AN INITIAL EXAMINATION OF THE STATUS OF THE
BANK ROCKFISH FISHERY OFF THE COAST OF CALIFORNIA

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INTRODUCTION

In recent years the council has expressed growing concern about minor groundfish species and the general lack of knowledge about their status. Bank rockfish (Sebastes rufus) is among the top ten most abundant rockfish in California commercial landings (Pearson and Ralston 1990). Estimated landings have averaged 1015 metric tons between 1981 and 1992 (Table 1).

At one time, this species was thought to be two separate species; hence, there were two common names (bank rockfish and red widow rockfish). In a careful morphometric study, Robert Lea confirmed that there was only one species, and believes the observed differences were due to the way the fish had been handled. In this study, bank rockfish includes red widow rockfish.

Few studies have been conducted specifically on bank rockfish, but a Master's Thesis by Watters in 1993 does have some age and growth information. In addition, several studies on rockfish in general have useful information on the life history of bank rockfish. There is very little length composition data from research surveys for this species; however, the triennial surveys have depth distribution and species composition data. Landing and length composition data were obtained from the California Cooperative Port Sampling program.

Ralston et al. (1991) showed a significant reduction in mean length of male bank rockfish from 1978-1988. In addition, Pearson and Ralston (1990) found an unusually large difference in mean length between ports north of San Francisco, and those to the south. A large fraction of the total landings are made by gill net which is only legal in ports for San Francisco south (Table 2).

The apparent high longevity (more than 50 years according to Watters), and slow rate of growth suggest this species may not be able to withstand high levels of fishing. The changes observed in the length compositions over time suggest that this species may be experiencing considerable fishing pressure.

In this paper I review the available information on life history and fisheries for bank rockfish. I examine changes in the length compositions, discuss fishing practices, estimate selectivity, natural mortality, $F_{35}$, and discuss potential management recommendations.

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1 R. Lea, California Department of Fish and Game, 20 Lower Ragsdale Road, Monterey, CA 93940, pers. commun. April 1994.
LIFE HISTORY

Watters (1993) wrote her Master's Thesis on age and age validation of bank rockfish. She used radiometric validation and then estimated preliminary von Bertalanffy growth parameters based on 167 fish (figure 1). The Watters study is the best available data for age and growth of bank rockfish. The otoliths used in her study were obtained from commercial market samples collected in California. To estimate the von Bertalanffy growth parameters she used the computer program FISHPARM on 81 male and 86 female fish. The oldest age she found (using the broken and burnt otolith technique) was 53 years. Since Watters estimated a very high L for females (594mm) compared to the size of fish in her sample, and her prior experience at ageing fish was minimal, I decided to briefly examined 20 additional sets of otoliths and found that the predicted curves were similar to the ages obtained by me over a variety of sizes.

There is no clear consensus regarding preferred habitat for bank rockfish. Miller and Lea (1972) report the preferred habitat is benthic over sand and mud substrate. Love et al. (1990) describe bank rockfish as a midwater aggregating species found over high relief terrain near the edges of banks. The commercial port sampling data suggests this species is often caught with bottom trawls. The fact that a large fraction of the total landings of bank rockfish are made by gill nets suggest that the species is somewhat mobile and may be found off the bottom. Taken together, these observations suggest that the species has a wide distribution and is not selective in its habitat preference. Commercial port sample data suggests that the majority of trawl caught bank rockfish are caught in depths between 100 and 200 fathoms. Love et al. (1990) report that juveniles probably have a somewhat shallower depth distribution.

