EXECUTIVE SUMMARY
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Overview
Stock assessments for west coast groundfish are conducted by staff scientists of the California Department of Fish and Game, Oregon Department of Fish and Wildlife, Washington Department of Fisheries, Southwest Fisheries Science Center of the National Marine Fisheries Service (NMFS), and the Alaska Fisheries Science Center of NMFS. Preliminary stock assessments were presented to an ad hoc review group in August 1990. These assessments were used by the Groundfish Management Team (GMT) to recommend preliminary levels of acceptable biological catch (ABC) which were adopted by the Pacific Fishery Management Council (PFMC) in September 1990. Final ABCs and resultant management measures will be adopted by the PFMC in November 1990. Full versions of the stock assessment documents will be published as appendices to the Stock Assessment and Fishery Evaluation document in November 1990. This executive summary is based on stock assessment documents revised on the basis of the August 1990 review.

General Features
Stock Synthesis Model: Assessments of west coast groundfish stocks in 1990 have generally been conducted through use of the stock synthesis model¹. This tool is similar to other stock assessment tools (e.g. cohort analysis, catch-at-age analysis) in its handling of the interaction between a fishery and the exploited stock, but it provides much greater flexibility in the types of fishery and survey data that can be examined. The model is structured to simultaneously analyze catch biomass, age and length composition and effort from multiple fisheries, and abundance and age and length composition from multiple surveys. This flexibility has

allowed quantitative examination of stocks and fisheries that could not be analyzed by other techniques. Although the nature of the available information rarely provide narrow constraints on the range of feasible model results, the model has provided a useful tool for organizing the available data and exploring the limits of our knowledge with regard to the history and current status of each stock.

F_{35\%} Exploitation Rate: This year the Groundfish Management Team has adopted a new standard for setting the target level of exploitation. This standard, F_{35\%}, is the fishing mortality rate that would reduce expected spawn production per female to 35% of its unfished level (Figure 1). This standard was reviewed in the analysis for the overfishing definition (FMP Amendment #5), and is supported by an independent analysis (Clark, 1990). F_{35\%} is intended as a proxy for F_{msy} (Figure 2), and it replaces other standards such as F_{0.1}. The problem with F_{0.1} is that it examines only the marginal increase in yield per recruit as fishing mortality is increased and can cause large decreases in spawning biomass if fish recruit to the fishery before they become mature. This is especially true for trawl-caught sablefish. The problem with F_{msy} is that it is tightly linked to an assumed level of density-dependence in recruitment. For no stock do we have sufficient information to determine the level of density-dependence in recruitment. F_{35\%} strikes a balance between obtaining a large fraction of the maximum sustainable yield if recruitment is highly insensitive to reductions in spawning biomass, and preventing a rapid depletion in stock abundance if recruitment is found to be extremely sensitive to reductions in spawning biomass.

No attempt is made to precisely state the long-term expectations under an F_{35\%} policy. The F_{35\%} policy recommends harvest of a fixed fraction of the stock each year. This harvest will reduce the expected, lifetime spawn production by each female entering the stock to 35% of the lifetime spawn production for females that are unfished, and will reduce the average total abundance of the female spawning stock to a level that is less than or equal to 35% of its virgin level. If this reduction in total stock causes no reduction in recruitment, then the long-term average female spawning stock level will be 35% of its unfished level and a large long-term average yield will be obtained. However, if the reduction in total female spawning stock causes some reduction in average recruitment, then future, total, female spawning stock levels will be less than 35% of the virgin level and future yields will be reduced also. Thus, the target level of female spawning biomass, relative to the virgin level, is between 35\% on the upper end and probably no lower than about 25\% on the lower end. In several cases we have calculated a level of maximum sustainable yield, MSY, under the assumption that recruitment declines to 90\% as spawning biomass is fished down to 50\% of its virgin level. This is just one of several plausible levels of MSY (Figure 2), depending on the true level of density-dependence in recruitment, and is included for reference and continuity with past reports.
Discard Mortality: An additional general feature of stock assessments conducted in 1990 is that a factor for discard mortality is incorporated where it is reasonable to assume that market conditions or trip limit regulations cause discard. The GMT's recommendations on dealing with discard mortality were submitted to the Council in April 1990. Discard was considered to be negligible for some species of rockfish, and range up to about 20% for trawl-caught sablefish. Levels of acceptable biological catch (ABC) continue to be set for landed catch. For sablefish, Dover sole, and widow rockfish there is an assumed level of discard mortality that will occur in addition to this landed catch. This level of discard is accounted for in the assessment and projections of potential yield. These assumed levels of discard are generally based on field observations, but there is no monitoring to verify the true, current level of discard.

