spiny dogfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

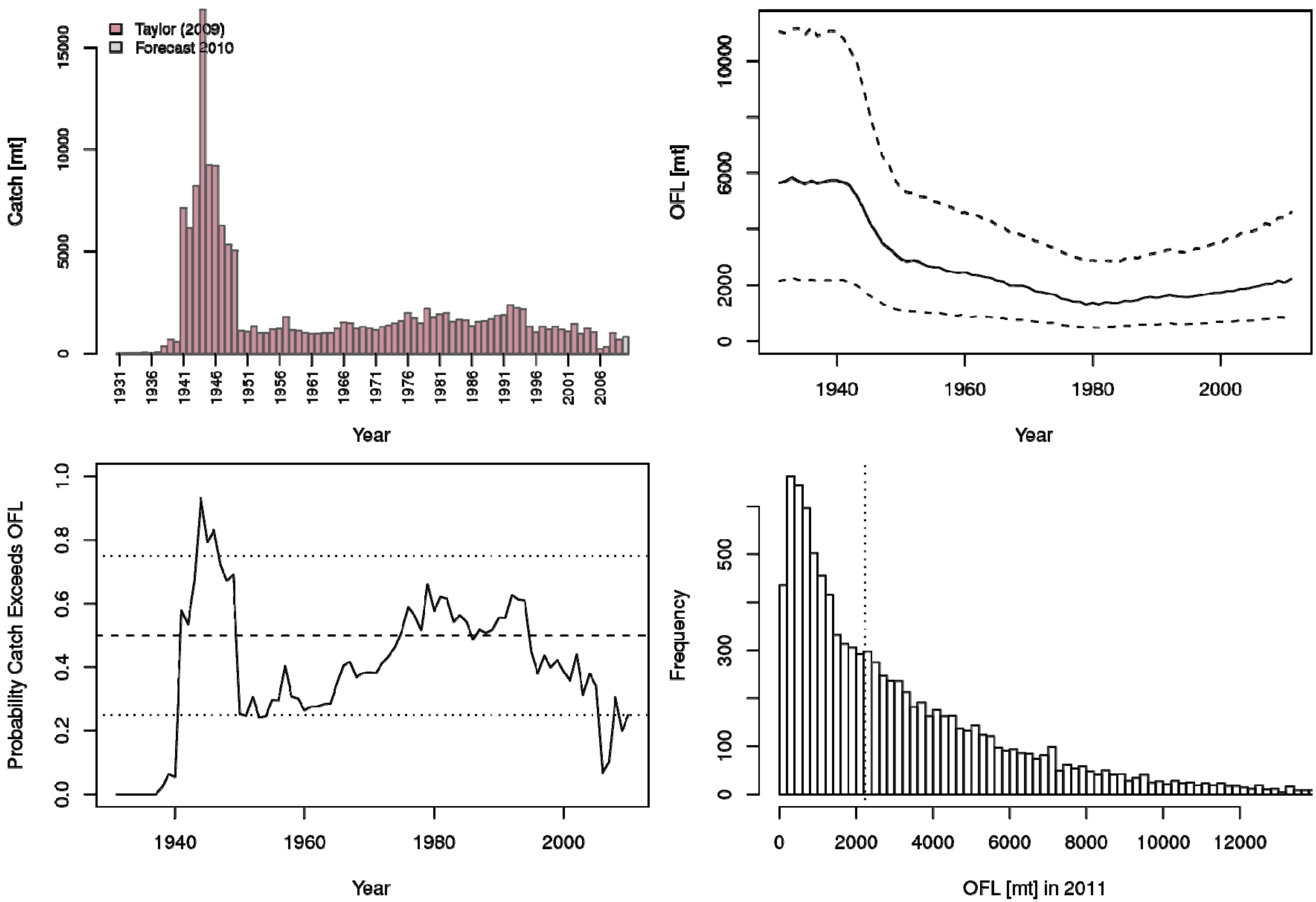


Figure 16. DB-SRA results for flag rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

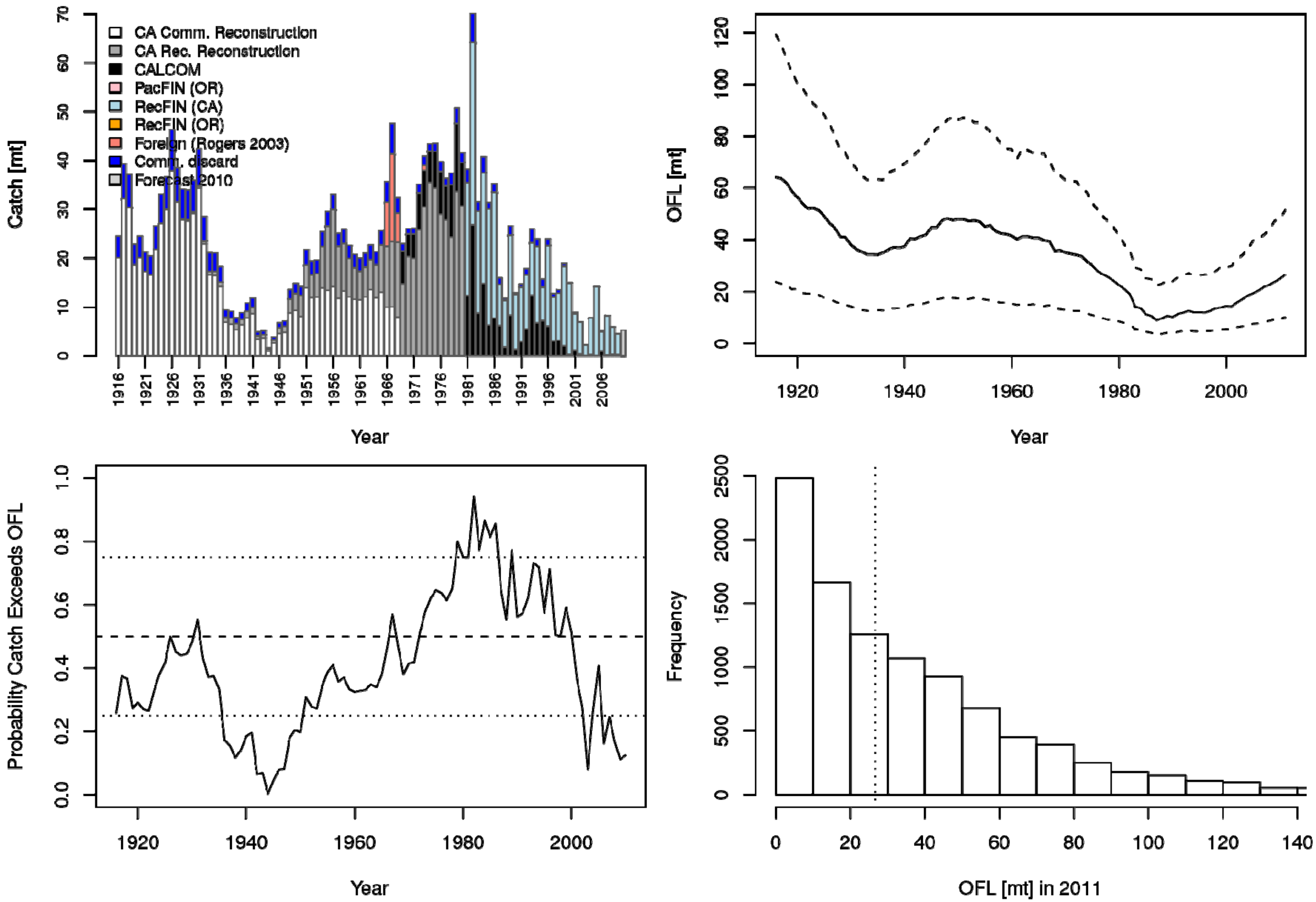


Figure 17. DB-SRA results for greenblotched rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

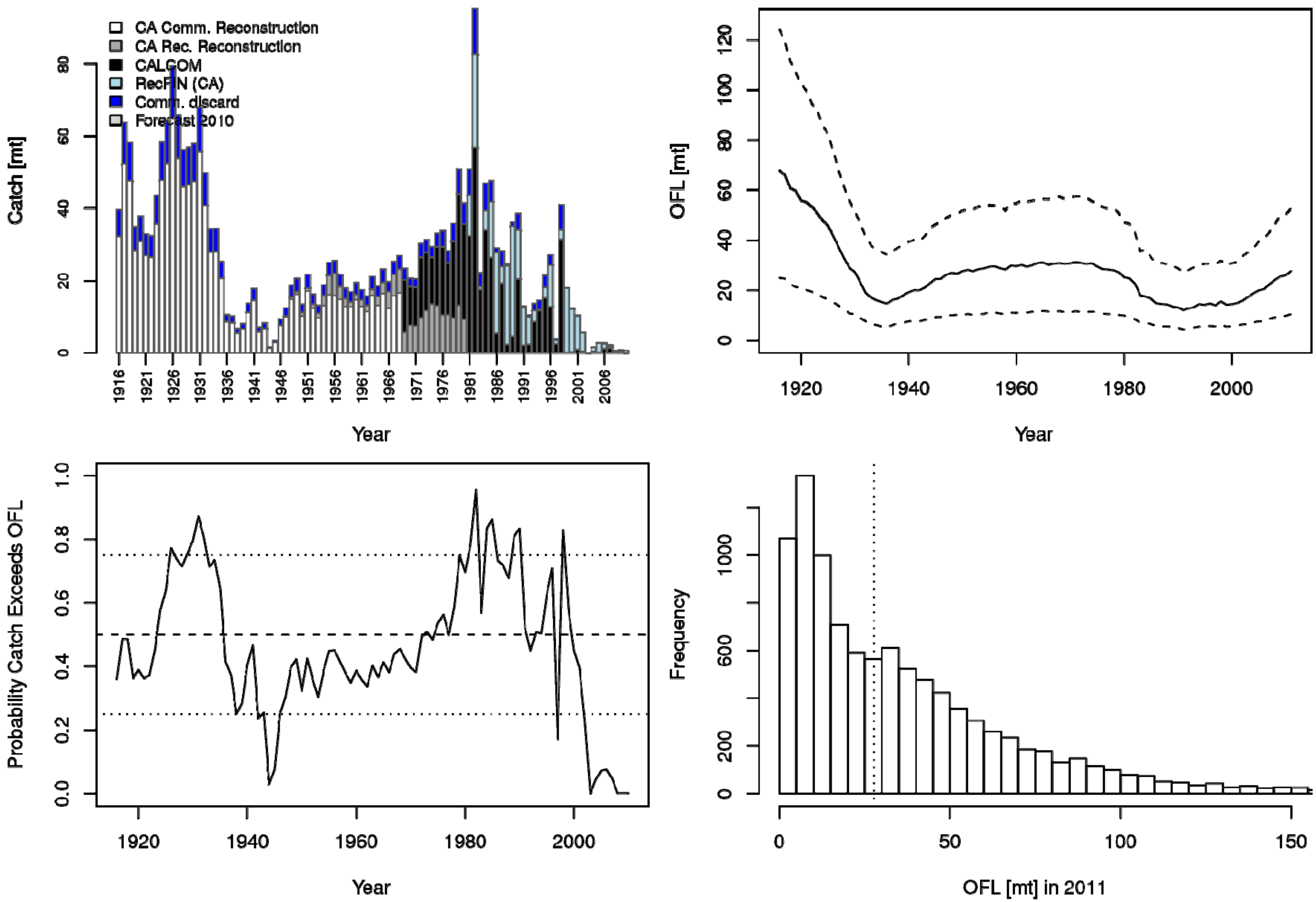


Figure 18. DB-SRA results for grass rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

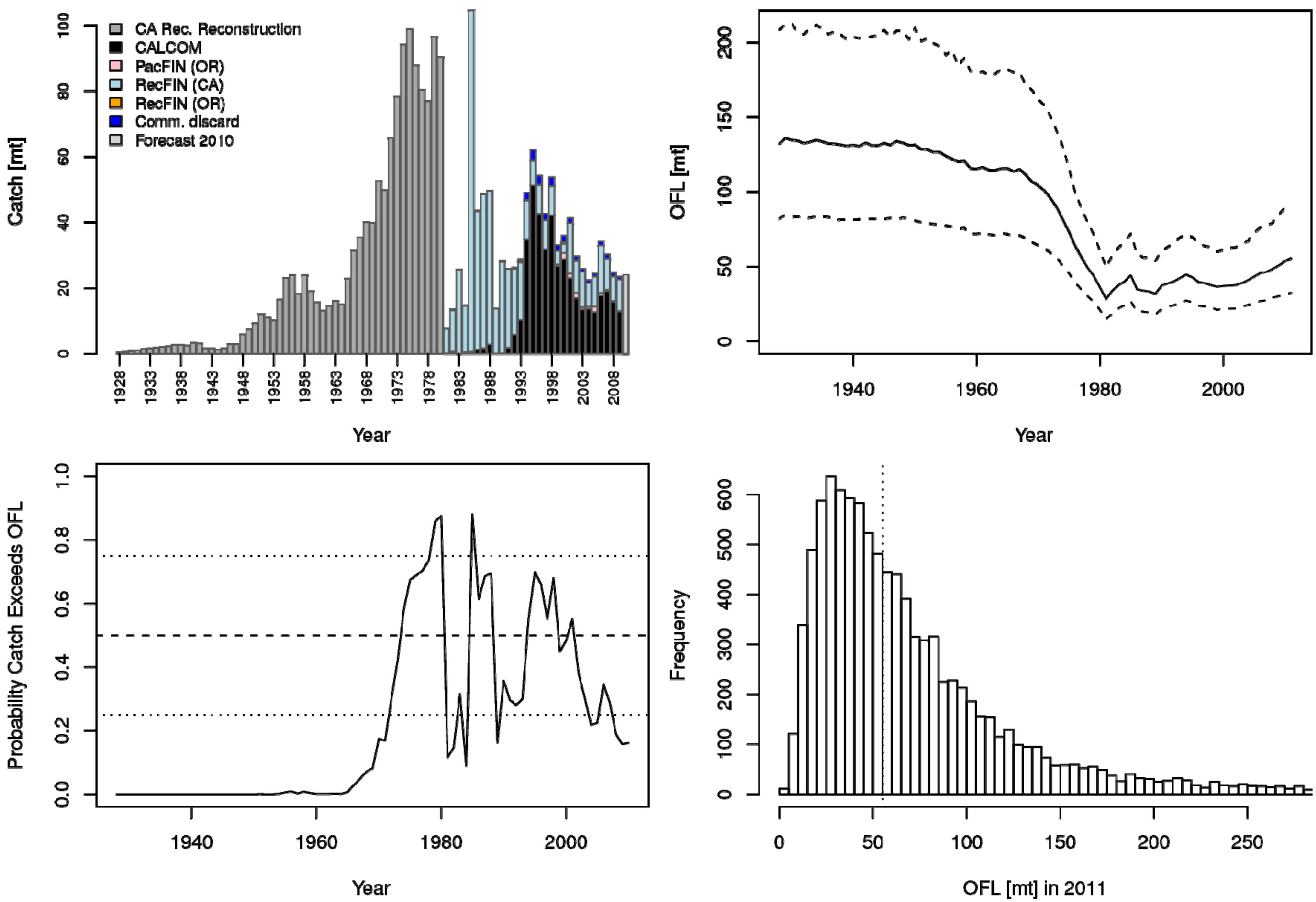


Figure 19. DB-SRA results for greenspotted rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

