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SOME EFFECTS OF INCREASING THE MINIMUM COMMERCIAL SIZE LIMIT OF OPAKAPAKA, *PRISTIPOMOIDES FILAMENTOSUS*

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ABSTRACT

The likely effects of a proposed increase in the minimum commercial size limit of opakapaka, Pristipomoides filamentosus, from 1 lb, the current limit, to 3 lb is examined by using a weight-based population simulation model. Depending on the assumed value of fishing mortality rate, the yield per recruit initially decreases by 48-66% after imposition of the size limit. It subsequently rises to a new equilibrium level that ranges from 4% less to 10% more than the previous level. At best, 24 years is required for the increase in annual yield to compensate for the initial losses. Spawning stock biomass is predicted to increase 100-290%. If, however, fish weighing 1-3 lb are not fully protected by the size limit and instead experience a fishing mortality one-half that experienced by legal-sized fish, then the resulting yield per recruit is likely to be below the current level. Spawning stock biomass would still increase, however, even with the assumed level of mortality in sublegal-sized fish.

INTRODUCTION

A yield per recruit analysis for each of the primary species supporting Hawaii's bottomfish fishery was recently conducted by Ralston and Kawamoto (1988), who reported that the yield per recruit of the most valuable species, opakapaka, Pristipomoides filamentosus, would be increased by increasing the minimum size limit. The Hawaii Department of Land and Natural Resources, Division of Aquatic Resources, responded to their report by initiating procedures that may lead to an increase in the minimum commercial size of opakapaka from 1 lb, the current minimum size, to 3 lb.

Although the specific effects of such a size limit on the opakapaka population and its fishery are not known, the general effects of changes in size limits are known from a theoretical perspective (Beverton and Holt 1957) and from applications on other snapper species (Huntsman and Waters 1987). Initially, yield will drop because part of the population is excluded from the fishery, but over time, the reduced mortality experienced by the excluded group will allow more fish to grow into the new commercial size range. In terms of yield, the benefits accrued to the fishery will therefore depend upon the relative magnitudes of the yield lost from the exclusion of fish and the yield gained from growth.

An increase in yield per recruit, however, is not the only consideration for a change in minimum size limit. Of equal or perhaps greater importance is the effect of such a change on the biomass of the spawning stock. This is especially true in light of the recent trend in Federal fisheries management plans to define measures of overfishing in terms of the relative size of the spawning stock (Goodyear 1989). Therefore, our report examines not only the effects of the proposed increase in minimum size on the yield per recruit but also considers the effects on the spawning stock biomass of opakapaka.

MATERIALS AND METHODS

Consequences of the proposed change in the minimum size limit are examined with a weight-based simulation model of an idealized population of opakapaka. This model is simply a computer program that attempts to mathematically mimic the changes in size distribution and biomass that are due to growth and mortality. A detailed description of this model is beyond the scope of this report but is available in Somerton and Kobayashi (In prep.). One important aspect of this model, however, must be considered here: the values of the various parameters used in the mathematical functions to describe the growth and death processes. Growth (in length) is described by the von Bertalanffy function with parameters ($\underline{K}$ = 0.15, $\underline{L}_{inf}$ = 78, and $\underline{t}_0$ = -1.67) obtained from Ralston and Miyamoto (1983). Body weight is related to length by using a power function with parameters (alpha = 0.0000839 and beta = 2.736) obtained from Uchiyama et al. (1984). Natural and fishing mortality rates ($\underline{M}$ = 0.3 and $\underline{F}$ = 0.3) are from Ralston and Kawamoto (1988), but we believe the $\underline{F}$ value is too low. Therefore, we also examine the consequences of $\underline{F}$ equaling 0.6. Estimates of the weight at entry to the fishery for both the main Hawaiian Islands (MHI; $\underline{W}_c$ = 1.5 lb) and the Northwestern Hawaiian Islands (NWHI; $\underline{W}_c$ = 5.0 lb) are from Ralston and Kawamoto (1988). Size at maturity (46 cm) is from Kikkawa (1984).

Besides the simulation model, we also examine the possible effects of the proposed minimum size limit by using size distribution data collected from opakapaka at the Honolulu fish auction by personnel of the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA. Procedures used to collect these data are described in Ralston et al. (1986).