Pacific Whiting

The total harvest of Pacific whiting by the U.S. and Canada in 1990 is expected to be 269,500 mt, down from a high of 309,000 mt in 1989. The fishery continues to be supported by the strong 1980 and 1984 year classes. Assessment surveys in 1989 estimated the population biomass as 1.637 million t, a decline of 24% from estimates made in 1986, but a lesser decline than projected in last year's assessment. In the 1990 assessment, the stock synthesis model is used to estimate age-structured population abundance, past levels of female spawning biomass, and recruitment for the 1959-87 year classes. The assessment model was revised to include geographic structure and to estimate the parameters of a function defining the age-specific, annual migration of fish across the U.S.-Canada border. Recruitment estimates and fishery selectivity coefficients from the stock synthesis model are used with an age-structured simulation model to estimate sustainable yield under different harvesting strategies and levels of reduction in female spawning biomass. Constant, $F_{35}$ exploitation rates are not recommended for this species because of its extraordinary variability in recruitment and its young, but difficult to sample, age at maturity. Several harvesting strategies are explored: a constant $F$ strategy; a variable $F$ strategy, where fishing mortality for a particular year is proportional to the level of female spawning biomass; and a hybrid strategy that combines features of the other two policies. The hybrid strategy avoids the extreme variability in yield of the variable $F$ strategy, yet increases protection of the stock at low levels of female spawning biomass. Long-term average yield depends on risk levels defined as the frequency with which female spawning biomass is expected to fall below a cautionary level of 457,000 mt. Estimates of average yield ranged from 168,000 to 227,000 t for the constant $F$ strategy, and

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from 187,000 to 235,000 t for the hybrid strategy over a reasonable range of low biomass frequency. When a hybrid fishing strategy is applied to the projected numbers at age in 1991, the potential yield is calculated to be 253,000 t. The prospects in the immediate future for the Pacific whiting resource are for stable or declining yields depending on the timing of the next strong year class.

Sablefish

The landings of sablefish in 1989 was 10,234 mt and the landed catch in 1990 is expected to be close to the ABC of 8,900 mt. The west coast sablefish stock was assessed in 1990 through application of the synthesis model to fishery size and age composition data from 1986-1989 and trawl and pot survey data. There were two significant changes in this year's assessment. First, the assessment was split into northern (U.S. - Vancouver and Columbia INPFC areas) and southern areas on the basis of known low rates of mixing of adult sablefish, and new evidence of slower growth among fish captured off California. Second, greater reliance was placed on the trawl survey biomass estimates from southern Oregon because this area constitutes a significant fraction of the northern assessment area and a survey in 1989 replicated abundance levels observed in 1984 and 1988. The recommended assessment results that match this biomass level do not, however, provide a good match to the decline in the pot survey's estimate of sablefish abundance. The northern area's assessment indicates that the biomass of age 3+ sablefish was about 80,400 mt at the beginning of 1990 and the biomass of mature females was 36,100 mt. This level of spawning biomass is intermediate between 38,800 mt (35% of virgin spawning biomass) and 31,800 mt (spawning biomass that produces MSY under previously assumed level of recruitment density-dependence), so this area's stock is judged to be approximately at its optimum level. Application of the F$_{33}$ exploitation policy to the expected 1991 biomass produces a recommended landed yield of 4,060 mt for the northern area, plus an expected trawl discard of 590 mt. The assessment in the southern area has greater uncertainty because of the lesser amount of survey data. The recommended assessment indicates that the biomass of age 3+ fish at the beginning of 1990 was 87,600 mt and the biomass of mature females was 45,200 mt. This level of spawning biomass is above 39,300 mt (35% of virgin spawning biomass) and 33,400 mt (spawning biomass that produces MSY under previously assumed level of recruitment density-dependence). Application of the F$_{33}$ exploitation policy to the expected 1991 biomass produces a recommended landed yield of 4,725 mt for the southern area, plus an expected trawl discard of 685 mt. A single, coastwide ABC of 8,800 mt is recommended for 1991.