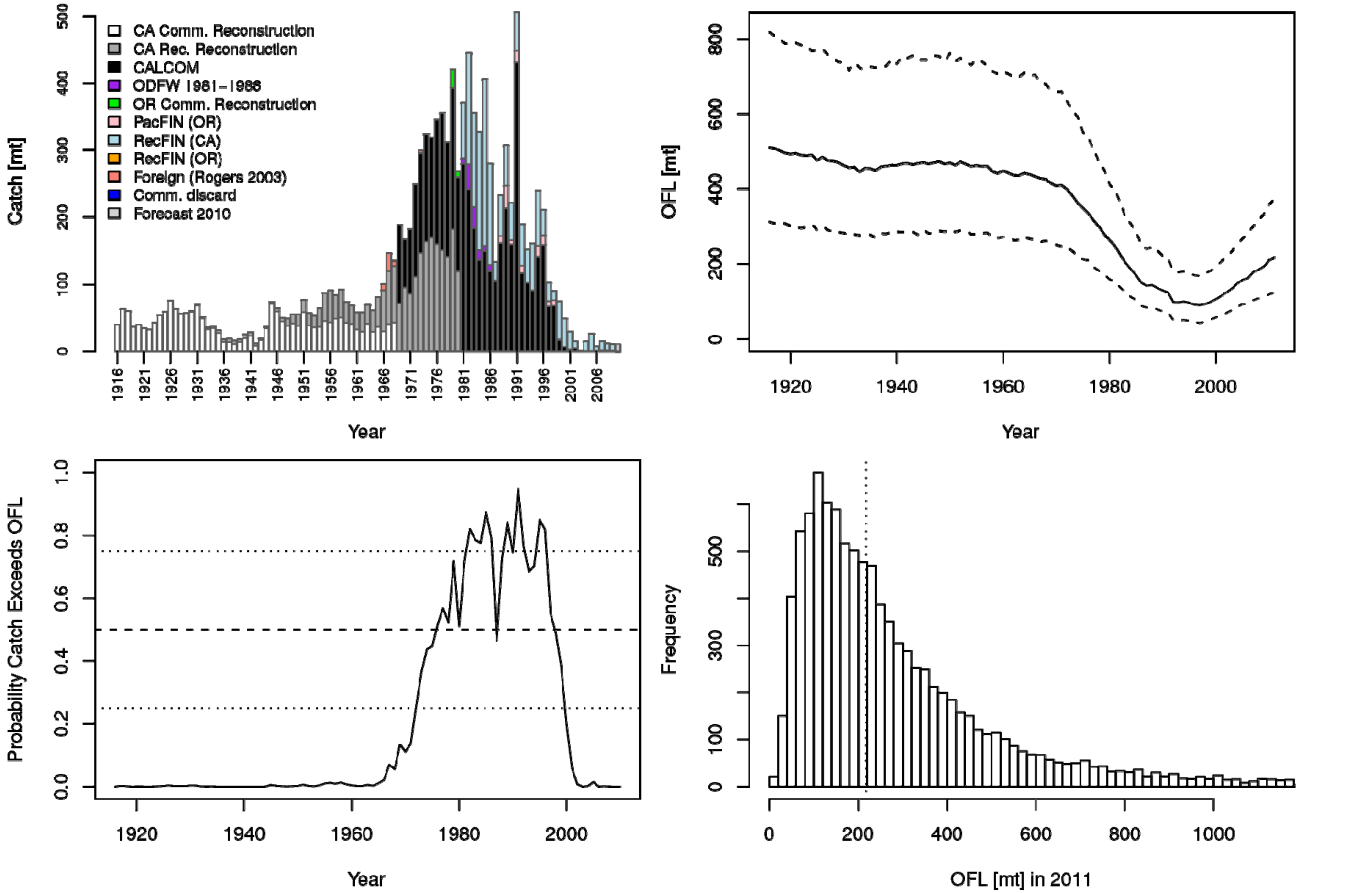


Figure 20. DB-SRA results for kelp greenling (California substock). Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

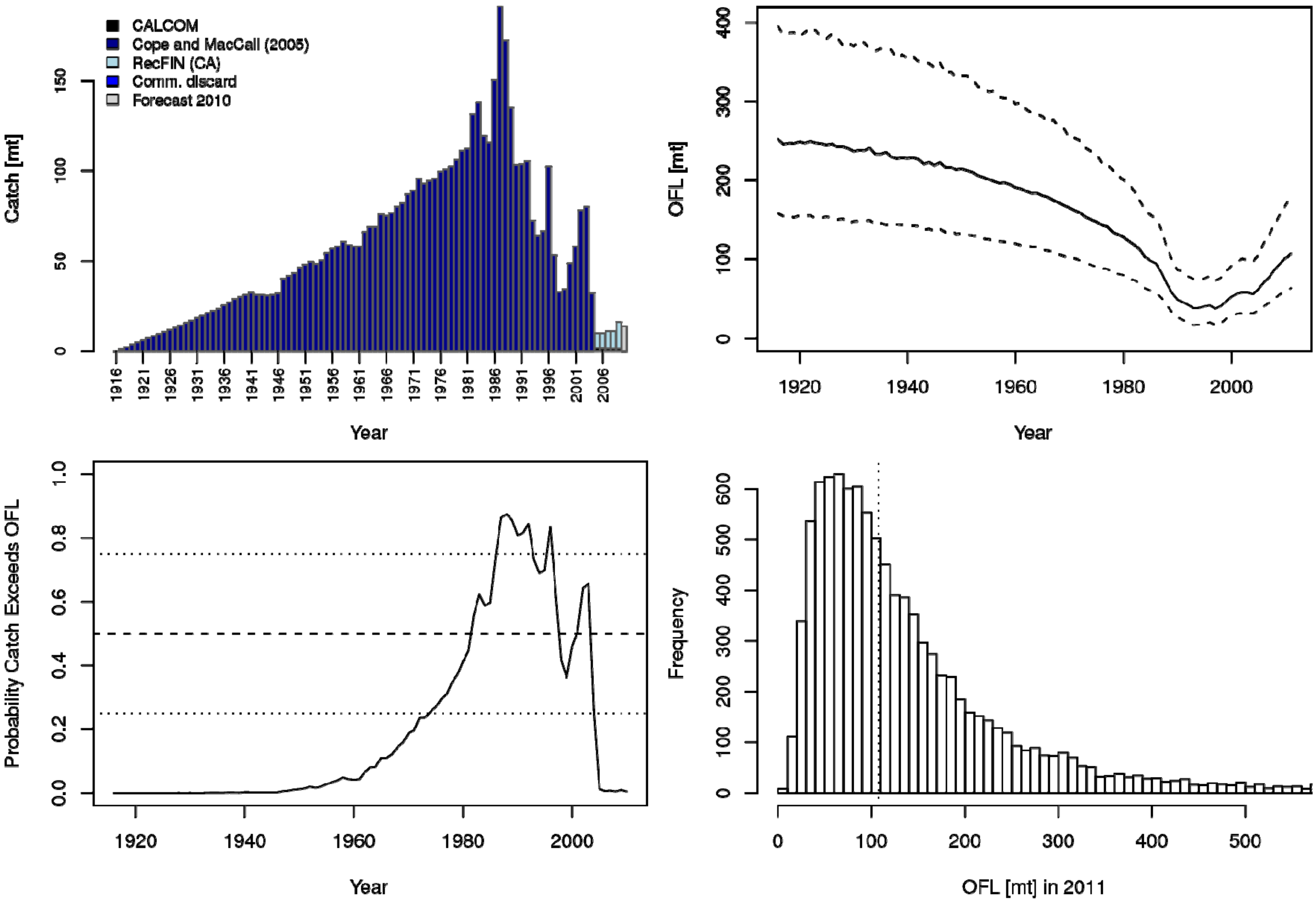


Figure 21. DB-SRA results for kelp rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

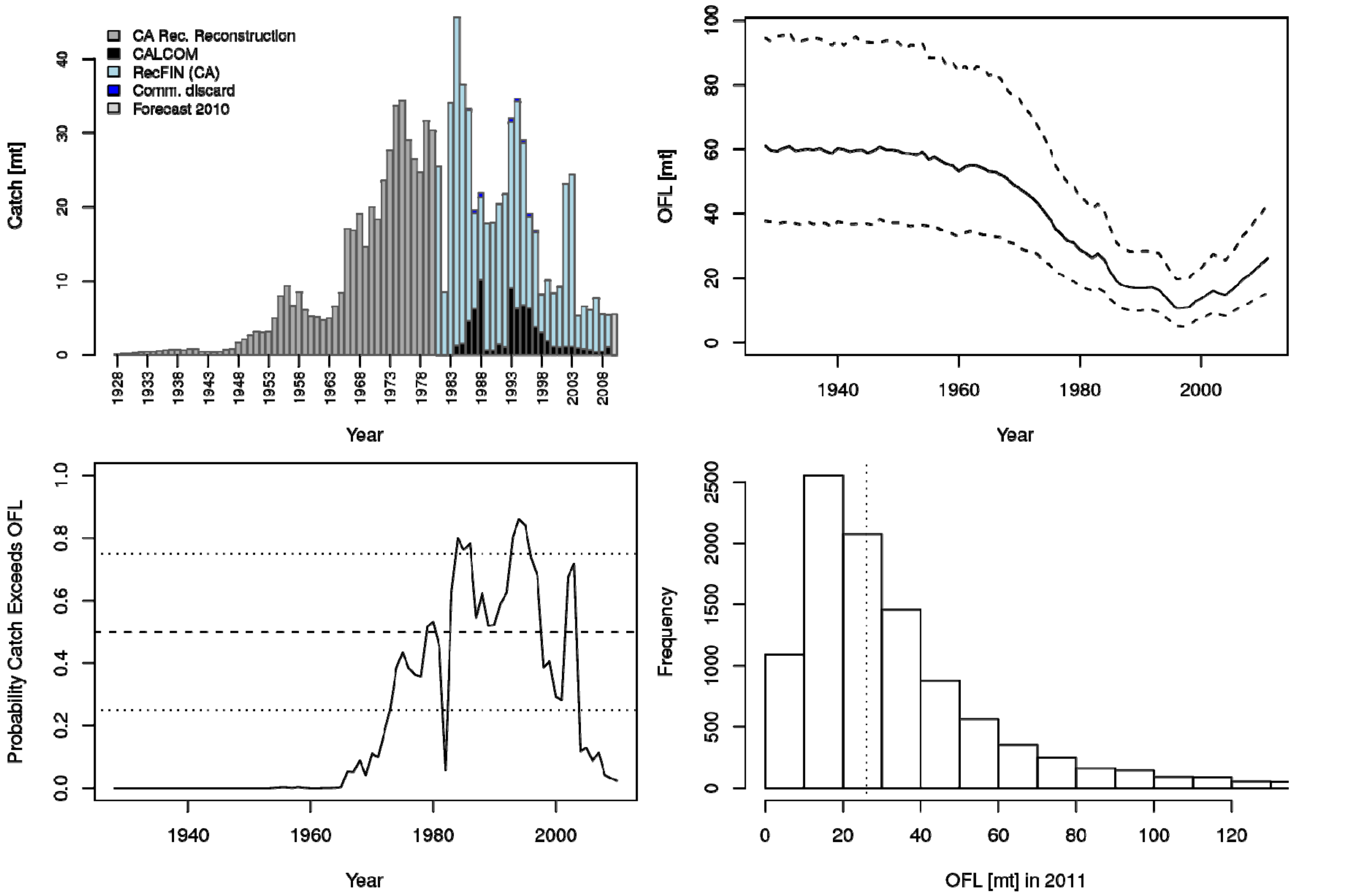


Figure 22. DB-SRA results for leopard shark. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

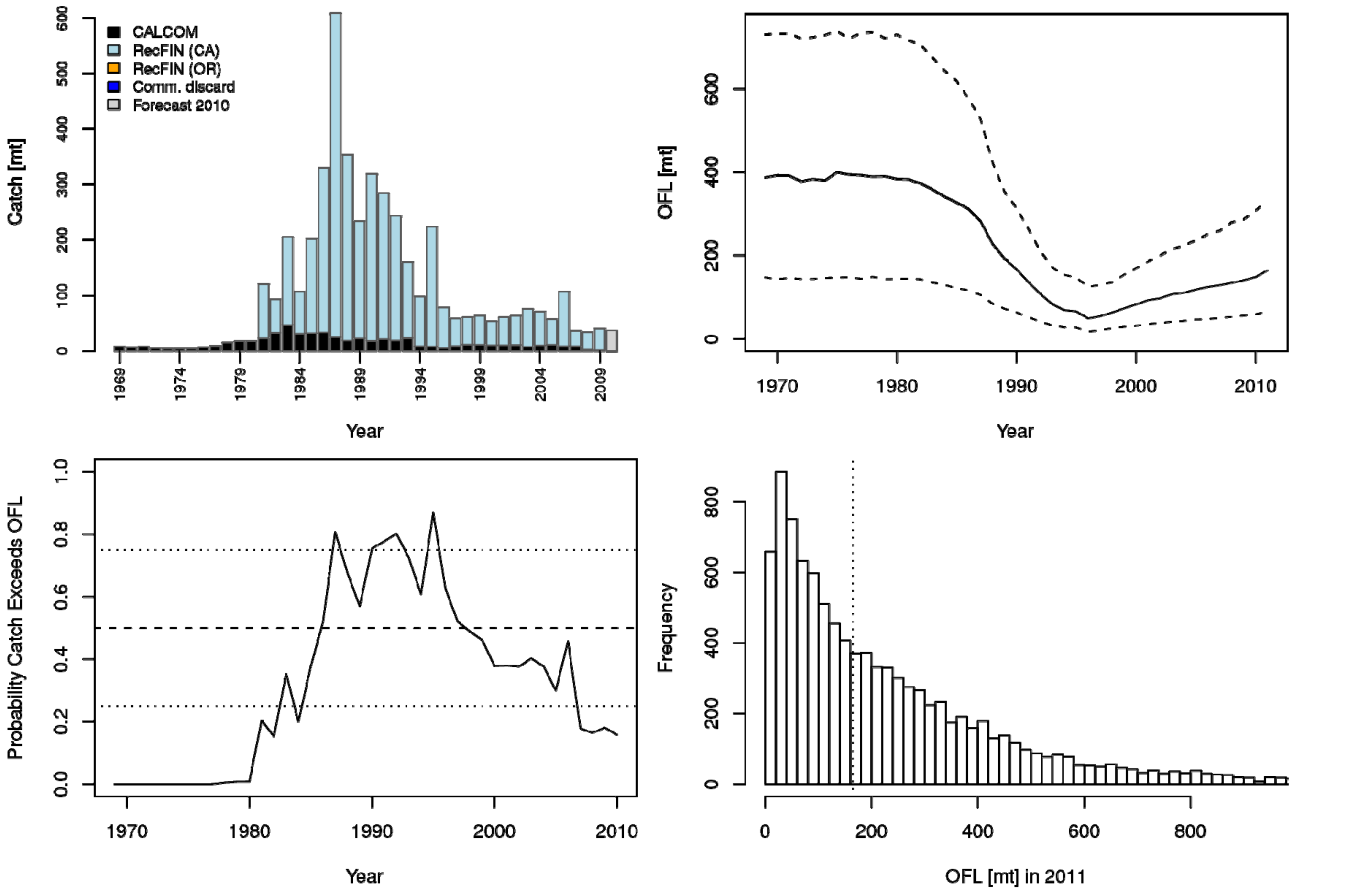


Figure 23. DB-SRA results for olive rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

