CHANGING THE SIZE LIMIT: HOW IT COULD AFFECT CALIFORNIA HALIBUT FISHERIES

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ABSTRACT

The minimum legal size limit for California halibut (*Paralichthys californicus*) is 559 mm TL for all fisheries. There appears to be a conflict of allocation among user groups, with recreational catches being preempted by intense commercial fishing. We evaluate two possible solutions: a uniform change in the minimum size limit to 660 mm for all fisheries, or a differential size limit (recreational = 559 mm, commercial = 660 mm).

The commercial fishery takes from 60% to 80% females, which grow longer than males. Because sexes are not identified in most of the fishery data, we examined two alternative interpretations. In one case we treated the catch as consisting entirely of female fish; in the other case we treated catches as a combination of males and females, with a common, intermediate growth curve. We also examined two possible levels of natural mortality rate: $M = 0.1$ and $M = 0.2$. The virtual population analysis gave average total biomass estimates of 2,600 to 6,000 MT, and average recruitment (age 1) estimates of 0.5 to 1.0 million fish.

Yield-per-recruit (Y/R) analysis indicates that overall fishing effort is about twice the optimum level and that Y/R would likely increase with reduced fishing effort. Our analysis of proposed size limit assumed present levels of fishing effort. Under a differential size limit the recreational fishery shows an increased Y/R, both in weight and in numbers, whereas the commercial fisheries experience a net loss. Under a uniform 660-mm size limit for all fisheries, if $M = 0.1$, the Y/R for both recreational and commercial fisheries increases in weight but not in numbers. For a higher natural mortality rate ($M = 0.2$), the Y/R is reduced in the combined sex analysis, but the case of a female-based catch shows slight gain. The yield-per-recruit analysis suggests that the California halibut fishery is currently utilized at the point of maximum yield and that proposed changes in minimum size are not likely to resolve allocation conflicts among user groups.

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RESUMEN

El tamaño mínimo legal para *Paralichthys californicus* en todas las pesquerías es de 559 mm LT. Parece haber un conflicto en cuanto a las cuotas de captura asignadas a ciertos grupos de usuarios, dado que una intensa pesca comercial se apropria de las capturas recreativas. Dos posibles soluciones son evaluadas: un cambio general del tamaño mínimo a 660 mm para todas las pesquerías o un límite diferencial (recreacional = 559 mm, comercial = 660 mm).

La pesquería comercial captura 60% a 80% de las hembras, las cuales alcanzan un mayor tamaño que los machos. Dado que no se indica el sexo en la mayoría de los informes pesqueros, examinamos dos explicaciones alternativas. En un caso, se consideró una captura compuesta exclusivamente por hembras; en el otro, se consideraron capturas compuestas por machos y hembras, con una curva de crecimiento común e intermedia. Se examinaron además dos niveles de tasa de mortalidad natural: $M = 0.1$ y $M = 0.2$. El análisis de poblaciones virtuales dió estimaciones de la biomasa total promedio de 2,600 a 6,000 TM y del reclutamients promedio (edad 1) de 0.5 a 1 millón de individuos.

El análisis de la producción por recluta (Y/R) indicó que el esfuerzo pesquero general es aproximadamente el doble del nivel óptimo y que Y/R probablemente aumentaría con una reducción del esfuerzo pesquero. Nuestro análisis de los cambios propuestos en tamaño mínimo supone niveles de esfuerzo pesquero similares a los actuales. Si se adopta un tamaño mínimo diferencial, la pesquería recreacional muestra un aumento en Y/R tanto en peso como en número de individuos mientras que la pesquería comercial experimenta una pérdida neta. Bajo el criterio de tamaño uniforme de 660 mm en todas las pesquerías, con $M = 0.1$, el Y/R de ambas pesquerías aumenta en peso pero no en número de individuos. Con una mortalidad natural más alta ($M = 0.2$), el Y/R es menor en el caso de un análisis con sexos combinados, pero en el caso de una captura compuesta sólo por hembras muestra un leve aumento. El análisis de producción por recluta sugiere que, actualmente, la pesquería de