To help identify trends in species associations and depth distribution, trawls from the 1977 Triennial Groundfish Survey were examined using 10 fathom depth intervals for all trawls made south of 40° latitude. The analysis was restricted to 1977 because this was the only year that the survey was made in water deeper than 200 fathoms and a large number of trawls were made in deep water. This analysis indicated that bank rockfish were most often caught at depths between 110 and 200 fathoms (figure 2). Splitnose rockfish showed at somewhat broader depth distribution, and blackgill rockfish showed a somewhat deeper depth distribution, but there was considerable overlap with the bank rockfish depth distribution. Between 100 and 250 fathoms, splitnose occurred in 81% of the trawls and bank rockfish occurred in 26% of the trawls. Between 150 and 250 fathoms, blackgill rockfish occurred in 34% of the trawls. The same analysis indicated that in more than 90% of the trawls where bank rockfish were caught, splitnose rockfish were also caught. This finding is due to the apparent widespread distribution of splitnose, and the similarity of their depth distribution.
Fishermen have reported that bank rockfish are difficult to target on. In Monterey, bank rockfish have been called "the lucky fish"; nonetheless, some fishermen appear to be able to target on the species. Port biologists in both Eureka and Morro Bay have suggested that bank rockfish are not abundant every year; however, when they are present, they seem to be found in certain localized areas that some fishermen know about. Both the Eureka and Morro Bay port biologists feel that bank rockfish are highly mobile.

Reproduction of bank rockfish was examined by Love et al. (1990) and Wyllie Echeverria (1987). Bank rockfish are reported to be multiple spawners, at least in the southern part of their range (Love et al. 1990). Fifty percent of female bank rockfish are sexually mature at a length of about 35cm (Table 3) (Love et al. 1990, and Wyllie Echeverria 1987) and produce about 110,000 eggs per fish (Love et al. 1990) of that size. The Watters (1993) study indicate that a 35cm female is about 16 years old.

**DESCRIPTION OF THE FISHERY**

Most of the reported landings of bank rockfish are from the Monterey and Conception INPFC areas (Table 2). Landings from southern California (south of Morro Bay) are not reliable in most years due to the absence of port sampling data. Small quantities of bank rockfish are landed in the Eureka and Columbia INPFC areas, but these landings are probably not well estimated due to the sporadic nature of the landings in these areas. Most of the reported landings for the Conception INPFC area were based on landings and samples taken in Morro Bay except from 1986-89 when samplers were able to obtain samples from both the gill net and longline fleets in southern California. Therefore, landings in 1981-1985, 1990, and 1991 underestimate the true landings for the Conception INPFC area. The majority of landings of bank rockfish are made by trawl and gill net, with line gear making up only a small fraction of the total landings. Total actual landings by line gear is not well estimated due to the low level of port sampling and may be higher than estimated in southern California where sampling has been sporadic. In addition, expansions of the landing data for California tend to somewhat underestimate the actual landings of all rockfish since a certain amount of the rockfish are landed by "Other Gear" and these are not included in the expansion. Based on a preliminary examination of the "Other Gear" market categories, it appears that about 5% of the actual landings of all rockfish may not be accounted for. While there are some problems with the data, the landings presented in this report are the best available data.

According to port biologists, bank rockfish are large enough, and product recovery rate is high enough, that it is unlikely that market considerations alone would be responsible for decreases in landings. It has been suggested by one dealer in Fort Bragg, that splitnose rockfish (§. diploproa) are not
desirable due to the low recovery rate and small average size. Since port sampling data indicate this species is often landed with bank rockfish, it is possible that a lack of demand for splitnose might result in lower landings of bank rockfish.

Examination of commercial port samples suggests that when bank rockfish are landed, a variety of other deepwater species are often landed, including: blackgill rockfish (S. melanostomus), splitnose rockfish, darkblotched rockfish (S. crameri), and aurora rockfish (S. aurora). They are less likely to be landed with chilipepper rockfish (S. goodei), widow rockfish (S. entomelas), yellowtail rockfish (S. flavidus), and bocaccio (S. paucispinus). There is no single species that is either always present, or always absent in samples containing bank rockfish in any given port.

LANDINGS

Bank rockfish are of only minor importance in the sportfish fishery in central and northern California. In southern California they have been reported to be about three percent of the rockfish taken by sport fishermen on commercial passenger fishing vessels between 1985 and 1989 (all the years for which the data was compiled)\(^2\). In both the Orange County and San Diego County areas, they were among the top 10 most abundant rockfish in sport landings. Estimated landings in 1986 were about 48,000 fish for the entire southern California area, with a three year average (1985-1987) of 27,300 fish per year. Assuming an average length of about 40 cm (from the length composition data presented by Ally et al. [1991]), and applying the weight-length relationship from Love et al (1990), this would be about 25 tons per year.