Pacific Cod

The GMT recommends no change in the coastwide ABC for Pacific cod from the previous level of 3,200 mt which was set in 1989 at the
highest catch of record. The catch reported by PacFIN for 1989 was 2,183 mt for all areas. No MSY is specified for this species because the Washington, Oregon and California area is the southern end of its range, and because environmental factors have a more significant influence on Pacific cod recruitment and stock abundance, in this area, than fishing.

Lingcod

No changes are recommended in the area-specific ABCs for lingcod. These are: Vancouver - 1,000 mt; Columbia - 4,000 mt; Eureka - 500 mt; Monterey - 1,100 mt; and Conception - 400 mt. The catch by area in 1989 was Vancouver - 807 mt; Columbia - 1,430 mt; Eureka - 377 mt; Monterey - 777 mt; and Conception - 21 mt.

Pacific Ocean Perch

A rebuilding program was established for Pacific ocean perch in 1981 following depletion of this stock during the 1960s and early 1970s. An assessment in 1987 indicated that the stock remained depleted. A review in 1990 of recent commercial fishery length data did not indicate any significantly strong year classes entering the fishery. The research surveys, which generally capture younger fish did indicate some evidence of incoming strong year classes, although none rivalled the magnitude of the 1970 cohort. This signal is encouraging, but significant rebuilding has not occurred, and the GMT recommends that the ABC remain at zero in both the Vancouver and Columbia areas.

The GMT recognizes that incidental catches will occur and recommends that trip limits be set to allow a purely incidental fishery. High landings of 943 and 1102 mt occurred in the Columbia area during 1988 and 1989, respectively. In 1990 the incidental catch rate was reduced to 3,000 pounds per trip and the landed catch decreased to about 400 mt, which is less than the pre-1989 level. With respect to other areas, Pacific ocean perch are neither common nor important and are included in the "Remaining Rockfish" category.

Shortbelly Rockfish

The age, growth and potential yield of shortbelly rockfish were re-examined in 1989 and no new work was conducted in 1990. Shortbelly rockfish remains an unexploited, virgin stock at present, thus is difficult to quantitatively assess. The extremes of the MSY estimates from two alternative yield calculations were 13,900 mt to 47,000 mt. The GMT recommends maintaining the ABC at 13,000 mt until further data can be collected.
Widow Rockfish

The stock synthesis model was used to estimate fishing mortality rates and population size for widow rockfish, using 1979-1990 landings estimates and 1980-1989 age composition data. For the three levels of fishing mortality (F) in 1989 considered most likely (0.25, 0.35, and 0.45), estimates of 1991 biomass ranged from 41,200 to 81,300 t. The estimate of \( F_{35\%} \) was 0.21 at a natural mortality rate of 0.15 and 0.255 for \( M=0.20 \). The projected 1991 landing at \( F_{35\%} \) ranged from 3,400 to 7,100 t, depending on the assumed F for 1989. The recommended ABC of 7,000 t is near the high end of this range, and is also consistent with last year's recommendation of 7,800 t which was obtained by applying a higher level of fishing mortality (based on \( F_{0.1} \)) to a lower level of estimated biomass. As in previous years, the age composition data for 1989 indicate a continued fishing down of the older age groups and that the 1982 and 1983 year classes are relatively weak.

Bocaccio

Trawl landings of bocaccio were about 2000 mt annually during the late 1970s, increased to about 4700 mt by 1981 with the recruitment of the large 1977 year class, then fell to just over 1000 mt since 1985. In 1989 the total landed catch of about 1,800 mt is composed of about 2/3 trawl catch, 1/6 set net, and 1/6 recreational catch. The previous assessment conducted in 1985 set the ABC at 6,100 mt. A new assessment was conducted in 1990 by applying the stock synthesis model to data from all three fishery components and NMFS trawl surveys. All data sources indicate a declining resource, and the model estimates that biomass has fallen from about 75,000 mt in 1978 to 7000 - 14,000 mt in 1990. A significant fraction of the observed decline is due to poor recruitment since 1978. The spawning biomass in 1991 is probably less than 25% of the average, unfished level. The projected yield at \( F_{35\%} \) in 1991 ranges from 800 to 1700 mt, and the preliminary ABC for 1991 was set equal to this range.