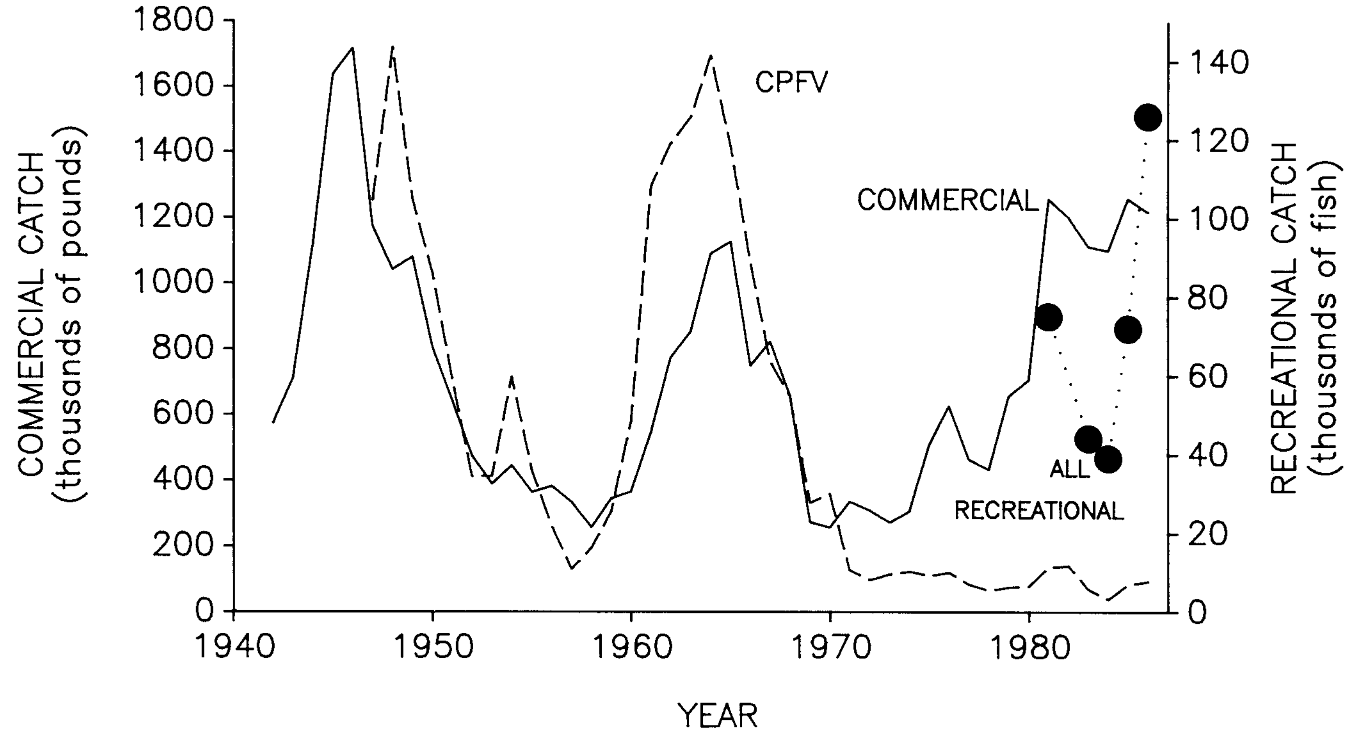

Figure 1. History of California halibut catch, 1947–85. Commercial landings (*solid line*) are reported in pounds. Commercial passenger fishing vessel (CPFV) landings (*broken line*) and total estimated recreational catch (Anon. 1984–87; *dotted line*) are reported in numbers of fish.

P. californicus en California es utilizada a un nivel de producción máximo y que los cambios en tamaño mínimo propuestos probablemente no resolverían los conflictos en cuanto a las cuotas asignadas a los grupos de usarios implicados.

INTRODUCTION

California halibut (*Paralichthys californicus*) is an important food and game fish, utilized heavily by both commercial and recreational fishermen in central and southern California. To prevent overexploitation of the resource, a uniform legal minimum size limit of 22 in. (559 mm) TL was enacted in 1971, with an allowance for a small number of undersized fish for the commercial fisheries. The expected result of this regulation was an initial decrease in the catch with an eventual recovery over the time period required for the halibut to grow to the minimum legal size and for the population to experience recruitment from a larger spawning population. Following this legislation, the recreational commercial passenger fishing vessel (CPFV) catch dropped from 29,451 fish in 1970 to 10,435 fish in 1971 and has continued at this low level, while commercial landings have increased in a pattern typical of historical catches, from 272,000 pounds in 1971 to 1,260,000 pounds in 1985 (Figure 1).