Most of the commercial landings of bank rockfish occur in the Monterey and Conception INPFC areas (Table 2). The landings have been erratic between ports among years. In 1984, an estimated 1500 tons was landed in Fort Bragg. Examination of the port sample data and programs used to estimate the landings suggest that about 600 tons of this were based on expansion of a single sample to the entire landings of a market category for the entire year. Nonetheless, the other 900 tons was based on a large number of samples which indicates that a large amount of bank rockfish were landed that year in Fort Bragg. In 1986, over 1,000 tons of bank rockfish were reported landed in the Conception INPFC area. More than half the landings were made by trawl in Morro Bay; however, a large amount was made by gill nets farther south (more than 250 metric tons in San Diego). These

\(^2\) R. Ally, California Department of Fish and Game, 330 Golden Shore Drive, Long Beach, CA 90802, pers commun. May 1994.

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estimates were based on a large number of samples and are probably reliable. Unfortunately, port sampling to the south of Morro Bay has been sporadic and it is not clear whether 1986 was an anomalous year, or whether actual landings in the southern part of the Conception area have been underestimated in other years. The reported landings may slightly underestimate actual landings since the new method used to expand receipts may not fully expand all market and gear categories containing bank rockfish.

Historically, most of the landings of bank rockfish have been made by trawl; however, in some years, gill nets have accounted for more than half of the coast wide landings (1986-1990) (Table 1). Since gill nets are not allowed north of 38° latitude (just north of San Francisco), I have divided the Monterey INPFC area into two subareas and provided estimated landings for both areas (Table 2). The rockfish gill net fishery was very small in the Monterey INPFC area before 1984, and at that time much of the fishery is believed to have been in shallow water targeting on white croaker. Sampling of the gill net fishery in 1984 in this area was limited because of the difficulty in locating the vessels, and problems with obtaining landing receipt data. By 1985, many of these problems had been corrected and sampling rate improved. Although the gill net fishery for rockfish in the Conception INPFC area has existed longer (at least since 1982), there were chronic problems with unreported landings and lack of samples. Therefore, the landings prior to 1985 are not well estimated.

Line gear, even though poorly sampled, has probably not accounted for much of the total landings of bank rockfish. Historically, line gear has been a large component of the groundfish fishery in southern California, and it is possible that line gear takes more bank rockfish in that area than the current estimates show. However, examination of the species composition data from the limited number of samples available, suggests that most of the line gear is in waters shallower than 100 fathoms. Since there are few samples of bank rockfish taken by line gear, the expansions of the length compositions are unreliable and therefore not presented in this assessment.

Assuming that the very high estimate of the landings in 1984 for Fort Bragg are somewhat overestimated, landings of bank rockfish increased through about 1986, remained high through 1990, and may have declined in 1991 and 1992; however, the landings for southern California are not included and this decline may not be real (Table 1). Recent regulatory actions by California have forced gill net operations into deeper water.

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3 C. Haugen, California Department of Fish and Game, 20 Lower Ragsdale Drive, Monterey, CA 93940, pers commun. May 1994.

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which has probably increased fishing effort in waters deeper than 100 fathoms. When a California State regulation was implemented in 1986 forcing gill net operations outside the 100 fathom curve in Monterey Bay, gill net landings of bank rockfish in 1987 for the port of Monterey doubled (Figure 3). The 100 fathom regulation did not affect either Morro Bay or San Francisco and the gill net landings in these ports remained relatively constant. It is believed that in 1993 and continuing in 1994, many of the gill net vessels began converting to line gear so that they could fish within the 3 mile territorial zone where gill net fishing is currently prohibited by state law.