RESULTS AND DISCUSSION

Three types of changes in yield per recruit that would occur after the imposition of a size limit are important: 1) the size of the initial decrease in yield, 2) the size of the ultimate increase in yield at the new equilibrium, and 3) the time required to reach the new equilibrium. All three types of changes are computed at each of the two levels of fishing mortality that we believe encompass the true value. The initial decrease in yield, expressed as a percentage of the initial equilibrium yield, ranges from -48% ($\underline{F}$ = 0.3) to -66% ($\underline{F}$ = 0.6; Fig. 1). The change in equilibrium yield per recruit ranges from -4% ($\underline{F}$ = 0.3) to 10% ($\underline{F}$ = 0.6). The time required to reach an annual yield equal to 95% of the new equilibrium value ranges from about 8 years ($\underline{F}$ = 0.3) to about 7 years ($\underline{F}$ = 0.6). Thus, the initial drop in yield, the subsequent rate of increase in yield, and the ultimate yield at the new equilibrium are all greater at the higher than at the lower level of fishing mortality.

Although each of these measures provides important information, a composite measure incorporating all three provides the best assessment of the potential impact of a size limit on the fishery. One such measure is the time to break-even. After the imposition of the size limit, annual yield per recruit at an $\underline{F}$ of 0.3 will always be less than the initial yield, but at an F of 0.6, it will equal the initial yield in 5.5 years and then continue to increase beyond that level until a new equilibrium is reached. Therefore, one important question is, What is the length of time required for the cumulative yield obtained after the change in minimum size, to equal the cumulative yield that would have been obtained without the change? In other words, What is the time required to break-even? For opakapaka, although the break-even point is never reached at an F of 0.3, it is reached in about 24 years at an F of 0.6 (Fig. 2). If, however, yield is instead evaluated in financial terms, economists would argue that the time required to break-even is even longer because of the discount of future revenues to the present value. In either case, a fairly substantial period must elapse before the fishery fully realizes any potential benefit, in terms of yield, that an increased size limit might allow.

In addition to increases in yield that might be achieved by increasing the minimum size limit, we also examine the potential increase in the biomass of the spawning stock. For opakapaka, the increase in equilibrium spawning biomass ranges from about 110% (F = 0.3) to about 290% (F = 0.6; Fig. 3). Any benefits gained from such increases in spawning biomass will be in terms of increased recruitment, but such benefits are difficult to quantify because the relationship between recruitment and spawning biomass is unknown. One general guideline being adopted in the United States (Goodyear 1989) and also Europe (Beddington and Cooke 1983) is that the minimum level of the spawning biomass should not fall below 20% of the virgin (unfished) spawning biomass to ensure continued recruitment. Estimates of the spawning biomass for opakapaka in the MHI are as low as 15% of the virgin biomass (Polovina 1987), suggesting that the opakapaka population might experience increased recruitment as a result of an increase in spawning biomass.

The predicted changes in yield and spawning biomass, however, are based on an idealized population and an idealized fishery, and for a variety of reasons, the actual changes could be substantially different. First, undersized fish are assumed to experience no fishing mortality. Opakapaka, however, occur in deep water, and few undersized fish would likely survive the effects of capture and release. Furthermore, even if the capture rate of small fish could be reduced, perhaps by using larger hooks (Ralston 1982) or by avoiding areas where small fish aggregate, the recreational fishery would still inflict substantial mortality on these fish. To estimate the effects of such sublegal fishing mortality, yield per recruit and spawning biomass are recomputed with fishing mortality rates in the sublegal size range equal to one-half that in the legal size range. The new equilibrium yields range from -27% (F = 0.3) to -34% (F = 0.6), relative to the initial equilibrium yield.

Thus, the annual yields remain so low that the break-even point is never reached. The equilibrium values for spawning stock biomass range from 47% ($\underline{F}$ = 0.3) to 113% ($\underline{F}$ = 0.6), slightly less that one-half of the increase predicted with no sublegal mortality. This result indicates that even a moderate level of fishing mortality on undersized fish eliminates all potential gain in yield and much of the gain in the spawning stock biomass.

Second, the predicted changes in yield are based on the assumption that the size at entry ($\underline{W}_c$) or the minimum size selected by the fishery is equal to the legal minimum size. Although this is nearly true in the MHI ($\underline{W}_c$ = 1.5 lb), it is not true in the NWHI ($\underline{W}_c$ = 5.0 lb) where fishers likely select for large fish (Fig. 4). When the actual size at entry is greater than the assumed value, the predicted changes in yield and spawning biomass will be too large. For example, the initial drop in yield can be estimated as the percentage of the opakapaka catch that would have been excluded by the proposed size limit. Based solely on the sizes of opakapaka sold at the Honolulu fish auction in 1988, 27% (by weight) of the MHI catch and less than 1% of the NWHI catch would have been prohibited from sale. Thus, the effects of the proposed minimum size limit would be primarily felt in the MHI.