The recreational catch of California halibut includes the catch from four general fishing modes: CPFVs, man-made structures, private boats, and shorelines. Although CPFV catches have been reported annually since 1947, data on all recreational fishing modes are available for only two relatively short periods. These studies indicate that the contribution of CPFV-caught fish to the total recreational halibut catch has decreased from approximately 40% in the mid-1960s (Pinkas et al. 1968) to about 10% in 1981–84 (Anon. 1984, 1985). Thus the recreational halibut catch may have recovered more than the CPFV catch indicates (Figure 1), but not to catch levels previously experienced.

Methot (1983) described the status of the California halibut resource as "uncertain." However, halibut length frequencies observed in commercial fish-market samples are relatively stable, and both the recreational and commercial fisheries have persisted through what appear to be cyclic decreases in the halibut population. Therefore we assume that the fisheries are at approximate equilibrium. But there is a conflict among user groups, with recreational catches appearing to be preempted by intense commercial fishing. Accordingly, the primary management problem is a matter of allocating the catch among the user groups. A management strategy that would improve recreational catches without seriously impacting the commercial yield would reduce the conflict between recreational and commercial users. In this paper we examine increasing the size limit to achieve such a strategy.

Two management alternatives to improve allocation of the California halibut resource are being considered by the California Department of Fish and Game: (1) a uniform size limit of 660 mm (26 in.) to allow the halibut an additional reproductive season before recruitment, or (2) a differential size limit (recreational = 559 mm or 22 in; commercial = 660 mm or 26 in.) to make more legal fish available to recreational anglers. The California halibut catch is presently regulated via a minimum size limit and some commercial gear limitations. The proposed changes in size limit are in keeping with current management strategies for this species, and we presume they could be implemented effectively. To evaluate the effect of these alternatives, we performed a yield-per-recruit analysis for multiple-gear fisheries using the program MGEAR (Lenarz et al. 1974) and data from records of the California Department of Fish and Game.

METHODS

Data

Three different general gear types are used to catch California halibut: (1) recreational hook and line; (2) commercial mobile gear (trawl, purse seine, lampara); and (3) commercial stationary gear (set net, entangling net, longline). The distinctions are made to identify user groups and to partition the fishing mortality rates among fishery segments.

Female California halibut grow faster and thus attain larger sizes at age than males. However, commercial and recreational landings have not been reported by sex categories, and until recently, the length-frequency information from fishery monitoring also has been for combined sexes. The sex of fish sampled from commercial catches was collected opportunistically beginning in late 1985. Females appear to represent 60% to 80% of the commercial landings (Calif. Dept. of Fish and Game, unpubl. data, J. Sunada, Long Beach), but these data contain biases resulting from fish-market cleaning and sampling practices.

Because true sex composition is unknown, we examined two alternative interpretations that include the true sex composition as an intermediate case: Schott[1] compiled a length-age key for combined sexes that included approximately 53% females, 26% males, and 21% unknown sex, as well as keys for individual sexes. This allowed us to base our analysis on Schott's "combined-sex" key as one extreme, and to treat the catch as being entirely female as the other extreme. To estimate population biomass in the latter case, we assumed landings of female fish to be 70% of the total landings.

Because data on female halibut exist only for the most recent years, data used in these two analyses are from somewhat different sources. Length frequencies from the recreational catch were sampled from 1981 through 1984 (N = 396; MRFSS 1981–84), but sexes were not identified (Figure 2). Length frequencies for commercial mobile gear were obtained from market samples of trawl-caught halibut; sampling was conducted from 1983 through 1986 (N = 2,072), but females were identified only in 1986 (N = 124). Length frequencies for commercial stationary gear were obtained from direct on-board observations of halibut caught by gill nets; these observations include undersized fish that are legally removed from the population (for personal use, etc.) but are not marketed. Length frequencies of halibut caught by gill nets were taken from 1983 to 1987 (N = 4, 219), but females were identified only in 1986 and 1987 (N = 695).