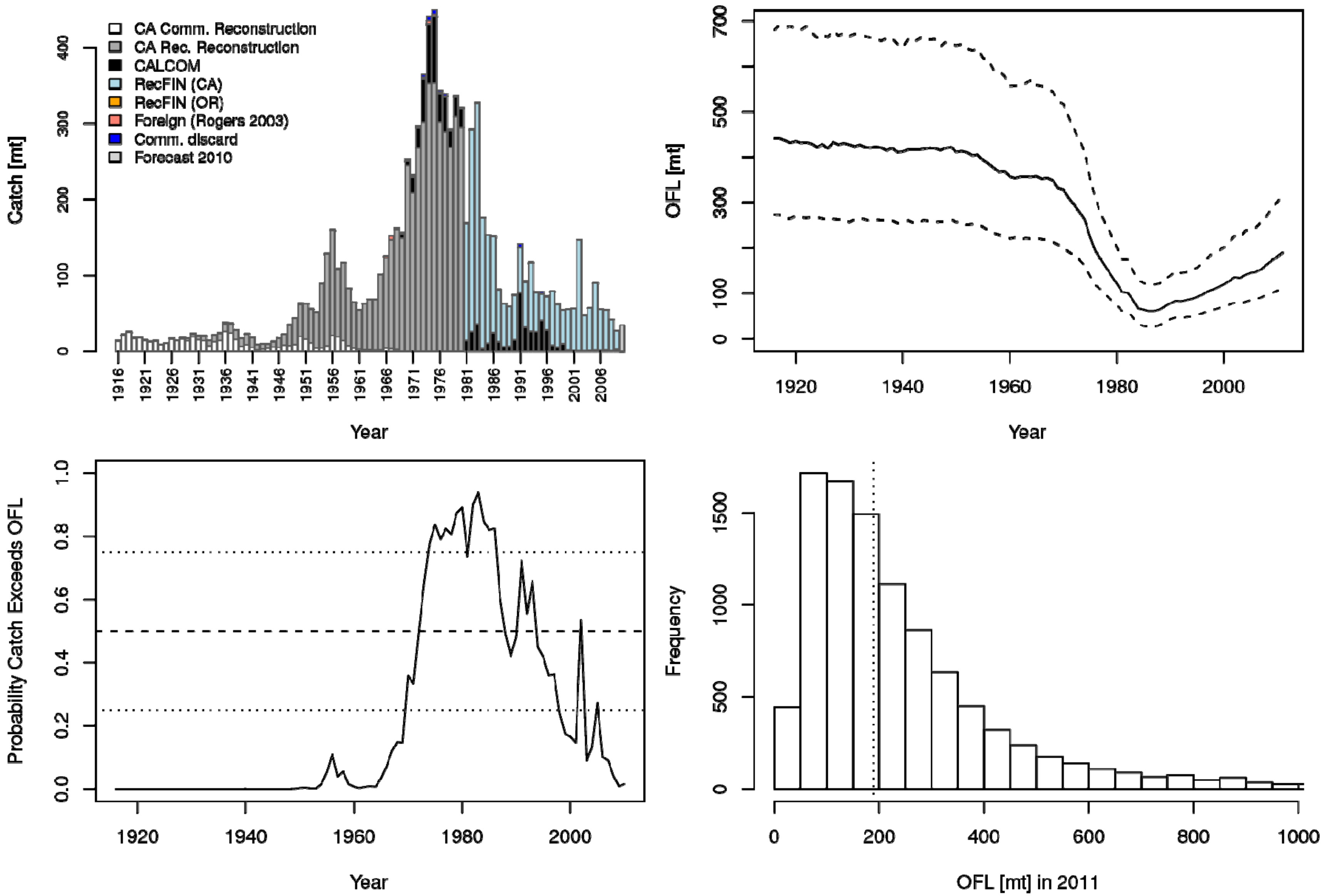


Figure 24. DB-SRA results for Pacific sanddab. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

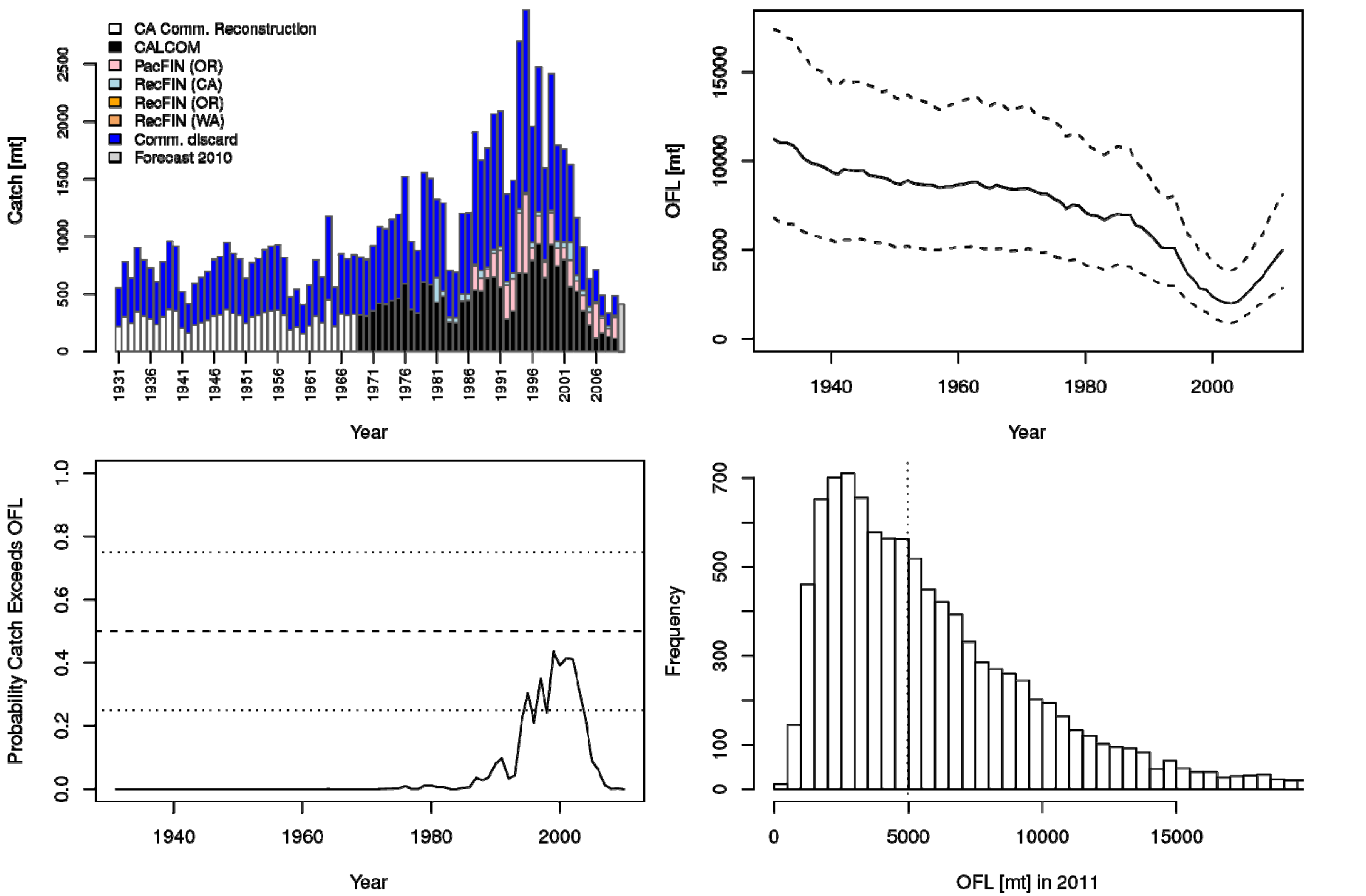


Figure 25. DB-SRA results for pink rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

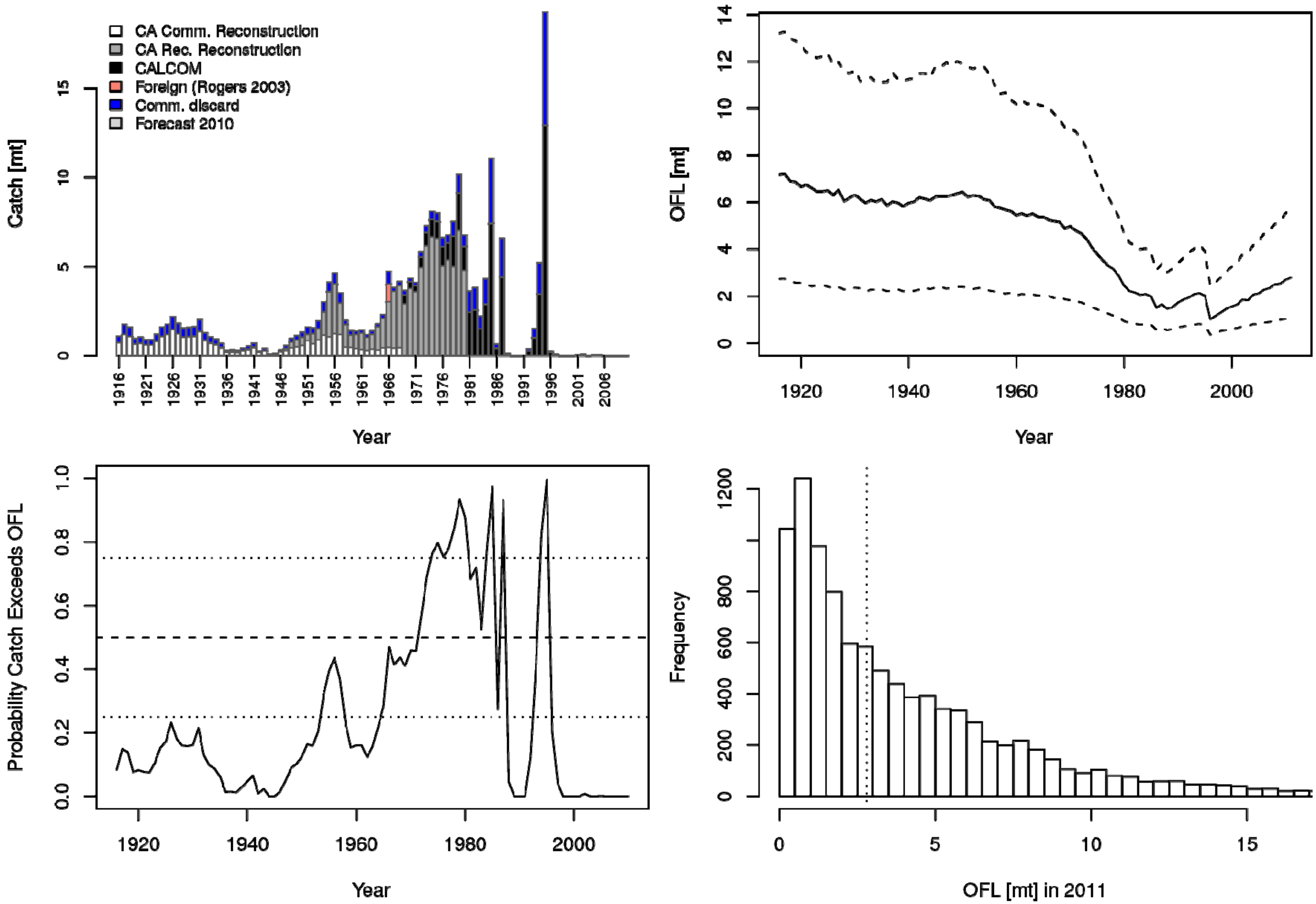


Figure 26. DB-SRA results for quillback rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

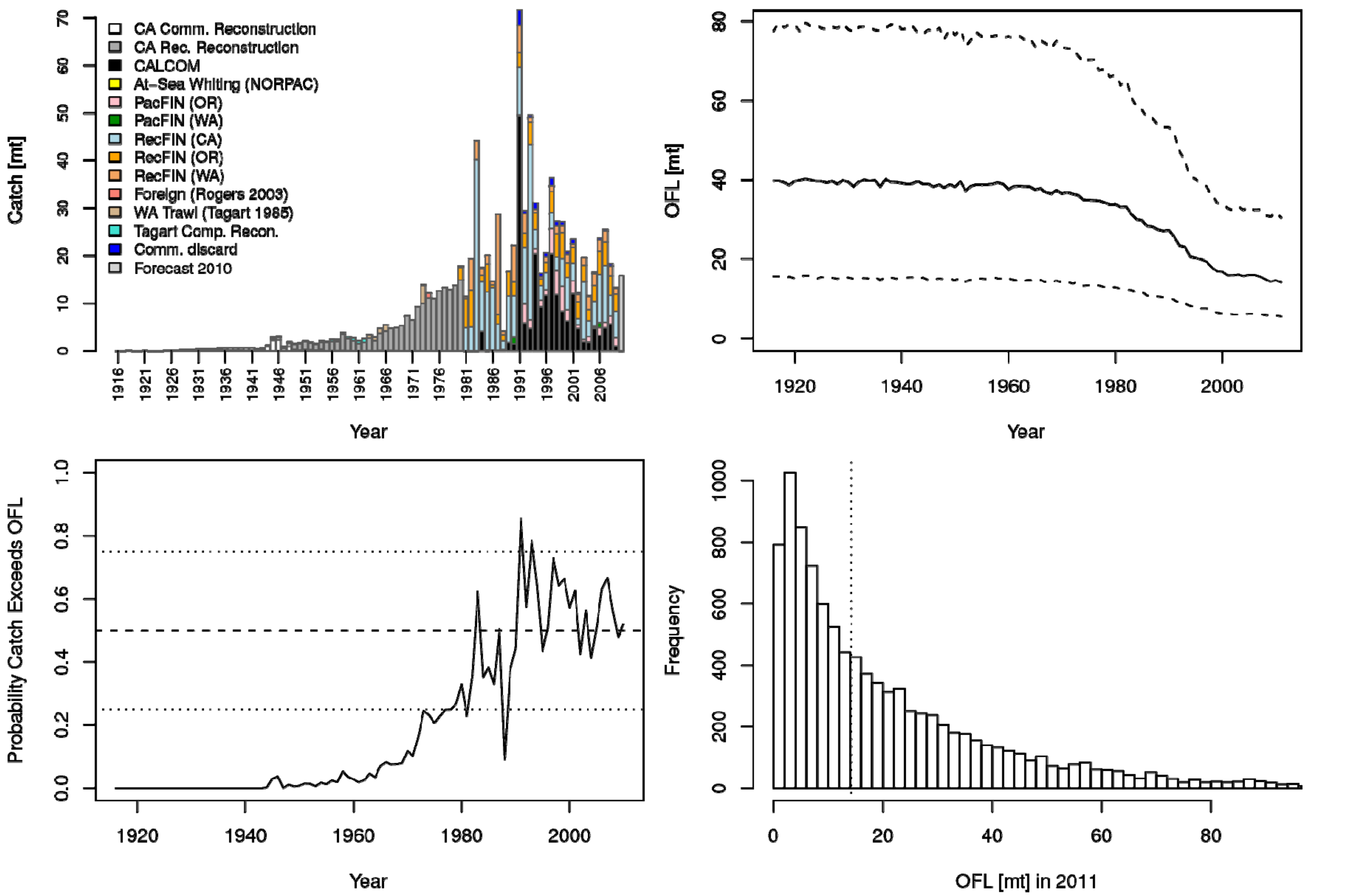


Figure 27. DB-SRA results for redbanded rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