LOGBOOK DATA

Examination of the California logbook database is problematic for several reasons: there is no separate field for reporting catches of bank rockfish, data editing has been inconsistent, several problems in the database have been identified affecting measures of effort, and enforcement of the regulations regarding logbooks has been sporadic. Even if a fisherman reports bank rockfish on the log, they are reported in the database as unspecified rockfish. In spite of these flaws, when trawls are examined during three time intervals (1979-1982, 1983-1986, and 1987-1991 with ports combined (figure 4), trawls which contain rockfish show a strong trend for more hours of trawling to be made in progressively deeper water. The increased number of trawl hours in deeper water can be expected to result in increased fishing effort on bank rockfish. In 1979, the average trawl depth for trawls with rockfish was about 125 fathoms; by 1991 the average depth had increased to 175 fathoms.

LENGTH COMPOSITION

In a study of the length composition of eleven species of trawl caught rockfish in California, Pearson and Ralston (1990) found that between 1978 and 1988, the mean length of male bank rockfish decreased due to a reduction in the number of large fish being caught. There was also evidence that the mean length of both male and female fish were smaller in the ports of San Francisco, Monterey, and Morro Bay than they were in the ports of Bodega Bay, Fort Bragg, and Eureka. In their study, they used expanded length composition data from the California commercial port sampling program and restricted their analyses to trawl caught fish.

In this analysis, expanded length compositions from the commercial port sampling program are used from both gill net and trawl fisheries. The data is from a new expansion program which more accurately assigns length compositions to ports (or port complexes) than the previous version. Data from 1980 and 1992 were omitted from the analysis due to a lack of samples. Data from 1981 through 1991 was initially divided into three time
intervals (with ports combined): 1981-1984, 1985-1988, and 1989-1991 (Figure 5). Due to a lack of samples, there were no length compositions for 1981-1984 for gill nets. In addition, since gill nets are not allowed north of San Francisco, there is no length composition data for gill nets for the ports of Bodega Bay, Fort Bragg, and Eureka. There is a clear pattern of decreasing size over time for both fisheries and for both sexes. In addition, there is a strong tendency for gill nets to catch fewer small fish than the trawl fishery.

Examination of the mean length of bank rockfish (unweighted means over years, trawl and gill net gears separate) for the six port complexes (figure 6) shows a clear difference in mean length between the southern ports (Morro Bay, Monterey, and San Francisco), and the northern ports (Bodega Bay, Fort Bragg, and Eureka). It also suggests than mean lengths for gill net caught fish in San Francisco, Monterey, and Morro Bay are sufficiently similar to each other that they can be combined. For both males and females, the mean length is greater in the north than in the south. This difference does not appear to be a latitudinal gradient because the change is quite abrupt between San Francisco and Bodega Bay which are only about 35 nautical miles apart. In addition, this is probably not due to difference in gear since mesh-size regulations were the same in both areas throughout the sampling period.

When mean length is plotted separately by north (Eureka, Fort Bragg, and Bodega Bay) and south (San Francisco, Monterey, and Morro Bay) areas over time (trawl and gill net fisheries separated) (figure 7), it can be seen that mean length has always been greater in the north than in the south throughout the study interval. However, since 1985, the difference between the two areas has increased with a trend for smaller mean length in the south and relatively constant mean length in the north. Since gill net fishing increased substantially in 1985, and gill nets take a comparatively higher proportion of large fish, and gill nets operated in the southern area and not in the north; gill nets may be partially responsible for this abrupt change. The 10th percentiles for male fish have remained relatively constant, while they have decreased for females indicating an increased catch of small fish. In the north, the 90th percentile has remained effectively constant for both males and females, while in the south, the 90th percentile has decreased, indicating a declining catch of large fish. For gill net caught fish, the trend is similar to trawl caught fish in the south. The mean length of trawl caught fish in the south is smaller than for gill net caught fish in the south. Based on the 10th percentile, there is a trend for increased numbers of small fish to be caught by gill net and a reduced number of large fish based on the 90th percentile.

The trend of declining mean length over time indicates that in recent years, more immature female fish are probably being
caught. The length of 50\% sexual maturity for females is about 35cm. In the plot of female fish for 1989-1991 (figure 5), a much larger number of presumably immature fish are being caught by both trawl and gill net than during the 1985-1988 time interval.