The length-frequency information described above was used for two purposes: to convert the commercial catch, which is recorded in weight, to catch in numbers, and to estimate catch by age. We calculated the average weight of the fish in the length-frequency distributions by means of a length-weight relationship developed by Schott (Table 1). For each commercial fishery segment, we divided the average annual catch in weight (1981–86) by the corresponding estimated average fish weight to produce estimates of each segment's catch in numbers (Table 2). Recreational catches are reported in numbers (Anon. 1984–87). We then used the appropriate length-age key[2] to convert each length frequency to an age frequency, and multiplied by the estimated total catch in numbers to obtain the catches at age for use in the virtual population analysis.

[1]Schott, J. W. Age and growth of California halibut *Paralichthys californicus* (Ayres). (Unpublished manuscript, California Department of Fish and Game files; available upon request from R. J. Reed.)
[2]Ibid.

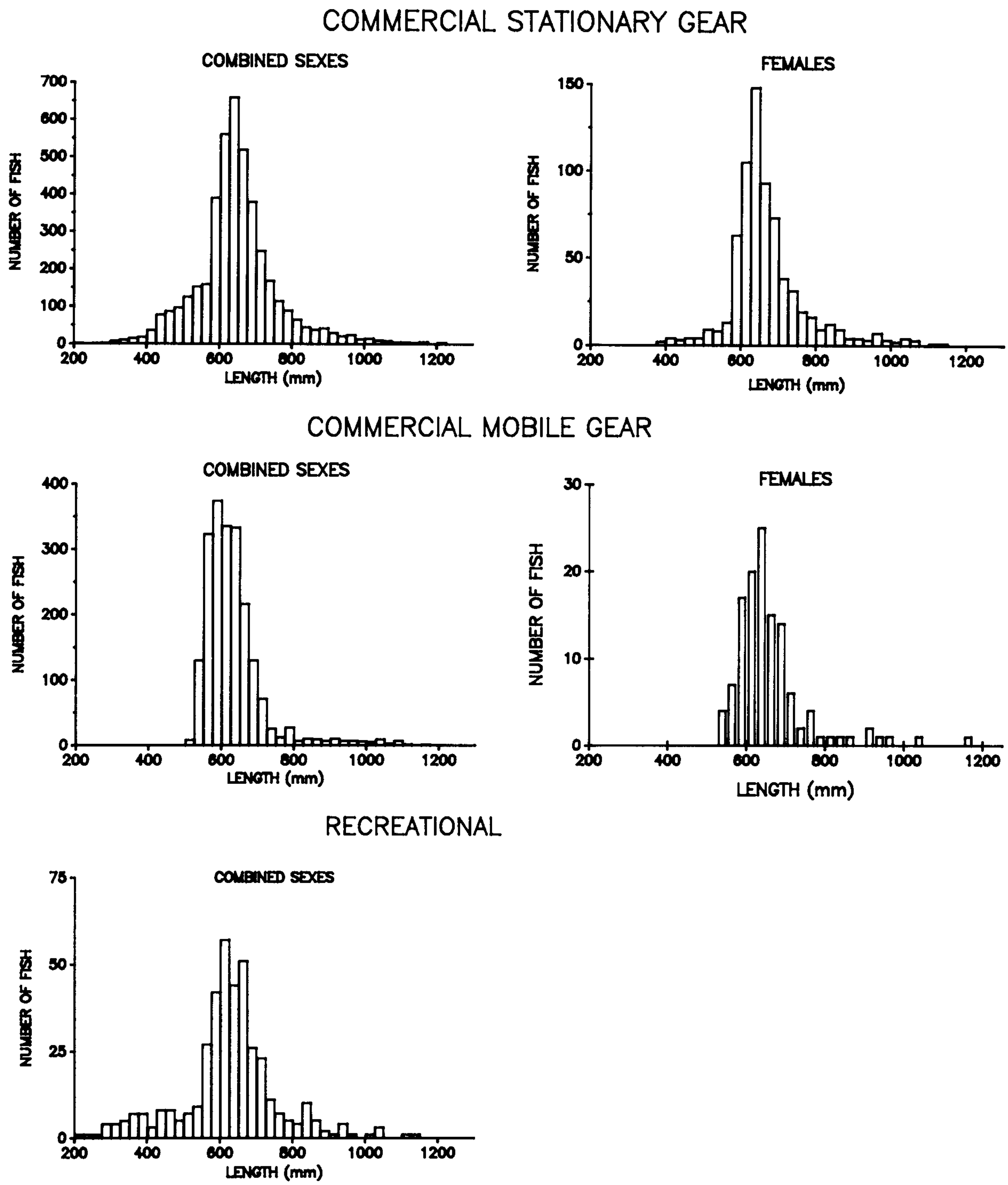

Figure 2. California halibut catch-length frequencies for major fishery segments and sex composition. Note: vertical scales differ.