Third, the predicted increases in yield and spawning biomass are based on the assumption that the parameter values used in the mathematical functions describing growth and mortality are close to the true values. However, opakapaka, like most tropical snappers, are difficult to age, and this difficulty results not only in poor estimates of growth but also poor estimates of mortality. The parameter most likely in error (that is, the fishing mortality rate) is specified at two levels that we believe bracket the true value. Although we have not conducted such sensitivity analyses on other parameters, we believe that the likely uncertainty in these parameters would have a less pronounced effect than the uncertainty in $\underline{F}$. Therefore, we believe that the true values of yield per recruit and spawning biomass occur within the interval defined by the two values of $\underline{F}$.

The ability of fishers to avoid catching small fish will clearly determine the efficacy of an increased minimum size limit, but at present, we have no clear idea of how successful they might be. At best, increases in yield would be small and not fully realized for many years. On the other hand, increases in spawning biomass would be substantial, even with the mortality of sublegal fish that is likely to occur. However, it is uncertain whether such increases in spawning biomass would eventually result in higher recruitment rates.

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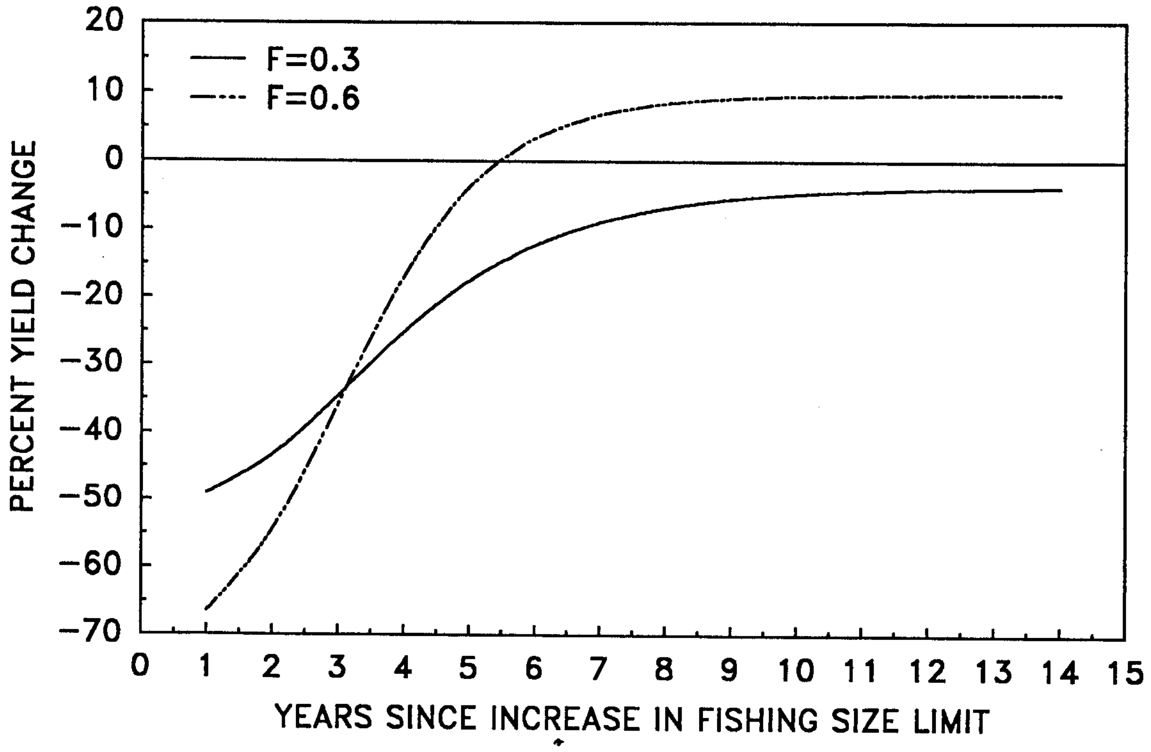

Figure 1.--Change in the yield per recruit over time, expressed as the percentage difference from the initial equilibrium yield per recruit.