Canary Rockfish

The status of the canary rockfish stock in the Columbia area was assessed through application of the stock synthesis model to catch data from 1967-89, age composition data from 1980-1988, trawl fishery effort data from 1980-1987, and triennial trawl survey data from 1977-1989. The model was used to determine that the most plausible level of virgin recruitment ranged from 1.25 to 1.75 million age 5 fish. At the extremes of this range, the female spawning biomass in 1989 was 16-33% of its virgin level, and fishing mortality for the age at maximum selectivity ranged from 0.143 - 0.370 in 1989. An interesting result is that male and female canary rockfish are estimated to have asymptotic availability to the trawl fishery, but the low observed proportion of old females is due to increased natural mortality for mature
females.

The $F_{35x}$ ranged from 0.135 to 0.190 and maximum long-term average yield at this level of fishing mortality would be 1060 to 1300 mt. Application of $F_{35x}$ to the range of estimated 1991 biomass produces yields in the range 1050 to 1950 mt, and the GMT recommends that the ABC for the INPFC Columbia area be set equal to the midpoint which is 1500 mt. Average catch from 1985-1989 was 1320 mt in this area and the previous ABC of 2100 mt has not been achieved since it was established in 1984. Catches in the INPFC Vancouver and Eureka areas have been close to or below current ABC levels of 800 and 600 mt, respectively. The GMT recommends no change in ABC for these areas.

**Chilipepper Rockfish**

The status of the chilipepper rockfish resource was last assessed in 1986. At that time the coastwide ABC was set at 3600 mt. The GMT does not recommend a change in the ABC for 1991, but does recognize that this species is an increasingly important component of the rockfish fishery in California, especially with the decline in bocaccio abundance. The GMT recommends a high priority for assessment of this species.

**Yellowtail Rockfish**

The status of the yellowtail rockfish stock was assessed in 1988 and the ABC for the U.S.-Vancouver and Columbia INPFC areas was set at 4000 mt. This species is a prime target of the rockfish fishery in Washington and northern Oregon, and landed catch in 1989 and 1990 slightly exceeded the ABC. The GMT examined the magnitude of this excess harvest relative to the status of the stock and concluded that the excess harvest would not, in the short term, drive the stock below its optimum level.

A new assessment was conducted in 1990 using the stock synthesis model. This assessment takes advantage of two additional years of fishery age composition data, and splits the stock's range into three assessment areas that correspond more closely to known patterns of the species' distribution. As in previous assessments, the estimated current biomass was difficult to pinpoint because of the lack of quantitative auxiliary data. The assessment identified that natural mortality probably increases for older females, e.g. the same pattern that was identified for canary rockfish. In the Eureka/S. Columbia area, the total population biomass is estimated at 13,100 - 21,600 mt and the female spawning biomass is greater than 50% of its virgin level. The recommended ABC in 1991 is 1350 mt. This level of catch would exceed the known catch of record of 1281 mt in 1983 and compares with 1088 mt landed in 1989. In the N. Columbia area, the 1991 total biomass is estimated to be 25,200 - 54,400 mt, and female spawning biomass is estimated to be between 28 and 64% of the unfished level. The recommended yield for 1991,
2085 mt, is based on application of F₃₅ₓ to the low end of this range because of recent declines in observed recruitment. This level of ABC is similar to the 1989 landed catch of 2048 mt. Stock condition was also estimated for the S. Vancouver area, which extends into Canadian waters to near the middle of Vancouver Island. Total biomass in 1991 is estimated to be in the range 20,600 - 39,700 mt and spawning biomass is estimated to be 23 - 48% of the virgin level. Application of F₃₅ₓ to the low end of this range produces a recommended yield in 1991 of 2040 mt. The recommended share for U.S. fishers is 60% or 1200 mt, which is slightly below the US harvest of 1400 mt in 1989. The GMT set the 1991 ABC for the U.S.-Vancouver and Columbia areas at 4300 mt which is 300 mt greater than the previous level. The total female spawning biomass for the three assessment areas was 8330 - 35,600 mt. These levels are 30 - 58% of estimated virgin levels and, at the low end, are essentially identical to the level that produces maximum sustainable yield under a level of density-dependence in which recruitment declines to 90% as female spawning biomass declines to 50% of its virgin level.