Virtual Population Analysis

Age-specific fishing mortality rates were derived using virtual population analysis (VPA). In addition to the catches at age, VPA requires estimates of natural mortality and terminal fishing mortality rates. Estimates of the instantaneous natural mortality rate (M) ranged from 0.3, on the basis of related flatfish species at similar temperatures (Pauly 1979), to 0.15, on the basis of longevity (Hoenig 1983). We derived the latter estimate from the maximum known age of 30 years, which was obtained from sampling in the mid-1960s[3]. The es-

[3]Ibid.

TABLE 1
Parameter Values of the von Bertalanffy Growth Equation and Length-Weight Regression for California Halibut

	Growth parameters			Length (mm)-weight (kg) parameters	
	$L_{infinity}$	k	t_o	a	b
Females and immatures	1417.42	0.1194	0.3801	0.000007768	3.0496
Males and immatures	1137.43	0.1218	0.1004	0.000009216	3.0165
Sexes combined	1217.51	0.1414	0.4073	0.000008807	3.0300

Adapted from Schott, J. W. Age and growth of California halibut *Paralichthys californicus* (Ayres). (Unpublished manuscript, California Department of Fish and Game files; available on request from R. J. Reed.)

timate using Hoenig's method reflects the total mortality rate, and because halibut have been exploited since the early 1900s, M would be expected to be lower than 0.15. In view of the longevity of California halibut, M could not possibly be as high as 0.3. We considered two arbitrary estimates of M (0.1 and 0.2) in order to explore the sensitivity of the yield-per-recruit analysis to a range of probable values of the natural mortality rate.

Our VPA employed a method described by MacCall (1986), which accounts for the seasonal pattern of catches by each segment of the fishery. In the present case, we used the equation:

$$N(t) = N(t+1)\exp(-M) + V_{rec}C_{rec}(t) + V_{stat}C_{stat}(t) + V_{mob}C_{mob}(t)$$

where $N(t)$ is abundance in numbers at the beginning of year t, $C(t)$ is catch in numbers during year t, and V is a coefficient that depends on the seasonal pattern of catches of the respective segment of the fishery (rec = recreational, stat = stationary commercial, mob = mobile commercial). Values of V were based on monthly catches by gill net and trawl gears from 1981 through 1986 (Calif. Dept. of Fish and Game catch records), and on bimonthly catches by the recreational fishery from 1984 through 1986 (MRFSS 1984–86). We calculated coefficients V for each year, and then averaged over the yearly values for each gear separately (Table 3).

We applied the VPA to the estimated age composition of the catch as a "synthetic cohort," which uses the average age composition of the catch over a relatively short period (3 to 6 years in this case) to approximate the age composition of a cohort over its lifetime. Lacking objective criteria, we calculated terminal fishing mortality rates (F) on the basis of internal consistency. We chose a terminal value (for ages 19 and older) of F that was equal to the average value of F for ages 11 through 18, given that terminal value. This approach gave a unique solution in each case, and depends only on the assumption that F is constant for ages 11 and older. Although we believe that this assumption is reasonable, we lack information by which to test its validity.

TABLE 2
Average Annual Recreational (1980–84) and Commercial (1981–86) Catch of California Halibut

Fishery segment	Average annual catch: Numbers	Weight (kg)	Average weight per fish (kg)
Recreational	71,200	184,009	2.5844
	(15,695)	(40,016)	(0.1040)
Commercial			
Stationary gear	141,066	426,330	3.0222
	(7,185)	(21,715)	(0.0359)
Mobile gear	52,201	118,423	2.2686
	(7,449)	(16,900)	(0.0438)
Total	264,467	728,762	

Standard errors are in parentheses.

Yield per Recruit

Yield-per-recruit analysis requires growth information in addition to the mortality information derived above. Males and females grow at different rates, but, as noted earlier, sex composition of the catch is unknown. For the analysis based on an assumed all-female catch, we used the von Bertalanffy growth curve and length-weight relationship developed by Schott for female halibut. For the combined-sexes analysis, we used Schott's relationships for combined sexes (Table 1).