NATURAL MORTALITY

Two methods were used to estimate natural mortality: the Hoenig (1983) approach using longevity, and the Pauley (1980) method using mean environmental temperature relative to growth. A total of 167 fish have been aged which is probably not adequate to determine the true maximum age for the species, so I used the reported maximum age (53 years) from Watters (1993), and a hypothetical maximum age (70 years) to examine the sensitivity. The Pauley method relies on mean ocean temperature and the von Bertalanffy growth parameters (figure 1). The von Bertalanffy parameters estimated by Watters were based on only 167 fish (81 males and 86 females). Watters reported bank rockfish reach a maximum age of at least 53 years, and since she did not have access to any fish less than 8 years old, the estimated von Bertalanffy parameters are probably not precise. A value for mean ocean temperature of 8° C was used based on the mean ocean temperature at a depth of 200 meters from the central California coast (Lynn et al, 1982).

The Hoenig estimates of $M$ were 0.08 for a maximum age of 53 years and 0.06 if the actual maximum age was 70 years. The Pauley method provided estimates of natural mortality for males of 0.12 and 0.10 for females. Given the uncertainty associated with the predicted von Bertalanffy parameter estimates, the best estimate of $M$ is probably closer to 0.08 (using the Hoenig approach). This estimate of $M$ is biased on the high side because it includes fishing mortality, and is based on a sample size which was unlikely to have found the oldest fish.

ESTIMATION OF $F_{35\%}$

I obtained selectivity curves from the length compositions from trawls and gill nets for 1985-1988 (figure 5). Although there was data for earlier years, there was very little data from the gill net fishery and there were gaps in the trawl data which suggested that using a later time interval was preferable. I assumed that selectivity could be represented by an ascending logistic curve. The values for selectivity were estimated by the length structured Stock Synthesis model (Methot 1990). The model was employed assuming equilibrium conditions during and prior to the 1985-88 period. In addition, since I questioned the von Bertalanffy parameters, I allowed the model to estimate new values of $k$ for both sexes and $L_0$ for females (males were assumed to be the same as females) with fixed values of $L_\infty$. Since the model estimated $L_0$ rather than $t_0$, the new parameters were based
on the size range for which I actually had data. It was necessary to fix \( L_\infty \) to obtain estimates from the model. Natural mortality was fixed at 0.08. Using the plots from Watters, I estimated a 95% confidence interval for length-at-age to provide the model with estimates of variability. The data shown in figure 5 suggest that selectivity is about 0.50 at 37 cm. The following equations result in total length selectivity estimates similar to the interpretations of figure 5:

\[
Sel_L = \frac{1}{1 + e^{(37.34 - 0.498L)}}
\]

Selectivity at length was then plotted (Figure 8), and incorporated in a relative fecundity per recruit analysis.

In the relative fecundity per recruit analysis, I assumed \( M = 0.08 \), and I used the percent mature based on length rather than age. Since the selectivity curve was for both males and females and both the gill net and trawl fisheries, the results are only a very rough approximation. The results shown in figure 9 suggest that \( F_{35%} \) is about 0.19.

**DISCUSSION**

Bank rockfish are slow growing and late maturing: by the time females are fully vulnerable to the fishery, they have just barely reached the length of 100% sexual maturity. In recent years the length composition of the fishery has been shifting towards increased harvest of smaller and presumably immature fish. The most likely explanation for the decrease in length is due to fishing pressure.

The estimates of maximum age and the von Bertalanffy growth parameters are probably not precise since they were based on only 167 fish. It is likely that natural mortality is lower than estimated because it included fishing mortality and was based on a sample size unlikely to have determined actual longevity.

The long term reduction in mean length, (part of which may be related to the gill net fishery), the increase in fishing effort in deeper water, the low \( F_{35%} \) value, and the possible decline in landings in recent years suggests that bank rockfish should be managed conservatively. Historically, bank rockfish have been smaller in the southern part of the Monterey INPFC area. Anecdotal information suggests that in the 1970's the foreign fishing fleets heavily fished the deepwater rockfish groups in the southern part of the Monterey INPFC area and the result could have been the current size difference. After the gill net fishery for rockfish developed in the southern portion of the Monterey INPFC area, there was a sharp decline in the mean length composition of both trawl and gill net fisheries.