**Thornyhead Rockfish**

The thornyhead (Sebastolobus spp.) market category supports an expanding fishery; coastwide landings during 1989 were almost 8000 mt and landings during 1990 are expected to be in excess of 11,000 mt. In 1989, thornyheads accounted for 21% of total revenues from the deepwater complex (thornyheads, Dover sole, sablefish, and arrowtooth flounder). Shortspine thornyhead account for the majority of the landed catch, but the proportion of longspine thornyheads has increased in recent years. Age determinations, although unverified, indicate that thornyheads are among the most long-lived rockfish with maximum ages near 150 years. Accordingly, estimated natural mortality and growth rates are low, and the recommended level of fishing mortality (F₃₅ₓ) is in the range 0.03 - 0.06 per year. Some estimates of shortspine thornyhead density are available from trawl surveys in the Columbia and Conception INPFC areas and from underwater camera observations. Expansion of these density estimates to available habitat in the Monterey-Eureka-Columbia INPFC areas provides an estimate of biomass in each area. Application of F₃₅ₓ to each of these biomass estimates indicates that recent harvests probably are too high, especially in the Eureka area. The GMT recommends a new 1991 ABC for shortspine and longspine thornyhead in the Monterey-Eureka-Columbia areas (where most of the harvest occurs) of 5900 mt. This harvest level is similar to the landed catch in 1988 and substantially below the expected catch in 1990.

**Remaining Rockfish**

Remaining rockfish in the Vancouver and Columbia areas are defined as all rockfish in the Sebastes complex except yellowtail, canary, widow, and shortbelly rockfishes. In the Eureka, Monterey, and
Conception areas, bocaccio and chilipepper rockfish are excluded from this category, but yellowtail and canary rockfishes are included. Thornyheads were nominally included in this category in past years but their contribution was small. The GMT recommends establishment of a separate ABC for thornyheads in the Monterey-Eureka-Columbia areas, but this action does not cause us to recommend reducing the ABC for the remaining rockfish category because this ABC was established at a time when the thornyhead contribution was very small.

The GMT recommends the ABCs remain unchanged in 1991, that is, Vancouver - 800 mt; Columbia - 3700 mt; Eureka - 1900 mt; Monterey - 4300 mt; and Conception - 3300 mt. However, an examination of declines in mean length for several rockfish species in the Conception-Monterey-Eureka area suggests that the fishery removals are having a noticeable impact on these stocks. The GMT does not have sufficient information to recommend a specific harvest guideline for the remaining rockfish in this area, but does recommend that fishing mortality in this area be restrained.

**Dover Sole**

Size and age composition data from the INPFC Eureka and Columbia areas were analyzed by the stock synthesis model. The assessment for the Columbia area included data from trawl surveys conducted by NMFS on the continental slope off southern Oregon. Strong and weak year classes are not obvious in the age composition data, so this preliminary assessment was conducted under the assumption of constant recruitment. Sharp increases in the percentage of small Dover sole occurred beginning in 1983-84, probably related to changes in market acceptance and in codend mesh sizes. The model accommodated these changes by introducing a new estimate of size-specific availability at that point in the time series. Two plausible levels of recruitment are identified for each area, and result in an approximately two-fold range in estimated current biomass.