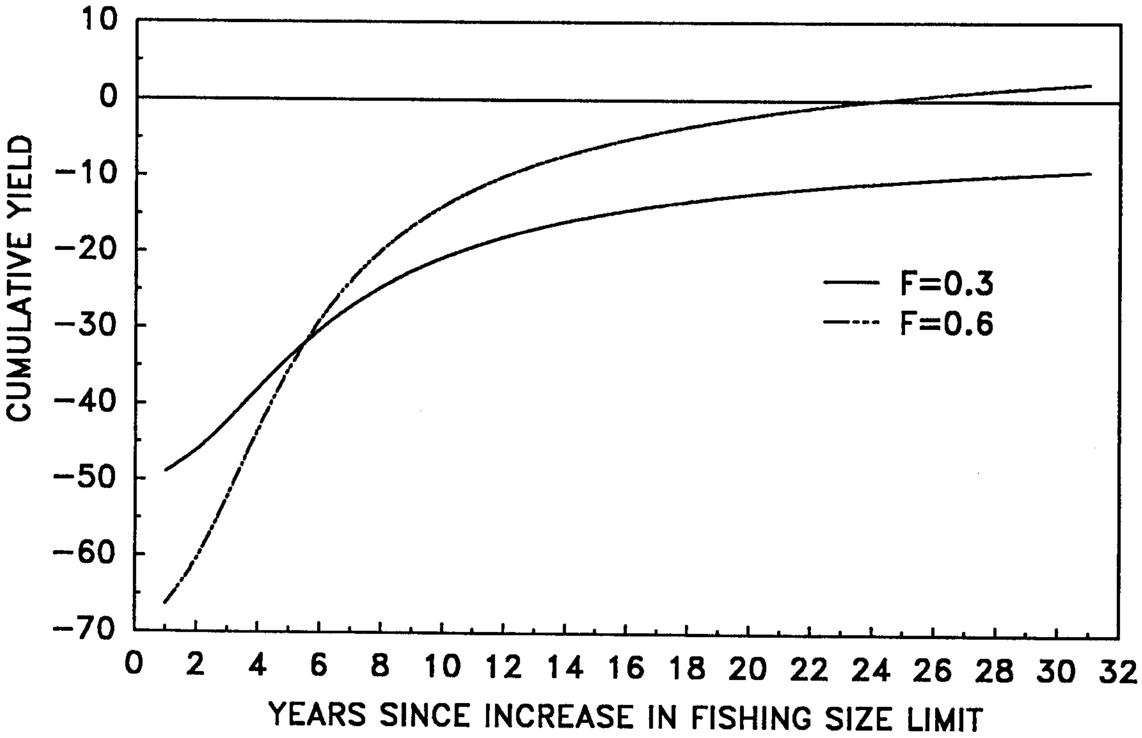

Figure 2.--Change in the cumulative yield over time, expressed as the percentage difference from the cumulative yield that would have been obtained without the size limit.