**RECOMMENDATIONS**

Many deepwater species have life history characteristics which cannot support high levels of fishing mortality. Other
rockfish species which were caught with bank rockfish in the 1977 Triennial survey include: darkblotched rockfish, splitnose rockfish, and blackgill rockfish. Currently there is a 100,000 pound monthly trip limit for sebastes complex south of Coos Bay. If a single vessel were to begin concentrating on deepwater rockfish, they could legally land 544 tons of deepwater rockfish every year. It would not take many vessels at this level of fishing to substantially increase the landings of bank rockfish and other species of deepwater rockfish. In a preliminary assessment of darkblotched rockfish, Lenarz (1993) found that the current levels of fishing are probably having a substantial impact on darkblotched rockfish. The results for bank rockfish shown in this analysis suggest that current levels of fishing are having an effect on the length composition of the bank rockfish fishery. If a switch in effort to deeper water were to occur, the effect on the deepwater rockfish could be severe. Therefore, the council may wish to consider creating a deepwater rockfish complex and manage it separately from the Sebastes Complex. In addition, by managing the deepwater rockfish complex separately, and thereby requiring them to be sorted and identified on the landing receipts, monitoring of total landings would be facilitated.

ACKNOWLEDGEMENTS

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LITERATURE CITED


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Table 1. Landings (mt) of bank rockfish by gear type for the coasts of California and Oregon, 1981-1992. Oregon Landings were obtained from the PacFIN database, California landings were estimated by expansion of PacFIN database market samples to market receipt data. Gill net landings prior to 1985 are poorly estimated due to an absence of sampling and failure of the gill net fleet to report their landings. Based on discussions with port biologists, it is likely that that the actual landings were small.

<table>
<thead>
<tr>
<th>YEAR</th>
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<th>Line</th>
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Table 2. Landings (mt) of bank rockfish by INPFC area for the coasts of California and Oregon, 1981-1992. Oregon Landings were obtained from the PacFIN database, California landings were estimated by expansion of market samples to market receipt data. Monterey North is the portion of the Monterey INPFC area north of 38 degrees latitude (where gill net fishing is prohibited), Monterey South is the portion of the Monterey INPFC area south of 38 degrees latitude (where gill net fishing is allowed). * = does not include estimates of landings made south of Morro Bay, California.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Conception</th>
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Table 3. Age (years) and total length (cm) of first, 50%, and 100% maturity. Length at first maturity from Love et al. (1990), Ages calculated using the von Bertalanffy parameters estimated by Watters (1993).

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<th>100% MATURITY</th>
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</tbody>
</table>
Figure 1. Von Bertalanffy growth curves and parameter estimates from Watters (1993). ( )=95% confidence interval.

Figure 2. Percent of trawls from the 1977 triennial groundfish survey containing splitnose, blackgill, and bank rockfish by 10 fathom depth intervals.
Figure 3. Estimated gill net landings from 3 ports of bank rockfish. A regulation forcing gill net operations into waters deeper than 100 fathoms in the Monterey area was enacted in 1986.

Figure 4. Trawled hours per 20 fathom depth interval for trawls containing rockfish during 3 time intervals. Source of data: California Trawl Logbook database.
Figure 5. Length compositions of bank rockfish in 2cm bins from the gill net and trawl fisheries. Note that these are numbers of fish from expansions of sample data to actual landings.
Figure 5 continued...
Figure 6. Mean length of bank rockfish caught by trawl and gill nets at six California ports from 1981-1991. Means are unweighted by year. No gill net fisheries exist at the ports of Eureka, Fort Bragg, or Bodega Bay.
Figure 7. Mean length, 10th, and 90th percentiles from length distributions of bank rockfish for the northern area (Eureka, Fort Bragg, and Bodega Bay) and the southern area (San Francisco, Monterey, and Morro Bay) by gear type.
Figure 8. Length specific selectivities for bank rockfish from the gill net and trawl fisheries in 1985-1988.

Figure 9. Relative fecundity per recruit analysis for bank rockfish versus fishing mortality showing the $F_{35\%}$ value.