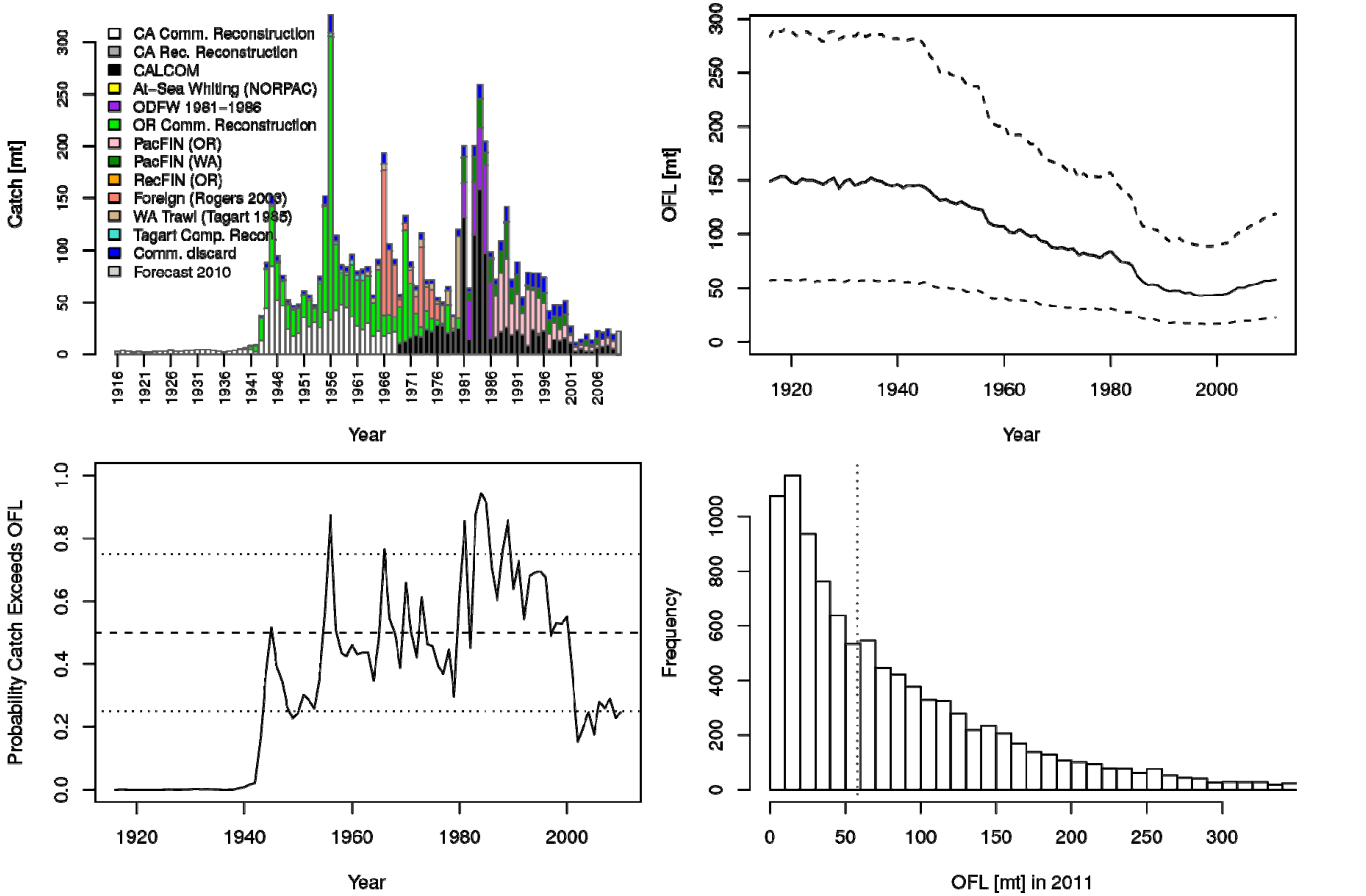


Figure 28. DB-SRA results for redstripe rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

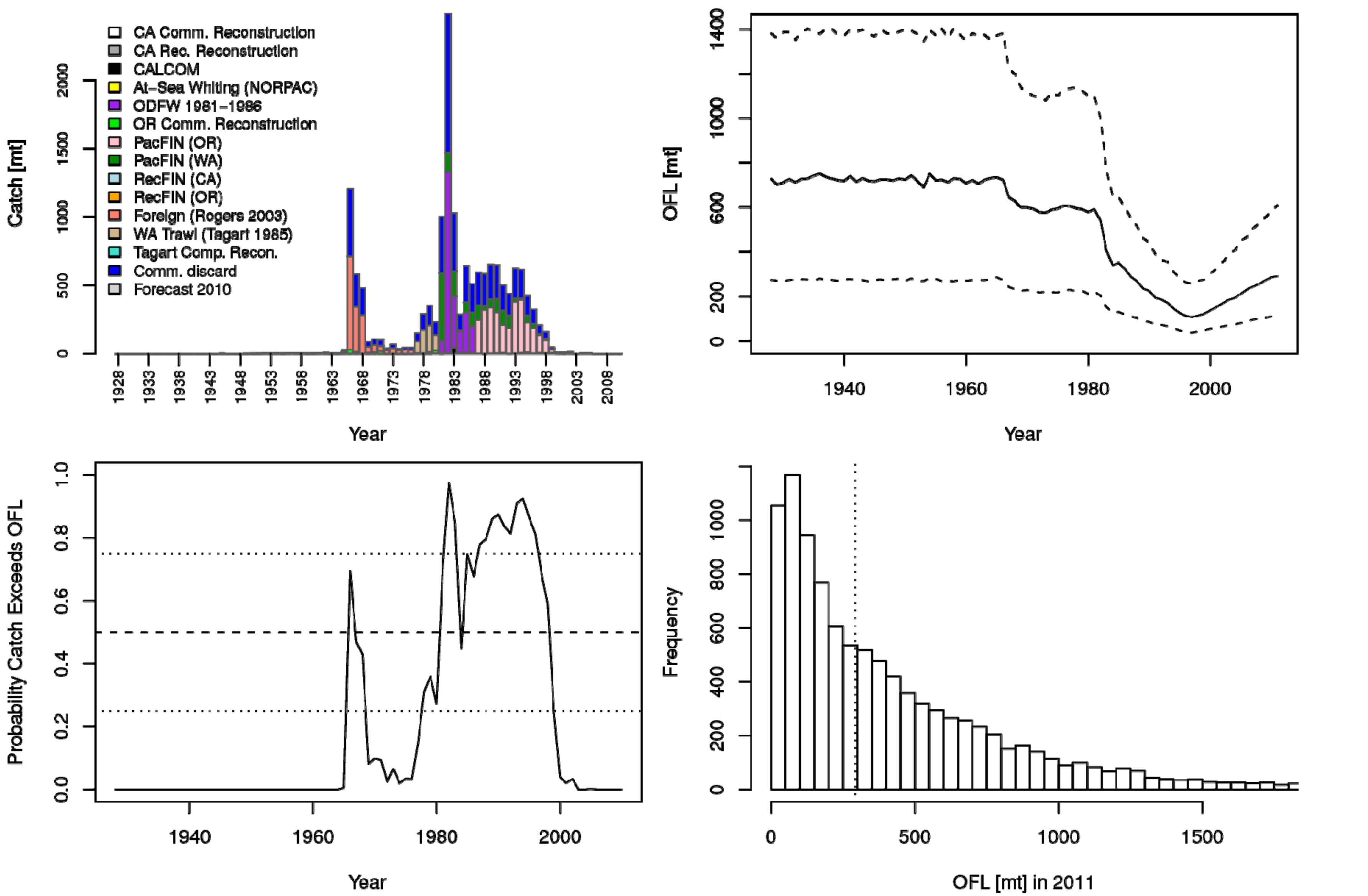


Figure 29. DB-SRA results for rex sole. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

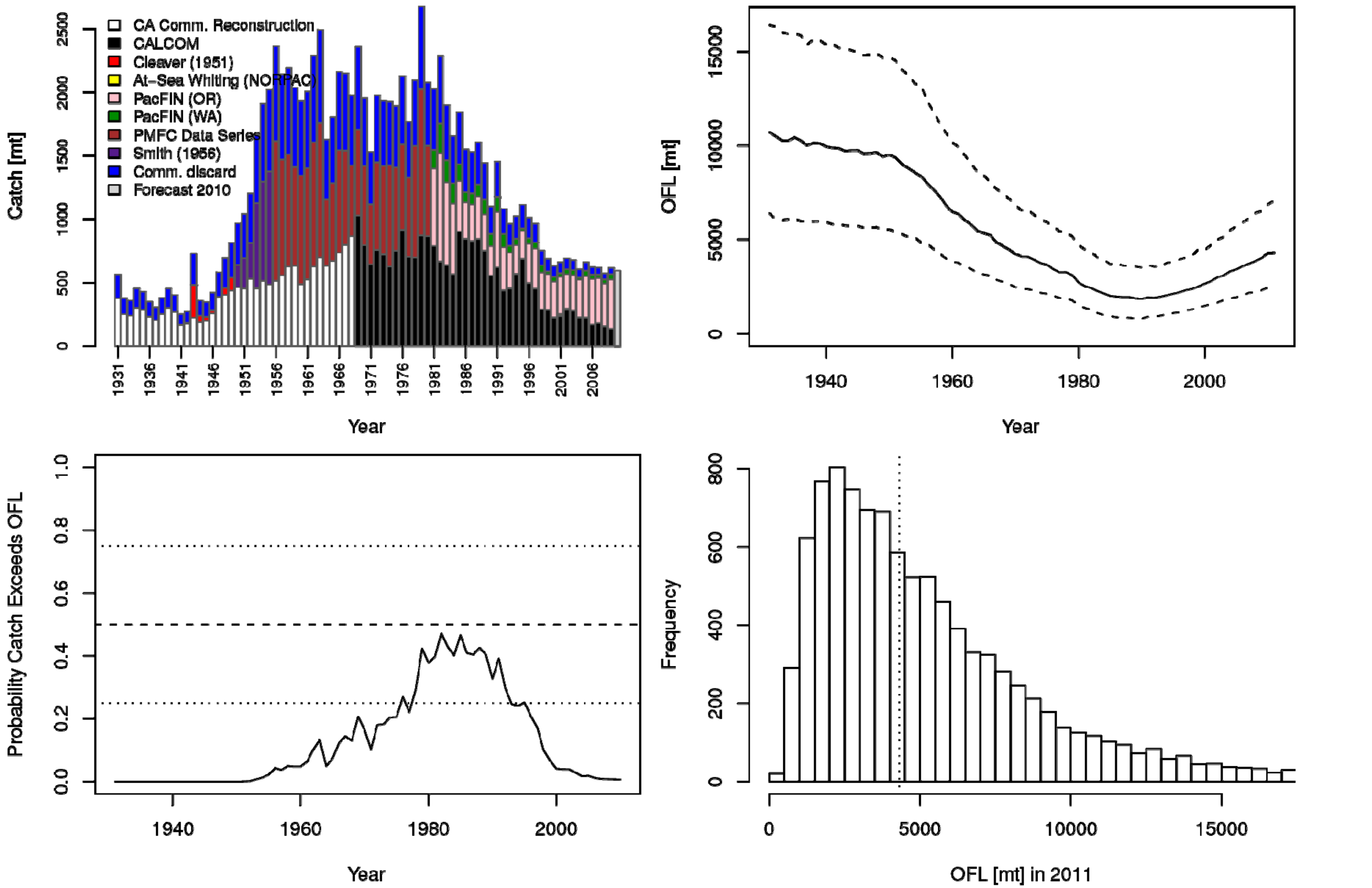


Figure 30. DB-SRA results for rougheye rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

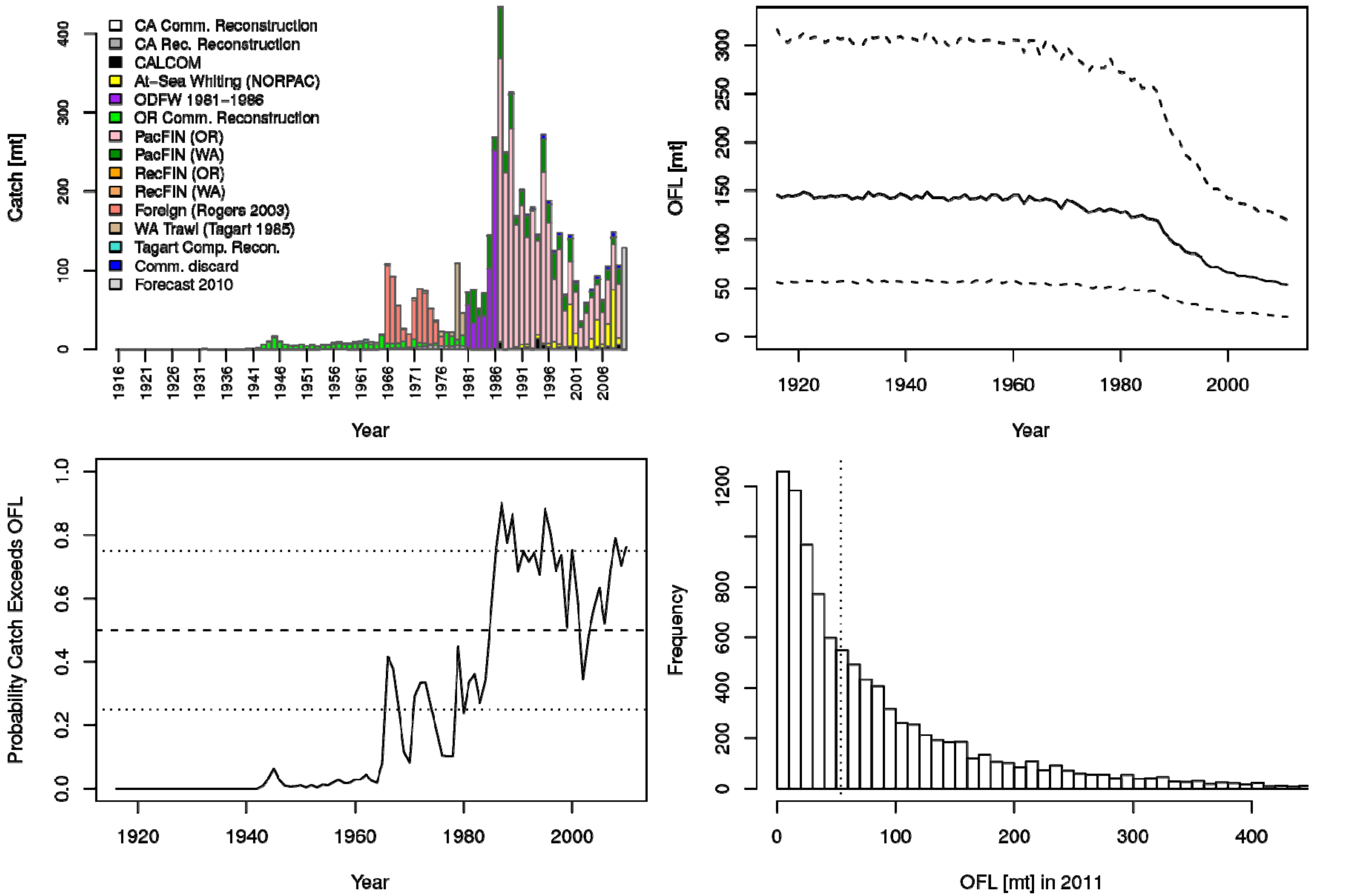


Figure 31. DB-SRA results for rosy rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