We modeled yield per recruit using the program MGEAR, which takes into account differences in

TABLE 3
Average VPA Coefficients That Compensate for Seasonality of California Halibut Fishery

	V_{rec}	V_{stat}	V_{mob}
Combined sexes			
M = 0.1	1.055437	1.047947	1.048698
0.2	1.114594	1.098704	1.100948
Females only			
M = 0.1	1.055437	1.047947	1.048698
0.2	1.114594	1.098704	1.100948

and interactions among fishery segments. Classical yield-per-recruit models have assumed instantaneous, or knife-edged, recruitment to the fishery at a given age. However, recruitment of California halibut occurs over a range of ages because of an allowance for the commercial take of undersized fish and because of differences in gear selectivity among the fishery segments. The program MGEAR allows for fish being recruited gradually and at different ages for different fishery segments by using age-specific *F* values for each fishery segment.

We estimated the effect of a change in size limit by using a modified set of age-specific *F* values. Selectivity curves for the various gears are not known, requiring an indirect method: for each gear, we assumed the peak value of *F* to indicate the age of full availability, and calculated availabilities of younger ages relative to that value. For each of the younger ages, we then used the information in Schott's length-age keys to estimate the length percentile corresponding to the retention rate implied by the availability as if retention were knife-edged.

For example, if availability was 0.8, we calculated the "selection length" at which 80% of the fish were larger. We then assumed that the unknown mechanisms leading to that selection length would change in proportion to the proposed change in size limit, which in the present case is 660 mm/559 mm, or an increase of 18%. Accordingly, we then determined the length percentile corresponding to an 18% increase in the selection length. We assumed that this new percentile represents the modified availability under the new size limit. We multiplied the estimate of modified availability by the peak *F* that was assumed to represent full availability, thereby obtaining the modified set of age-specific *F* values for use in the yield-per-recruit analysis (Figure 3). To measure the effect of the uniform and differential size-limit policies, we compare the yield per recruit (Y/R), in weight and in numbers of fish caught, to the Y/R under the current uniform 559-mm size limit to determine the relative percentage change.

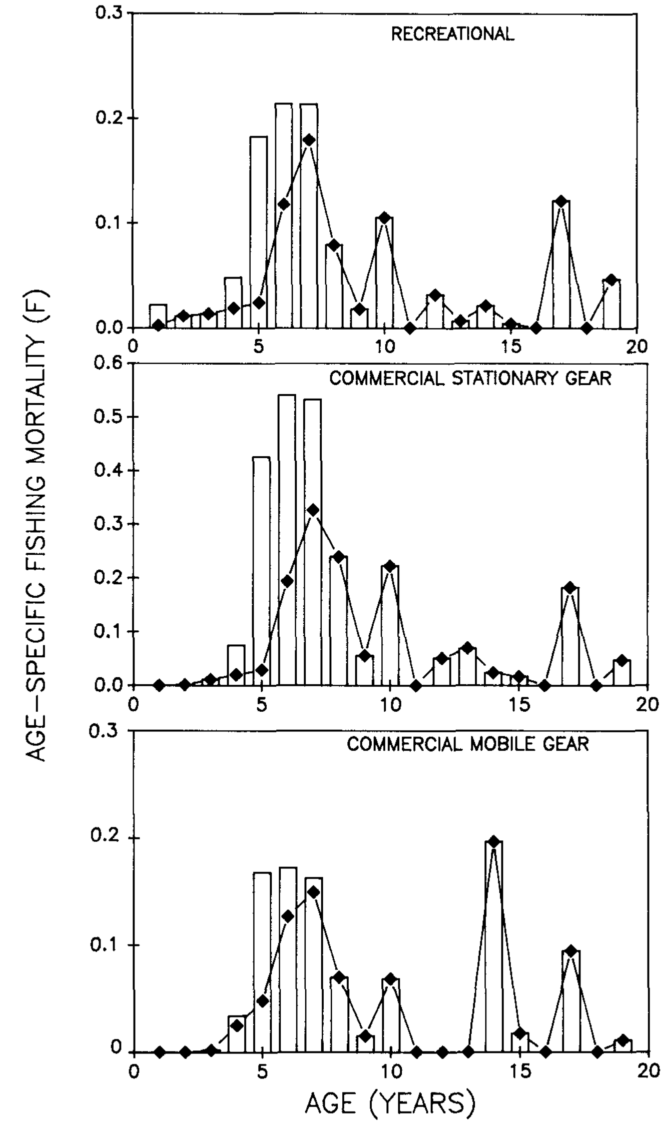

Figure 3. An example of the change in age-specific fishing mortality (*F*) to simulate the increase of the minimum California halibut size limit from 559 mm to 660 mm. Treatment is all-female catch, $M = 0.1$.