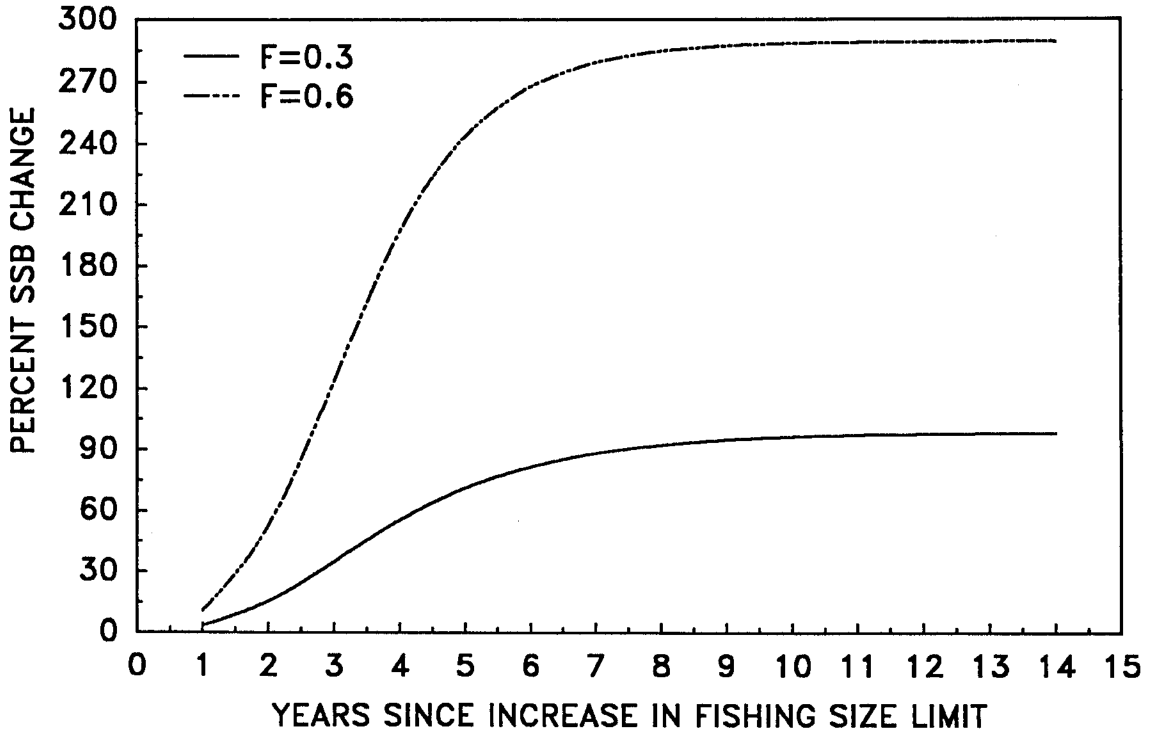

Figure 3.--Change in the spawning biomass over time, expressed as the percentage difference from the initial equilibrium spawning biomass.

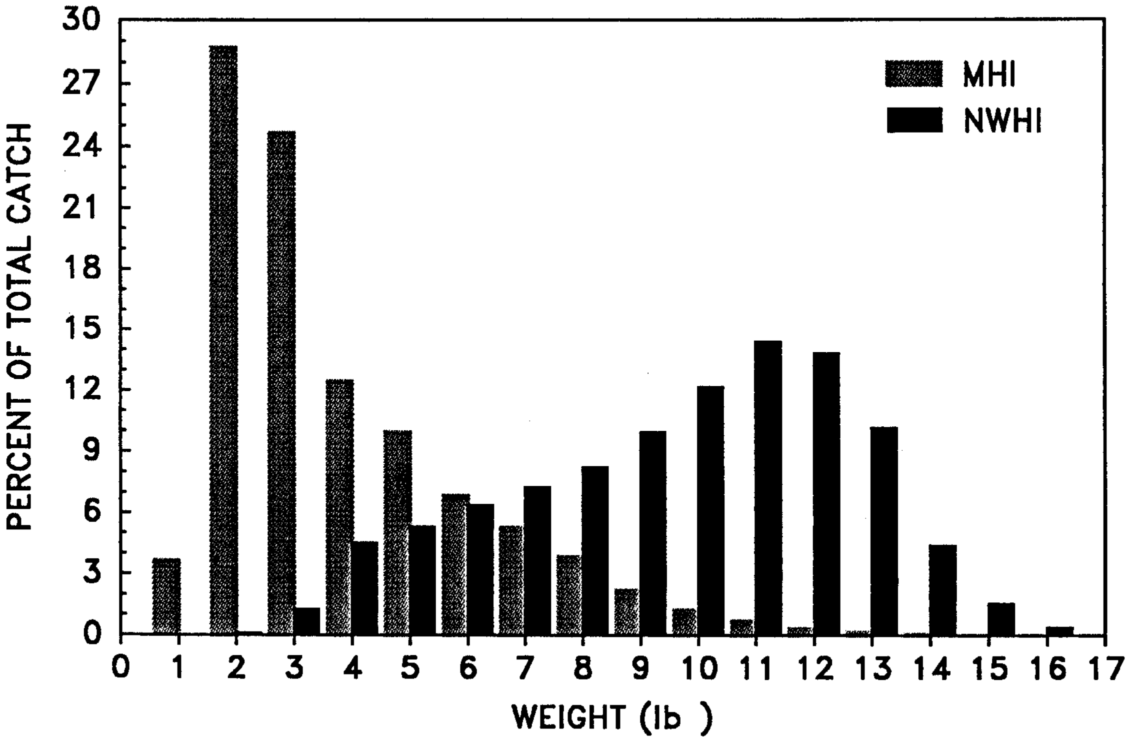

Figure 4.--Weight-frequency histograms of the opakapaka catch sold at the Honolulu fish auction during 1988. Catch originated either in the main Hawaiian Islands (MHI) or the Northwestern Hawaiian Islands (NWHI).