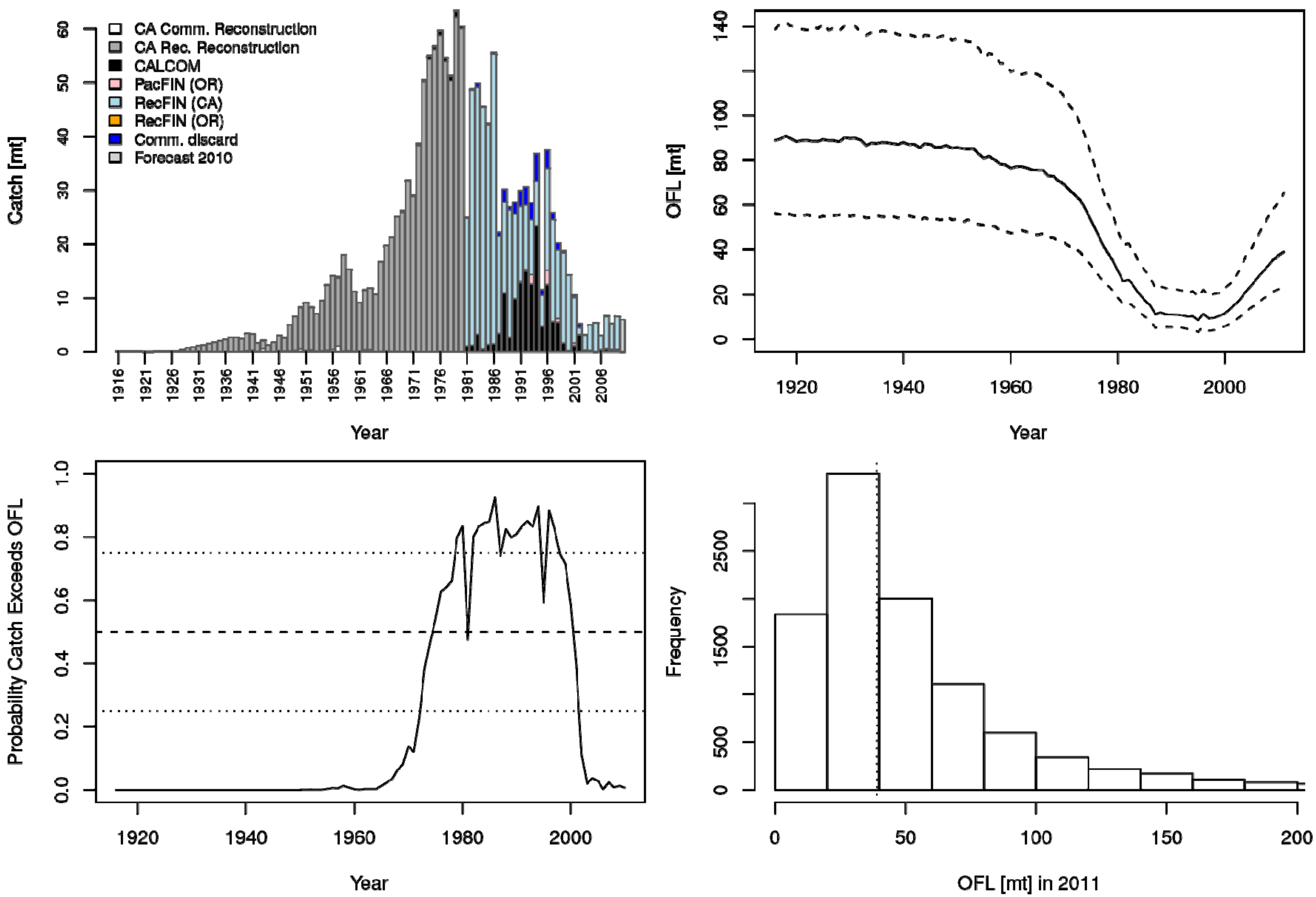


Figure 32. DB-SRA results for rock sole. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

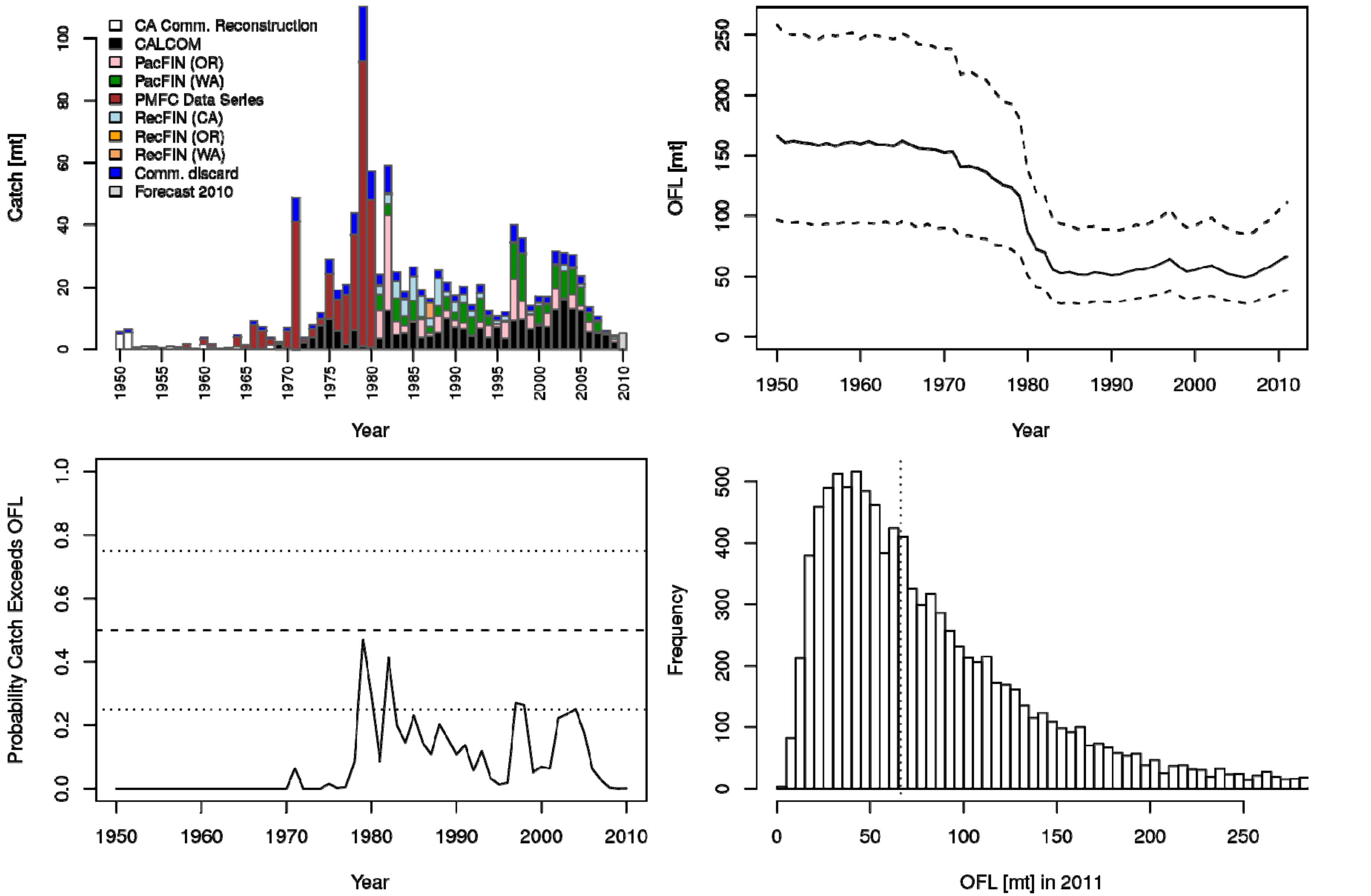


Figure 33. DB-SRA results for rosethorn rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

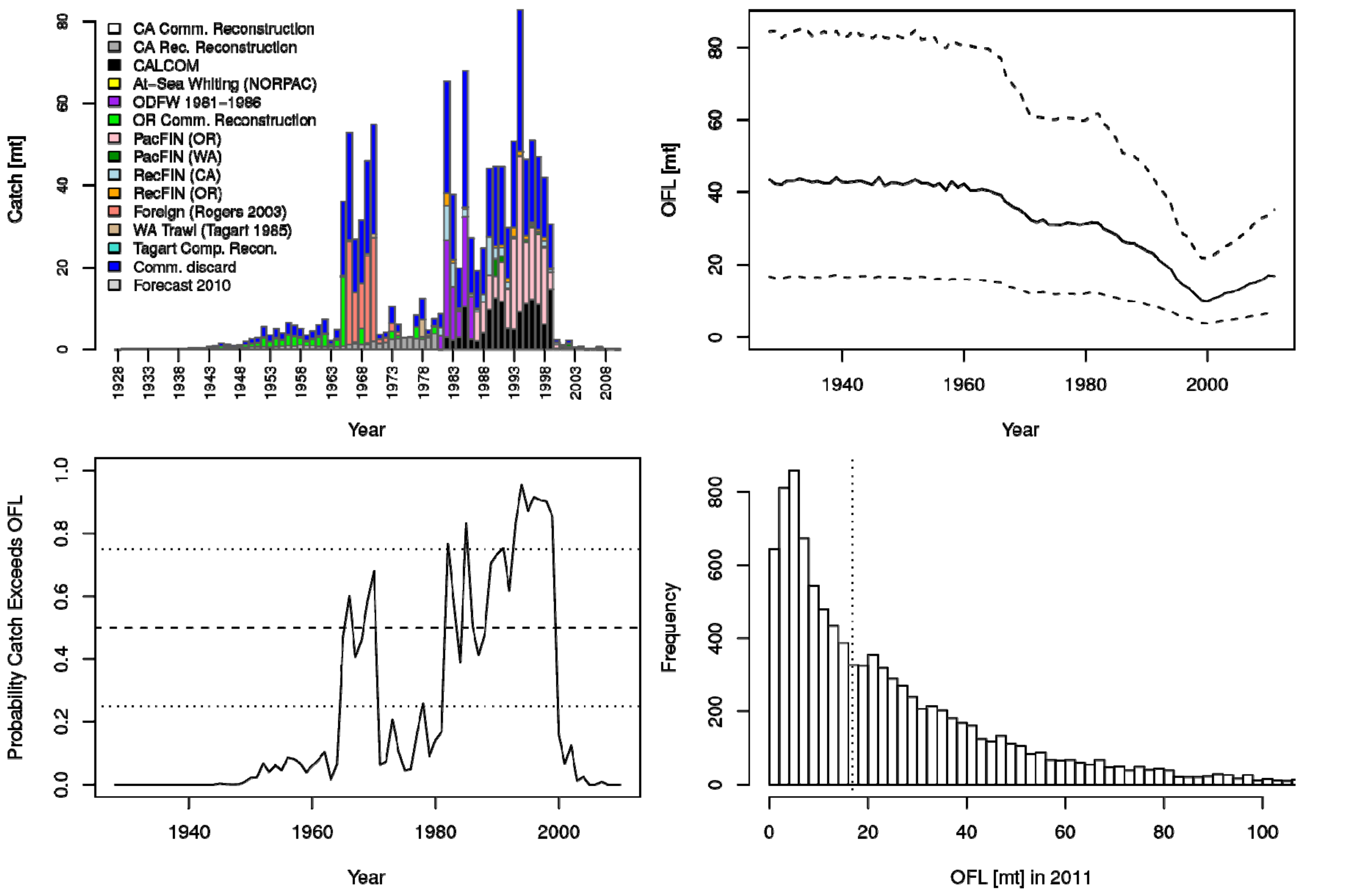


Figure 34. DB-SRA results for sharpchin rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

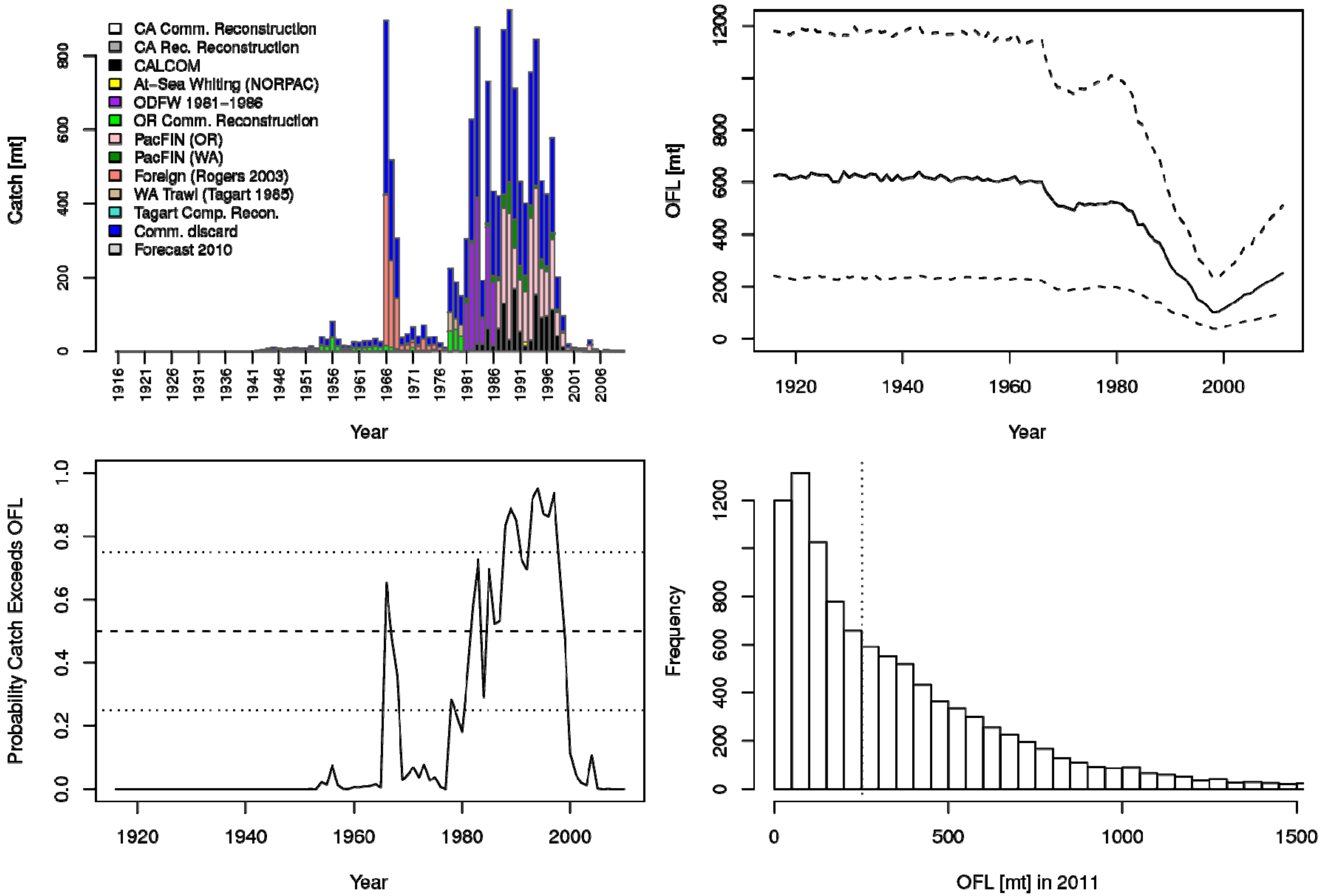


Figure 35. DB-SRA results for silvergrey rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