RESULTS AND DISCUSSION

Estimates of Abundance

Although our VPA estimates were based on "synthetic" rather than actual cohorts, the results provide estimates of the approximate magnitude of the California halibut resource. The estimates vary with the assumed rate of natural mortality and with the treatment of the sex composition of the catches (Table 4). The probable total biomass is estimated in the range of 2,600 to 6,000 MT. Abundance estimates based on all-female catches must be augmented by a presumed biomass of males, which is somewhat smaller because of their smaller weights at age, but would fall within the above range. Recruitment, in number of fish at age 1, may be treated similarly; estimates based on female catches, which we have assumed to be 70% of the total, should be increased about 30% to include males. Thus we estimate annual recruitment to be between 0.45 and 1.0 million fish (Table 4). The estimates provided by "synthetic" cohorts are, in a poorly defined way, average values. If the record of catches (Figure 1) is any indication, actual

TABLE 4
VPA Estimates of Biomass and Recruitment of California Halibut

Assumed natural mortality rate	Treatment of catches	
	Combined sexes	Females only
$M = 0.1$	$B = 2{,}600$ $R = 450{,}000$	$B = 2{,}300$ $R = 430{,}000$
$M = 0.2$	$B = 6{,}000$ $R = 950{,}000$	$B = 3{,}200$ $R = 750{,}000$

Biomass (B) in metric tons; recruitment at age 1 (R) in number of fish.

biomasses may have varied as much as fivefold, and recruitments have varied much more.

Present Status of the Fishery

Before examining the individual segments of the fishery, it is useful to evaluate the status of the fishery as a whole, particularly with regard to the overall level of fishing intensity. Given the present patterns of size selectivity or age selectivity, and relative intensities of the three fishery segments, the resource is probably overfished (Figure 4); i.e., a reduction in fishing intensity would increase total catch in biomass. Both of the cases where M was assumed to be 0.1 show peak Y/R at fishing intensities lower than present levels. In the cases where M is assumed to be 0.2, the present fishing intensity is at peak Y/R for the all-female case; only for the combined-sexes case is peak Y/R to be found at fishing intensities higher than the present level.

Optimal levels of fishing intensity are nearly always below those that produce maximum yield per recruit. One popular rule of thumb is the $F_{0.1}$ policy suggested by Gulland and Boerema (1973). This policy establishes a nominal upper limit to fishing intensity as the level at which the marginal increment in catch per effort is one-tenth that of a nearly unfished resource. In three out of the four cases shown in Figure 4, the $F_{0.1}$ policy indicates optimal fishing intensities in the vicinity of one-half the present level. Only in the case of $M = 0.2$ and combined-sex treatment of catches is the $F_{0.1}$ level of fishing intensity above the present level. It is our opinion that the latter case is the least likely of the four cases examined, because M is probably much lower than 0.2, and the catch is known to consist mostly of female fish.

Changes in Yield per Recruit

Under a uniform 660-mm size limit for $M = 0.1$, the Y/R increased for all fishery segments, by weight but not by number (Table 5); larger but fewer halibut were caught. When $M = 0.2$, the

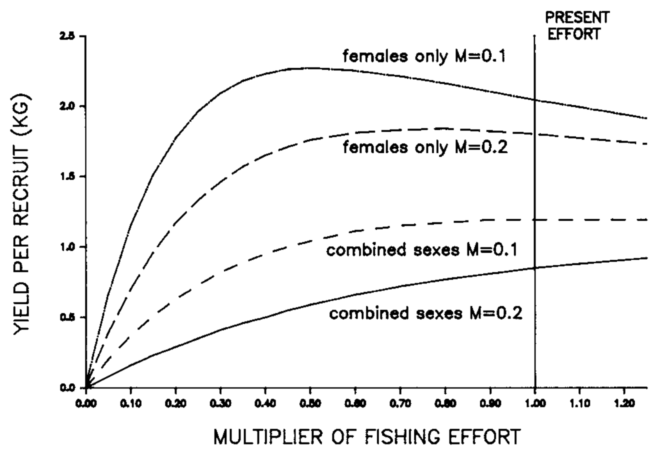

Figure 4. Yield per recruit for California halibut at different levels of fishing effort. Present level = 1.0.