In the Eureka area, recent landed catches have declined to about 4000 mt and the stock seems to be in equilibrium, although lack of auxiliary data and movement of the fishery into deeper water hamper quantitative assessment. MSY, estimated under an assumed level of density-dependent recruitment, is in the range 4200 - 5300 mt. The current female spawning biomass is estimated to be well above the target level, and the range of $F_{35}$ yields for 1991 is 7970 - 11,900 mt. The GMT recommends an ABC at the lower end of this range, especially pending a trawl survey planned for the Eureka area in late fall 1990. In the Columbia area recent landed catches have increased to about 8000 mt. MSY is estimated to be in the range 3400 - 4800 mt. Female spawning biomass in 1991 is estimated to be in the range 30,500 - 67,600 mt, which is 37 - 56% of virgin spawning biomass and above the target level of spawning biomass. Application of $F_{35}$ in 1991 would produce yields of 4160 - 7960 mt and the GMT recommends the midpoint of this range, 6100 mt. If the
lower biomass scenario is actually correct, then continued harvests of 8000 mt will drive the Columbia area stock below its target level in about three years.

**English Sole**

No full analysis of the status of this species has been conducted since 1986. The GMT recommends no change in the coastwide ABC of 1900 mt, but identifies this species as a good candidate for future stock assessment efforts because landed catch in 1989 was slightly above this level.

**Petrale Sole**

A stock assessment for the Vancouver and Columbia areas was conducted in 1987. The GMT recommends continuation of the ABCs recommended at that time: Vancouver - 600 mt; Columbia - 1100 mt; Eureka - 500 mt; Monterey - 800 mt; and Conception - 200 mt. This total ABC of 3200 mt is greater than the 1989 landed catch of 2110 mt.

**Other Flatfish**

The GMT recommends no change in the ABCs for this group of species: Vancouver - 700 mt; Columbia - 3000 mt; Eureka - 1700 mt; Monterey - 1800 mt; and Conception - 500 mt. This coastwide ABC of 7700 mt is greater than the 1989 catch of 6500 mt (3545 mt of arrowtooth flounder and 2955 mt of other flatfish). The landed catch of arrowtooth flounder has increased in recent years and the GMT recommends that an assessment of this species be conducted in the near future.

**Jack Mackerel**

No new information is available for this species and the GMT recommends no change from the previous ABC of 12,000 mt.

**Other Groundfish**

The GMT recommends no change in the coastwide ABC of 14,700 mt.
Figure 1. Expected relative yield per recruit and spawning biomass per recruit as a function of the rate of fishing mortality. Spawning biomass per recruit is equivalent to the expected lifetime egg production by a female entering the population. The level of fishing mortality indicated by \( F_{35\%} \) will reduce spawning biomass per recruit to 35% of its unfished level.
Figure 2. Relationship between equilibrium yield and female spawning biomass is displayed by the two curves, with tic marks indicating levels of fishing mortality at which these curves were evaluated. The upper curve describes a situation in which recruitment is independent of spawning biomass. The lower curve indicates a plausible, but arbitrary, level of density-dependence with a Beverton-Holt type of recruitment function. A set of possible MSY levels for a range of density-dependence is delineated by the stars. The relation between yield and spawning biomass upon application of the $F_{35\%}$ level of fishing mortality, which reduces each female's expected lifetime egg production to 35% of its unfished level, is indicated by the dotted line. The stock is expected to come to equilibrium where this dotted line intersects the true, but unknown, yield-spawning biomass curve. If the lower curve shown on the figure is the true level of density-dependence, then application of $F_{35\%}$ will produce MSY in this example.
Table 1. Preliminary GMT recommendations for ABCs for 1991 in mt for the Washington-California region by INPFC areas.

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</table>

\( ^{\text{a}} \) U.S. portion.
\( ^{\text{b}} \) Total all areas.
\( ^{\text{c}} \) These species are not common nor important in the areas footnoted. Accordingly, for convenience, Pacific cod is included in the "Others" category for the areas footnoted and rockfish species are included in the "Remaining Rockfish" category for the area footnoted only.
\( ^{\text{d}} \) Based on 90 percent of the coastwide ABC of 253,000 mt.
\( ^{\text{e}} \) The GMT recommended 7,900 mt ABC for 1990; Council set OY at 9,800 to 10,000 mt.
\( ^{\text{f}} \) Includes Eureka area, but its contribution is small, and recreational catch.
\( ^{\text{g}} \) Includes sharks, skates, rays, ratfish, morids, grenadiers, and jack mackerel.
\( ^{\text{h}} \) All areas north of 39°N latitude.