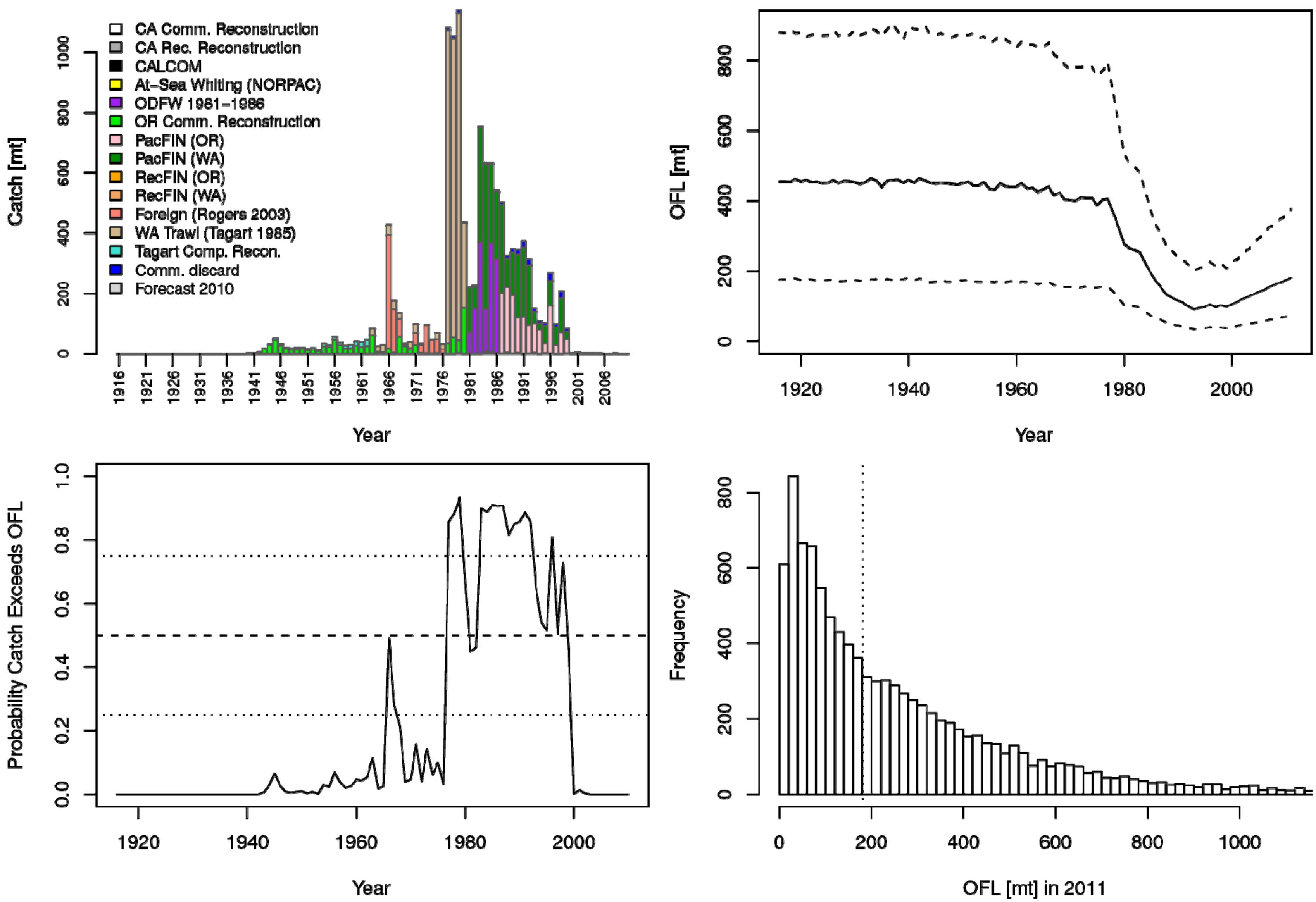


Figure 36. DB-SRA results for speckled rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

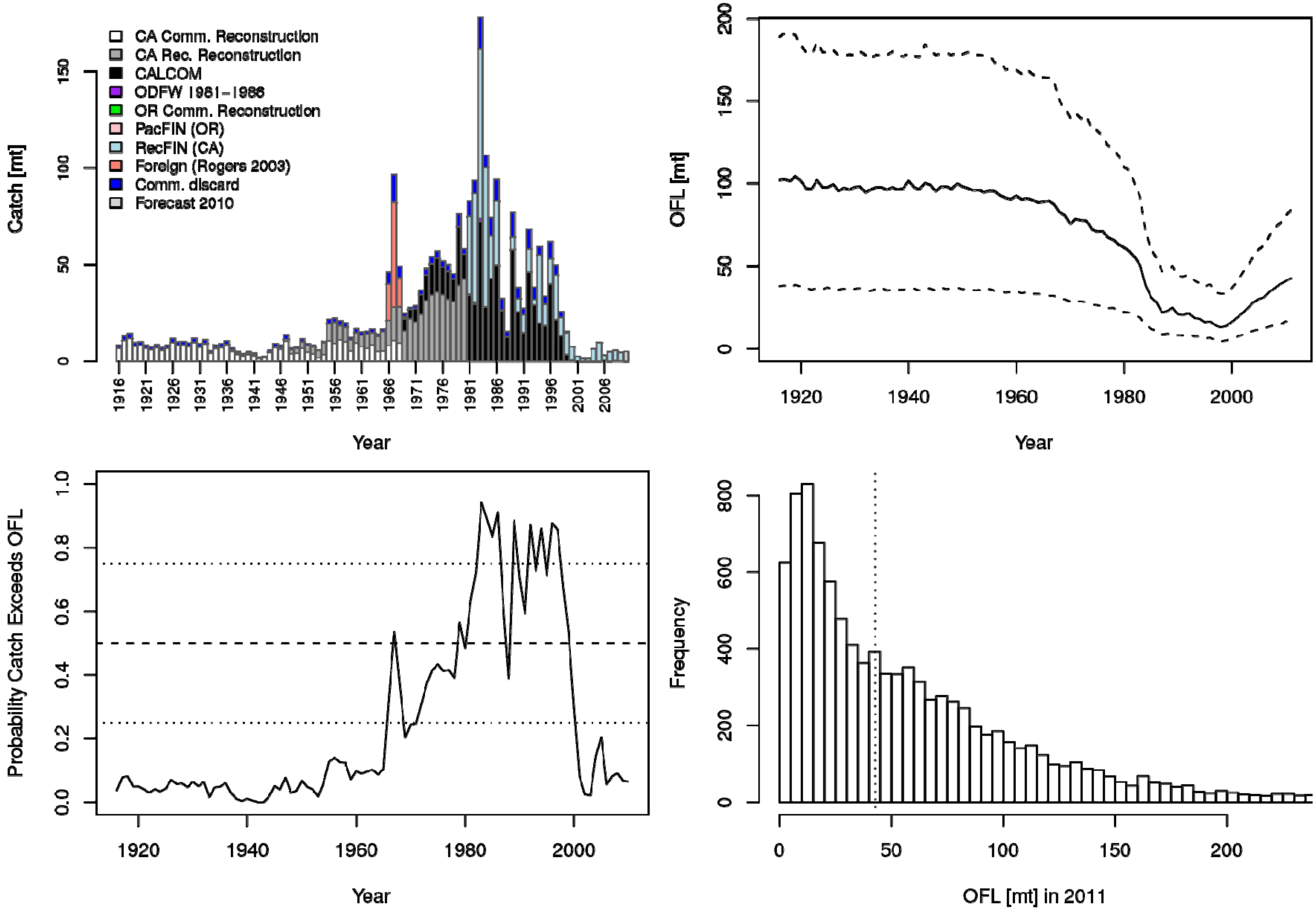


Figure 37. DB-SRA results for shortraker rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

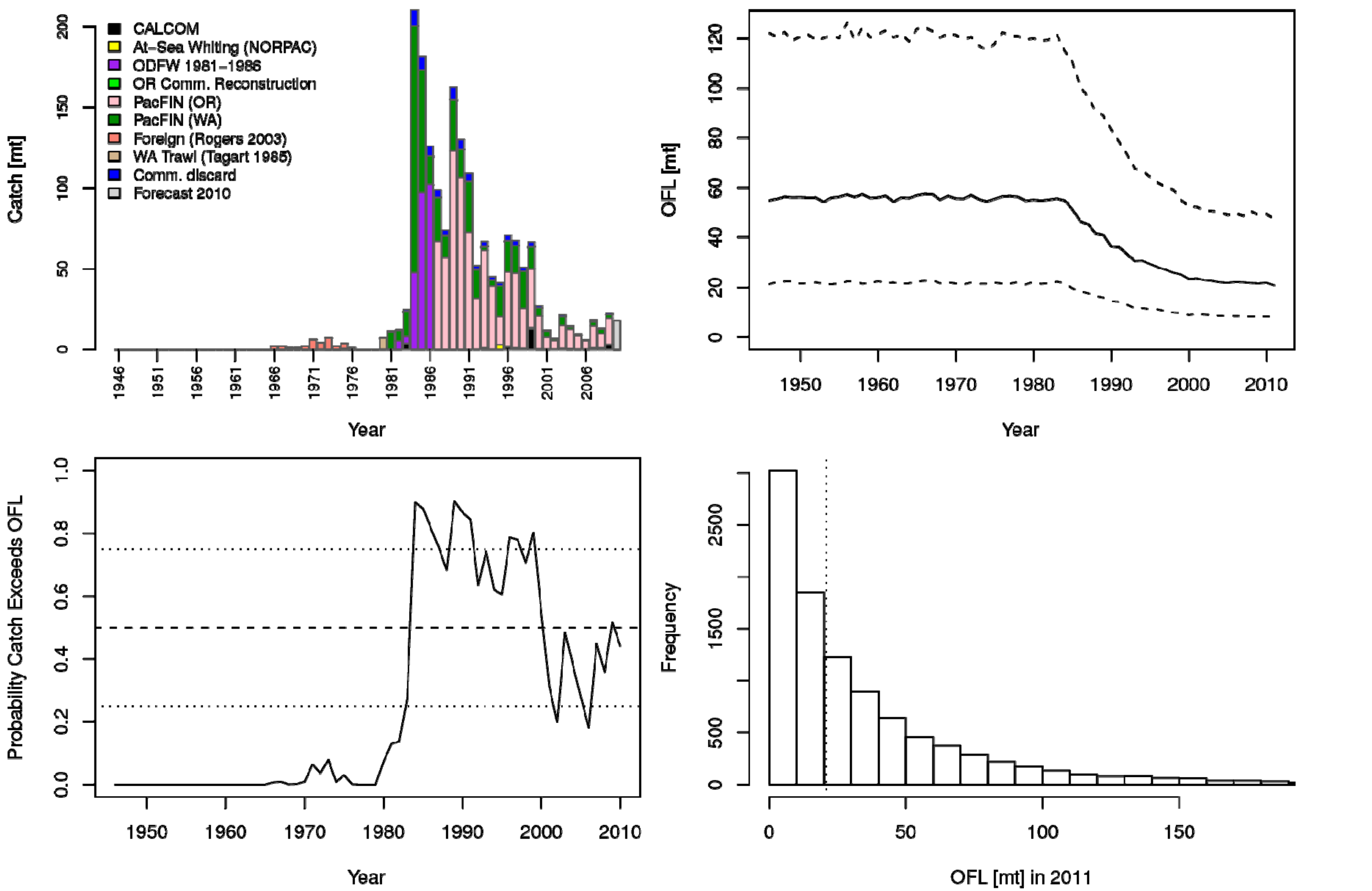


Figure 38. DB-SRA results for sand sole. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