Y/R shows a loss for all fishery segments in weight and number assuming combined sexes, and no significant gain assuming a fishery based solely on female fish. It would appear that some benefit would be realized under a uniform 660-mm size limit, given the lower natural mortality rate. However, the commercial catch is valued by weight (pounds of fish sold), whereas recreational anglers tend to value their catch based on the number of fish caught (Fritz and Schuler 1984). Therefore we assume that a strategy which reduces the number of fish in the recreational catch would not alleviate the current allocation conflict.

Under a differential size limit, the recreational Y/R increases by weight and by number in all cases (Table 5), but the commercial stationary gear Y/R shows a concomitant decrease. The Y/R for commercial mobile gear increases for a catch based on female fish but tends to decrease for a catch based on both sexes. A differential size limit will improve the recreational fishery segment, but at the expense of commercial fishery segments.

Since females grow faster than males, an increased minimum size limit is expected to increase the percentage of females in the catch. Recent data indicate that the commercial catch is already biased toward females. Of the four cases examined, the least benefit would be expected when the natural mortality is high and males are included in the catch with females. The net change in Y/R for the entire fishery suggests that some benefit would be realized with an increase in size limit, except in the last case.

This analysis simulates an increase in size limit by decreasing the availability of smaller fish, and does not consider the possibility of a concomitant increase in availability of larger fish. Because the

TABLE 5
Percentage Change in Yield per Recruit by Weight and Number ( ) under a Differential Size Limit (559-mm recreational/660-mm commercial) and under a 660-mm Uniform Size Limit Compared to a Uniform 559-mm Size Limit

Male and female combined catch	Recreational	Commercial		Entire
		Stationary gear	Mobile gear	
M = 0.1				
Uniform	+17 (−23)	+8 (−30)	+37 (−2)	+16
Differential	+85 (+54)	−21 (−45)	+3 (−22)	+18
M = 0.2				
Uniform	−9 (−29)	−15 (−35)	−53 (−72)	−21
Differential	+41 (+29)	−24 (−41)	−59 (−75)	−28
Female catch only				
M = 0.1				
Uniform	+38 (−11)	+12 (−31)	+69 (+15)	+31
Differential	+90 (+54)	−14 (−45)	+31 (−6)	+21
M = 0.2				
Uniform	+14 (−16)	−12 (−41)	+29 (−4)	+3
Differential	+59 (+37)	−25 (−49)	+13 (−14)	+3

commercial net gears used to catch California halibut tend to be size selective, a possible means of implementing a differential size limit would be via an increase in minimum mesh size. It is possible that, due to differences in mesh selectivity, catch rates of older fish might increase (Hamley 1975). Preliminary comparisons of the performance of commercial halibut gill nets of different mesh sizes indicate an increase in the availability of larger fish (Calif. Dept. of Fish and Game, unpubl. data, K. Miller, Long Beach). This is a case we were unable to analyze with available data. However, any increase in the catch of older fish could compensate for the loss of smaller fish resulting from an increase in the size limit. This would increase the relative percentage change in Y/R for the affected fishery segment. A change in the selectivity of commercial stationary gear or similar increase in the availability of larger fish could change our conclusions regarding the utility of a change in size limit.

CONCLUSIONS

Although Y/R increased by weight under a uniform 660-mm size limit, we assume that this management strategy would increase recreational users' dissatisfaction by decreasing the number of fish in the catch. Alternatively, the differential size limit would be expected to increase recreational satisfaction by increasing the number of fish in the catch. Unfortunately, this increase would substantially impact the commercial fishery segments, particularly commercial stationary gear, which represents over 67% of all commercial landings. The results of this yield-per-recruit analysis indicate that allocation conflicts among user groups are not likely to be resolved by a management strategy that increases the minimum size limit. Instead, the fishery is most likely to benefit from a management strategy that limits fishing effort to $F_{0.1}$ or similar optimum yield level.

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