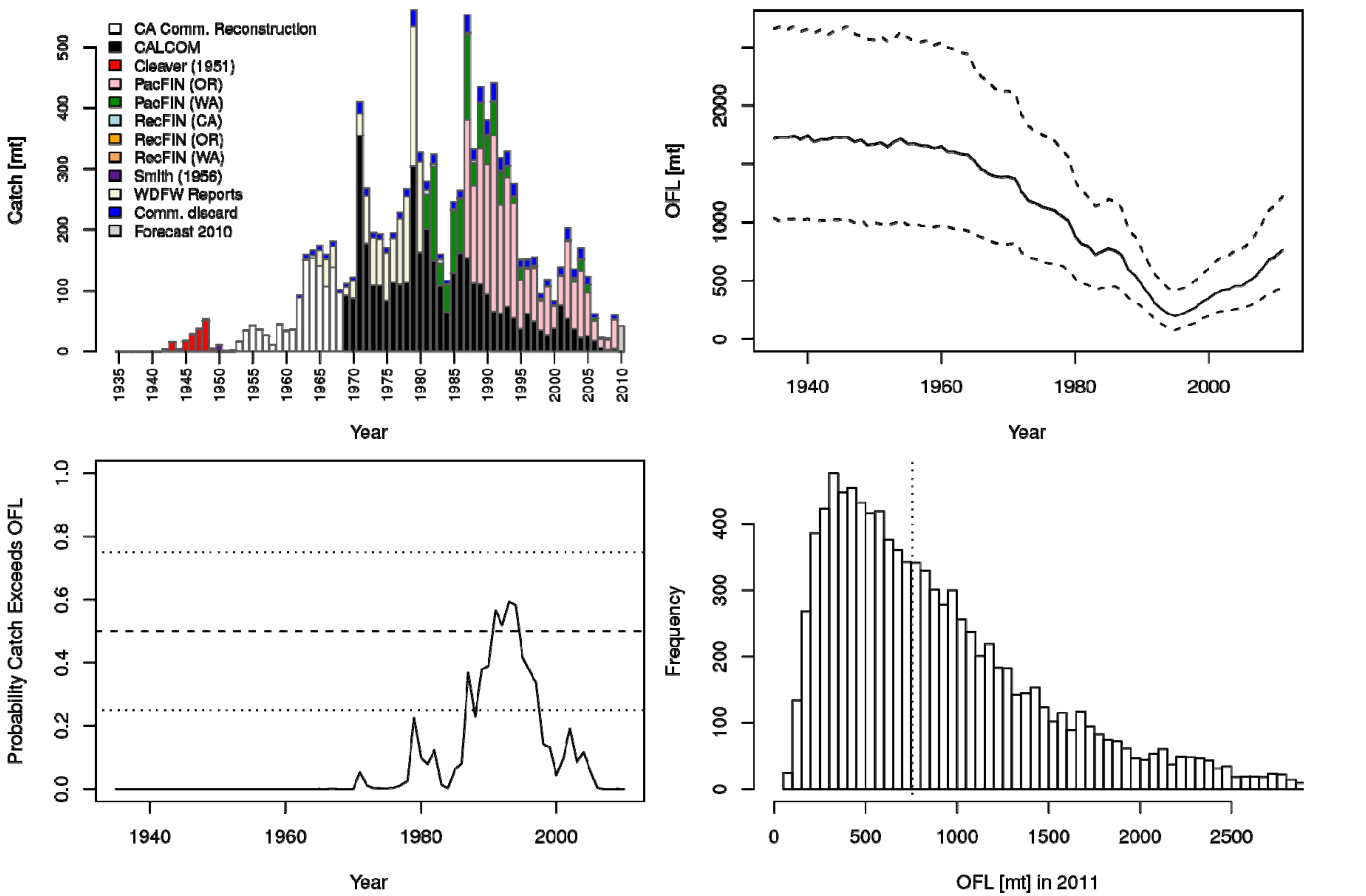


Figure 39. DB-SRA results for starry rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

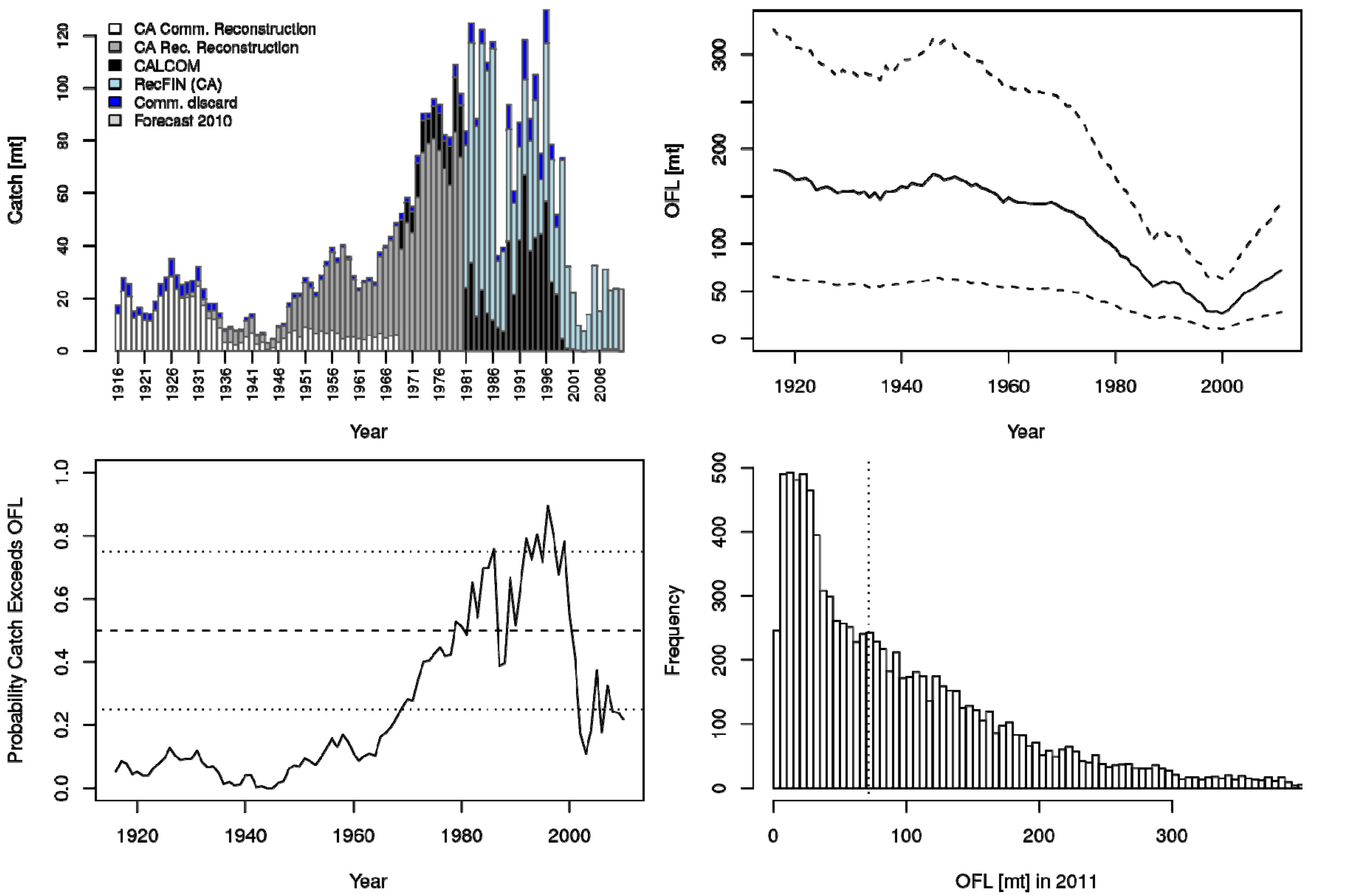


Figure 40. DB-SRA results for stripetail rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

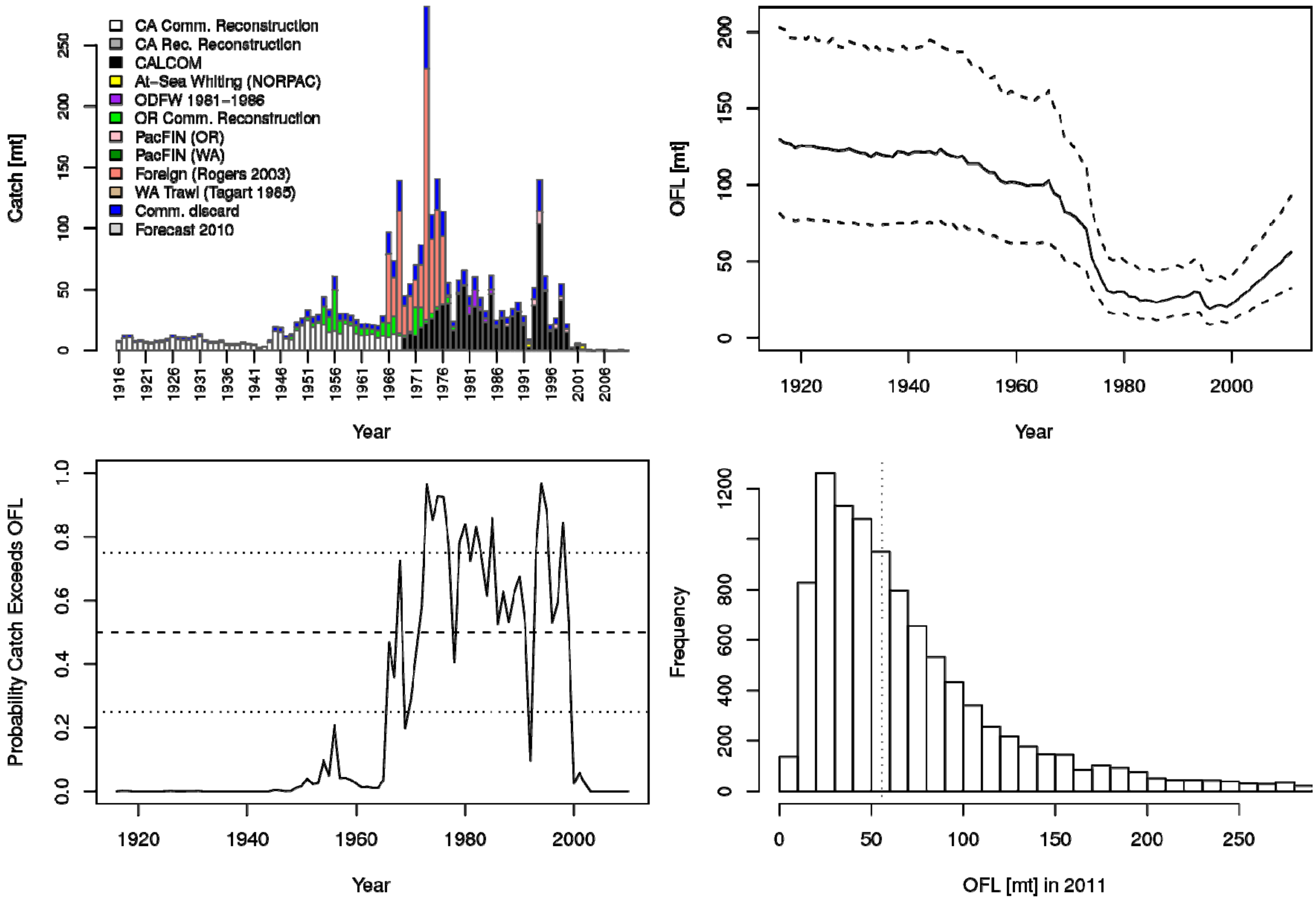


Figure 41. DB-SRA results for swordspine rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

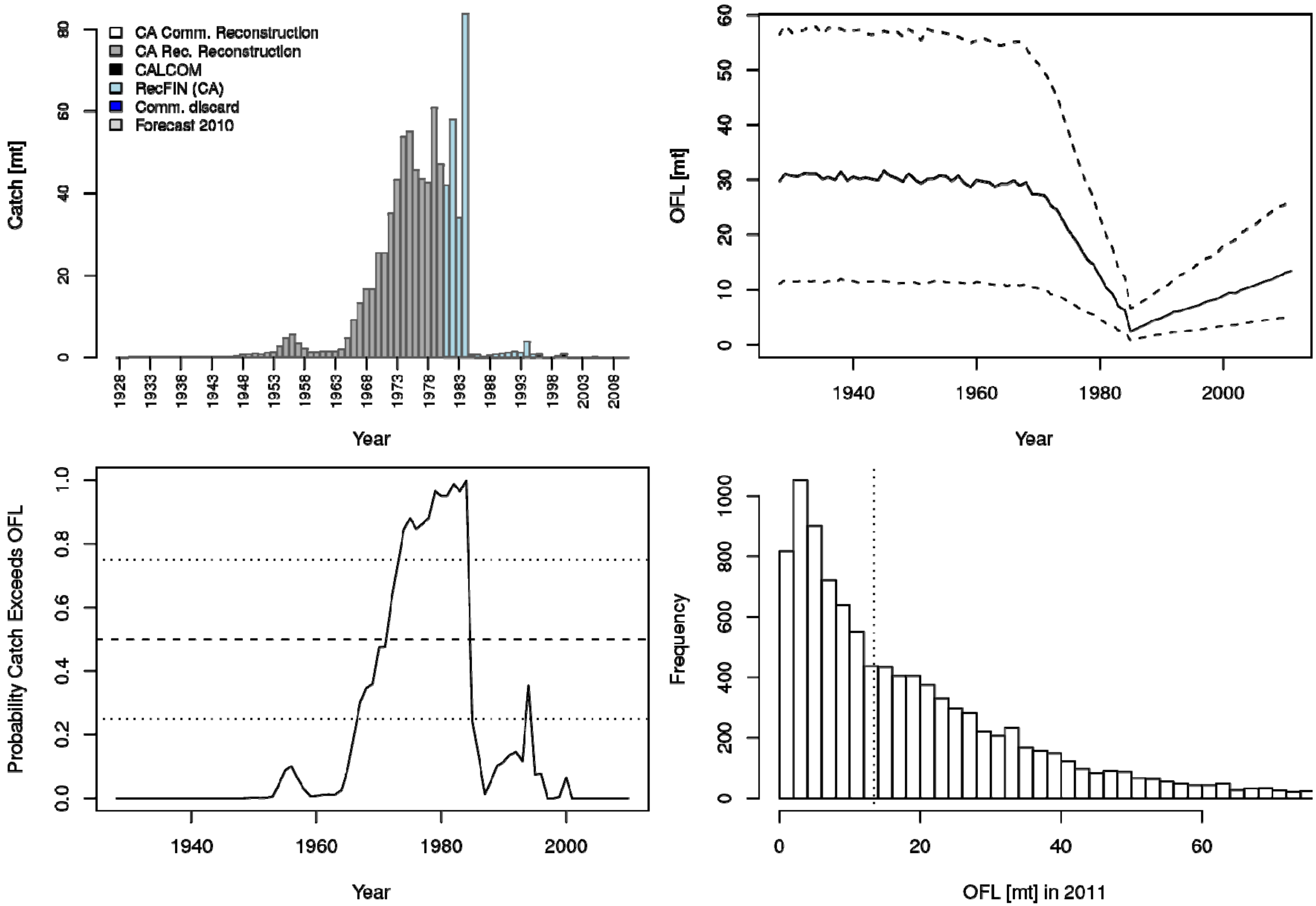


Figure 42. DB-SRA results for treefish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

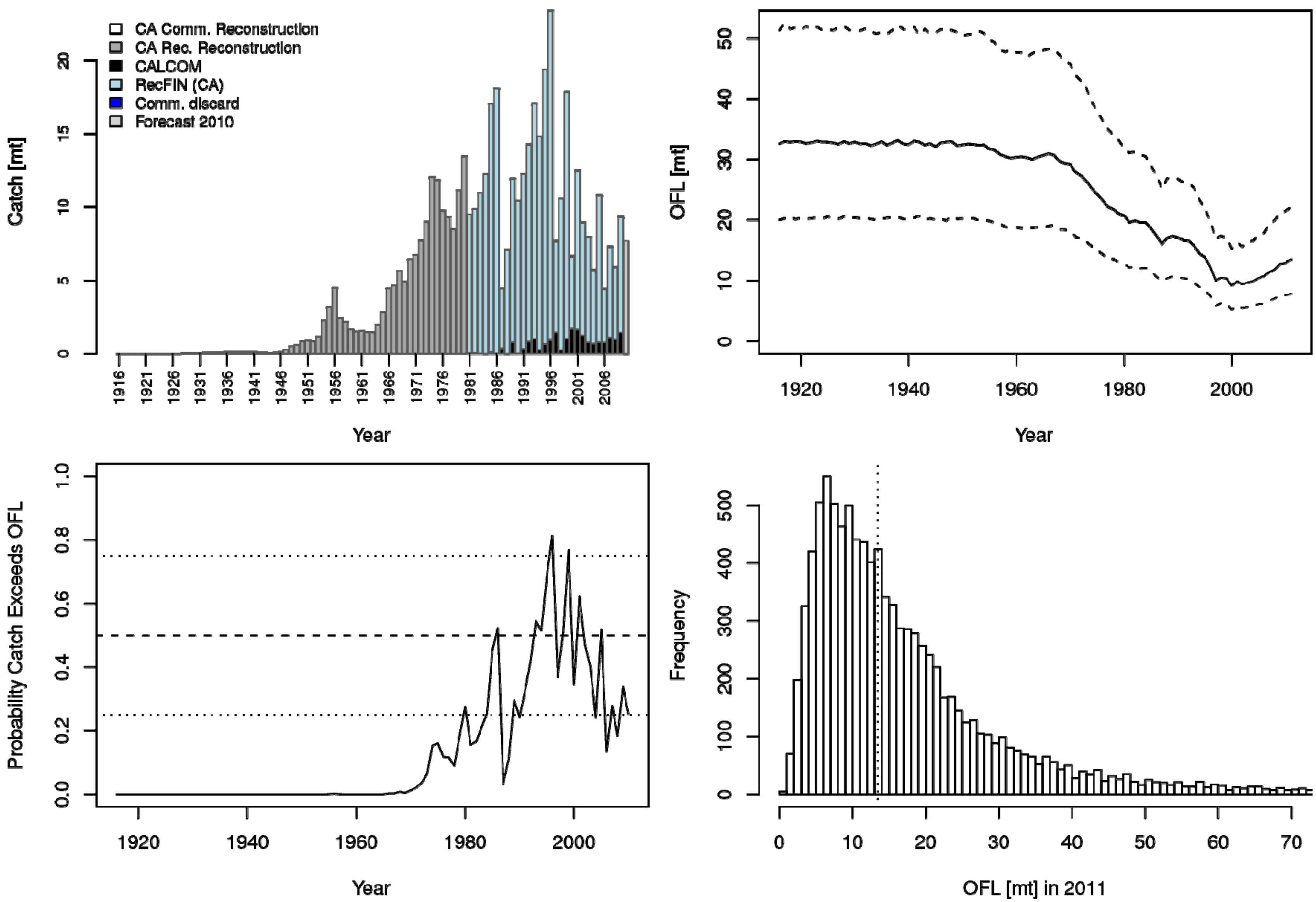


Figure 43. DB-SRA results for vermillion rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).

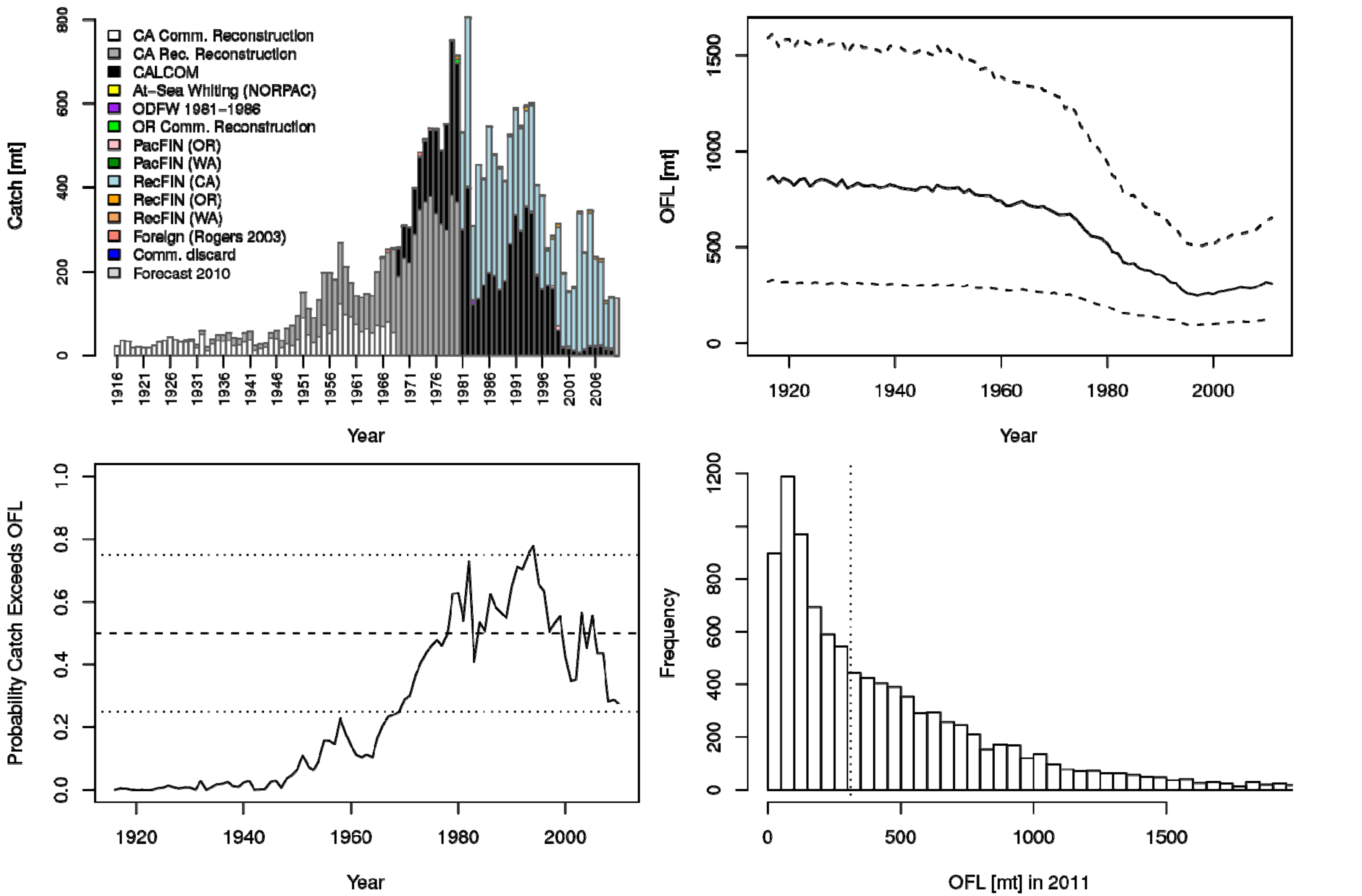
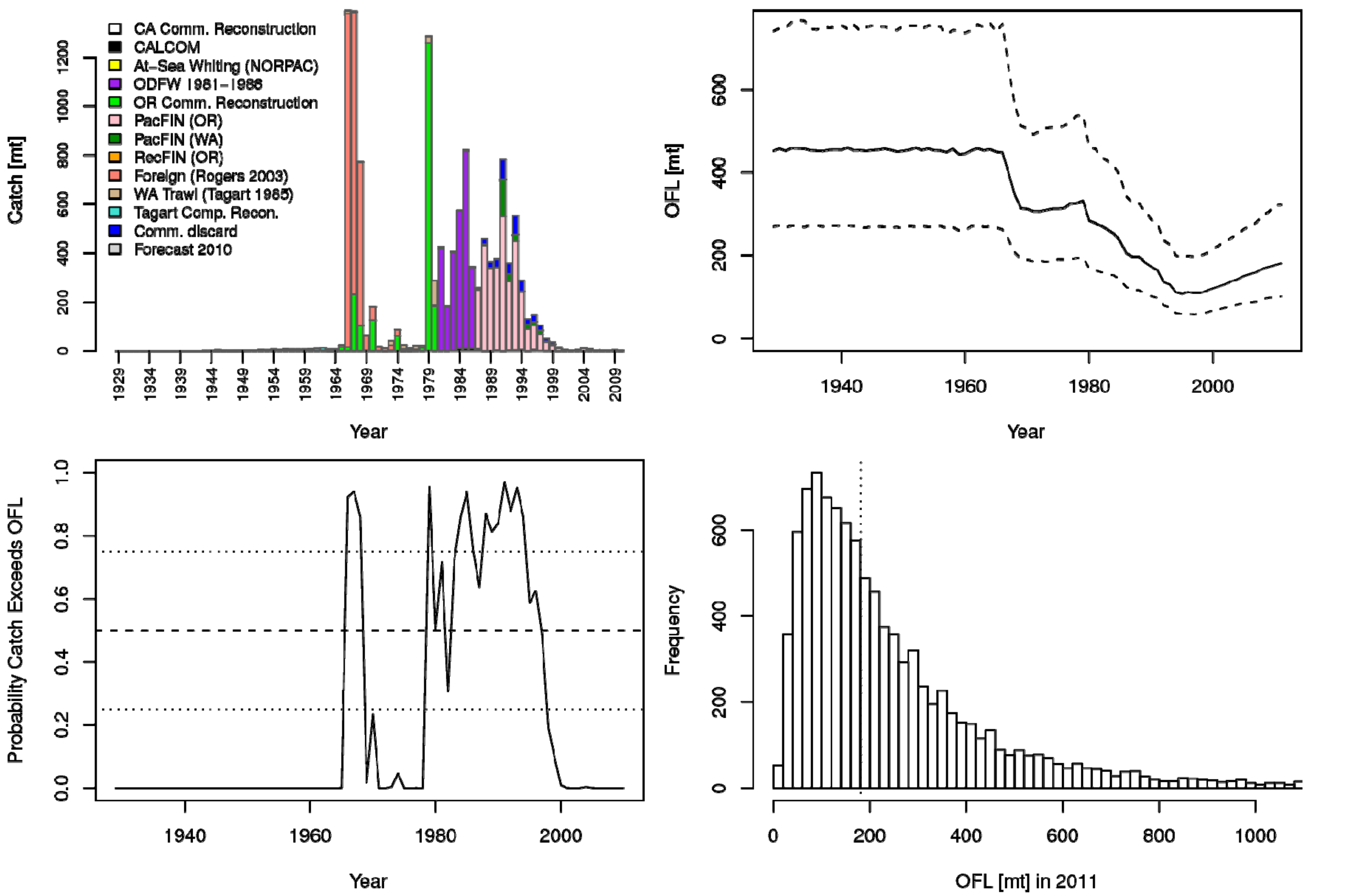


Figure 44. DB-SRA results for yellowmouth rockfish. Catch by data source (upper left), OFL time series (upper right; median = solid line, 25% and 75% quantiles = dotted lines), probability that catch exceeded the OFL by year (lower left), and OFL (mt) forecast in 2011 (lower right; median = dotted line).



Appendix A
Structured Query Language (SQL)

PacFIN (source of Oregon and Washington commercial landings, 1981-2009)
[query date: 2/25/2010; see text for details regarding OR rockfish landings, 1981-86]

```
SELECT    (sc.lbs/2204.62) "catch.mt", sc.spid, sc.year, sc.arid, sc.pcid,
          sp.cname, sc.agglvl, sc.period
FROM      sc, gr, ar, sp
WHERE     ar.arid = sc.arid and
          sp.spid = sc.spid and
          gr.grid = sc.grid and
          ar.arid in ('UP','1A','1B','1C','2A','2B','2C','3A','3B','3S') and
          pcid in ('AOR','AWA') and
          sp.mgrp = 'GRND' and
          substr(sp.cname, 1, 1)<>'_' and
          agglvl = 'Y' and
          gr.type = 3
ORDER BY  pcid, year, spid
```

CALCOM (source of California commercial landings, 1969-2009)
[query date: 2/24/2010]

```
SELECT      Sum(com_lands.pounds)/2204.62 AS 'catch.mt',
            com_lands.species AS 'sp.code', com_lands.year AS 'year',
            com_lands.port_complex AS 'area', species_codes.species_grp
FROM        CALCOM.dbo.com_lands com_lands, CALCOM.dbo.species_codes species_codes
WHERE       (species_codes.species_grp IN ('ROCKFISH', 'FLATFISH', 'OTHER_GF',
            'SHARK', 'SKATE')) AND
            (com_lands.species=species_codes.calcom_code) OR
            (com_lands.species In ('RATF')) AND
            (com_lands.species=species_codes.calcom_code)
GROUP BY    com_lands.species, com_lands.year, com_lands.port_complex,
            species_codes.species_grp
ORDER BY    com_lands.species, com_lands.year, com_lands.port_complex
```

NORPAC (source of at-sea catch by Pacific whiting fleet, 1991-2008; obtained via PacFIN)
[query date: 2/25/2010]

```
SELECT     NPAC4900.year, sp.spid, sp.cname, ar.arid,
           sum(NPAC4900.total_weight) as total_mt,
           sum(NPAC4900.wt_retained) as retained_mt
FROM       NPAC4900, sp, ar
WHERE      NPAC4900.spid = sp.spid
           and NPAC4900.arid = ar.arid
           and ar.arid in ('UP','1A','1B','1C','2A','2B','2C','3A','3B','3S')
           and sp.mgrp = 'GRND'
GROUP BY   NPAC4900.year, sp.spid, sp.cname, ar.arid
ORDER BY   year, spid, arid
```

California commercial catch reconstruction (1916-1968; obtained via CALCOM) [query date: 2/25/2010]

```
SELECT    Sum(RECON_COM_LANDS.pounds)/2204.62 AS 'catch.mt',
          RECON_COM_LANDS.species AS 'sp.code',
          RECON_COM_LANDS.year AS 'year', RECON_COM_LANDS.region_caught AS 'area',
          RECON_COM_LANDS.gear, RECON_COM_LANDS.source,
          species_codes.common_name, species_codes.species_grp
FROM      CALCOM.dbo.RECON_COM_LANDS RECON_COM_LANDS,
          CALCOM.dbo.species_codes species_codes
WHERE     RECON_COM_LANDS.species = species_codes.calcom_code AND
          (species_codes.species_grp In ('ROCKFISH','FLATFISH','OTHER_GF'))
GROUP BY  RECON_COM_LANDS.year, RECON_COM_LANDS.species,
          RECON_COM_LANDS.region_caught,
          RECON_COM_LANDS.gear, RECON_COM_LANDS.source,
          species_codes.common_name, species_codes.species_grp
ORDER BY  RECON_COM_LANDS.year, RECON_COM_LANDS.species,
          RECON_COM_LANDS.region_caught
```

California recreational catch reconstruction (1928-1980; obtained via CALCOM) [query date: 2/25/2010]

```
SELECT     Sum(RECON_REC_LANDS.POUNDS)/2204.62 AS 'catch.mt',
           RECON_REC_LANDS.SPECIES AS 'sp.code',
           RECON_REC_LANDS.YEAR AS 'year',
           RECON_REC_LANDS.AREA AS 'area',
           species_codes.common_name, species_codes.species_grp
FROM       CALCOM.dbo.RECON_REC_LANDS RECON_REC_LANDS,
           CALCOM.dbo.species_codes species_codes
WHERE      RECON_REC_LANDS.SPECIES = species_codes.calcom_code
GROUP BY   RECON_REC_LANDS.SPECIES, RECON_REC_LANDS.YEAR, RECON_REC_LANDS.AREA,
           species_codes.common_name, species_codes.species_grp
```