Southwest Fisheries Science Center
Administrative Report H-90-16

SOME EFFECTS OF A SEASONAL FISHING CLOSURE ON OPAKAPAKA, *PRISTIPOMOIDES FILAMENTOSUS*

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December 1990

ABSTRACT

The likely effects of a seasonal closure on the yield and spawning stock biomass of opakapaka, *Pristipomoides filamentosus*, were examined using a weight-based population simulation model. If a 1- to 3-month closure were implemented, annual yield would initially drop by 8-24% of the pre-closure level. In subsequent years, yield would increase and reach a new equilibrium level in about 6-8 years. In none of the closure scenarios, however, would the new equilibrium yield exceed the original. Therefore, initial losses in yield could never be recouped from future increases. Spawning stock biomass would increase 15-130%, depending on the mortality rate and duration of the closure.

INTRODUCTION

The Fishery Management Plan for the Bottomfishes and Seamount Groundfishes of the Western Pacific Region (FMP) was recently amended [Western Pacific Regional Fishery Management Council (WPRFMC) 1990] to specify that a species will be considered as overfished when a measure of the relative biomass of its spawning stock, known as the spawning production ratio, is reduced to a level below 20% of that which occurred before the initiation of the fishery. Based on this measure of overfishing, Somerton and Kobayashi (1990a) evaluated the current status of the five most important bottomfish species in the main Hawaiian Islands (MHI) and found that four of these species were sufficiently close to the overfishing level of the spawning production ratio to justify concern. In response to this, the WPRFMC directed its Plan Management Team to examine the various management measures allowed in the FMP and to determine which would be most suitable to employ in the event that any of the species became overfished. After considering such issues as the enforceability and feasibility of each management measure, the Plan Management Team determined that minimum size limits and seasonal closures were the most suitable and recommended that the biological and economic consequences of these two management measures be examined further.

Some consequences of the first of these management measures, that is, minimum size limits, was examined by Somerton and Kobayashi (1990b) for the most important of the MHI bottomfishes, opakapaka, *Pristipomoides filamentosus*. The primary focus of the study was on three effects of a minimum size limit: 1) the initial decrease in catch due to the exclusion protected fish, 2) the subsequent increase in catch due to the growth of the protected fish, and 3) the increase in the biomass of the spawning stock.

In the present study, we examine the biological and economic consequences of the second of the management measures, that is, seasonal closures, focusing again on opakapaka and the same three effects as in the previous study.

MATERIALS AND METHODS

Consequences of a seasonal closure were examined with a weight-based simulation model of an idealized population of opakapaka. This model is simply a computer program that attempts to mimic, mathematically, the changes in size distribution and biomass of a species that can occur over time because of the combined effects of growth and mortality. A detailed description of this model is beyond the scope of this report, but is available in Somerton and Kobayashi (in press). One important aspect of this model, however, must be considered here, that is, the values of the various parameters that are used in mathematical functions to describe growth and death processes. Growth in length is described by the von Bertalanffy function with parameters (K = 0.15, L_{inf} = 78, and t_0 = -1.67) obtained from Ralston and Miyamoto (1983). Body weight (W) is related to length (L) using $W = 0.0000839\ L^{2.736}$

from Uchiyama et al. (1984). Natural and fishing mortality rates ($M = 0.3$, $F = 0.3$) were obtained from Ralston and Kawamoto (1988), but believing the value of F was too low, we therefore also examined the consequences of $F = 0.6$. Estimates of the weight at entry into the fishery for both the MHI (W_c = 1.5 lb) and the Northwestern Hawaiian Islands (W_c = 5.0 lb) were obtained from Ralston and Kawamoto (1988). Size at maturity (46 cm) was obtained from Kikkawa (1984).

To assess the effects of a closure, the model was first run for as many simulated years as was required to reach equilibrium levels of yield per recruit and spawning stock biomass. Starting from these equilibrium conditions, the model was then rerun using a value of the fishing mortality rate adjusted for the loss of catch due to the specified closure. Yield per recruit and spawning stock biomass were calculated in each subsequent year until the new equilibrium was reached. To adjust the fishing mortality rate for the loss of catch due to a specified seasonal closure, we assumed that each month of closure resulted in the loss of one-twelfth of the annual catch. The adjusted value of F (F_a) was then computed from the proportion of the annual catch remaining (P_C) by iteratively solving the following equation:

$$P_C = \frac{\dfrac{F_a}{F_a+M}\left(1-e^{-(Fa+M)}\right)}{\dfrac{F}{F+M}\left(e^{-(F+M)}\right)} .$$

RESULTS AND DISCUSSION

The initial effect of a seasonal closure is a reduction in the total annual yield. For the closure periods considered here (1, 2, or 3 months), this reduction in yield ranges from 8% to 24% (Fig. 1). In subsequent years, the yield will increase with time as more fish grow to larger sizes, but the rate of increase will progressively diminish as the new equilibrium is reached. The time required to reach the new equilibrium and the ultimate level of yield produced depend upon the assumed fishing mortality rate. For opakapaka, the new equilibrium will be reached in about 8 years at $F = 0.3$ or in about 6 years at $F = 0.6$ (Fig. 1). The equilibrium yield will vary with closure duration as well as fishing mortality rate. At $F = 0.3$, the variation is relatively large, and the longest closure duration results in an equilibrium yield of nearly 8% less than the original equilibrium yield. At $F = 0.6$, however, the variation is small, and all three closure durations produce equilibrium yields nearly the same as the original (Fig. 1).

One important result of the equilibrium yield calculations is that in none of the cases does the new equilibrium yield exceed the original. This means that the initial losses in yield due to imposition of the seasonal closure will never be recovered from future increases in yield. As plots of cumulative yield indicate (Fig. 2), the resulting loss in total yield can range from as much as 10% for a 3-month closure at $F = 0.3$ to as little as 1% for a 1-month closure at $F = 0.6$. In short, seasonal closures appear to be ineffective for increasing the yield of opakapaka.

With respect to increasing the biomass of the spawning stock, however, seasonal closures appear to be quite effective. In general, spawning biomass should increase with an increase in closure duration, because the resulting decrease in fishing mortality rate causes an increase in both the number and the average size of spawning fish. For opakapaka, expected increases in spawning biomass range from as little as 15% for a 1-month closure at $F = 0.3$ to as much as 130% for a 3-month closure at $F = 0.6$ (Fig. 3).

Based on the model predictions, implementation of a seasonal closure would result in an increase in the spawning stock biomass and a likely decrease in long-term yield. This interpretation, however, must be tempered with the following qualifications. First, the model predictions of future yields are based on the assumption of constant recruitment. If, however, a closure were implemented when the stock was recruitment overfished and the increase in spawning stock resulted in increased recruitment, then the actual yield could be substantially larger than the predicted yield. Second, the model predictions of both yield and spawning stock biomass are based on the assumption of a constant fishing mortality rate. However, the monthly catch of opakapaka varies seasonally (Fig. 4), and the fishing mortality rate is therfore not constant. Thus, the actual effects of a closure will depend on which months are closed. Other examples of potential variability in fishing mortality not considered by the model include increased effort by fishers during open season to compensate for the closed season and increased total fishing effort over time. Third, the model's predictions do not consider possible secondary effects of a closed season, such as protection of spawning fish from disturbance.

In summary, a seasonal closure appears to be an effective way to increase the spawning stock biomass of opakapaka, but it will result in increased yield only when the increases in spawning stock biomass result in increases in recruitment. Besides the biological implications, closed seasons are an attractive approach to management because they are relatively easy to enforce, are currently used by State of Hawaii's Division of Aquatic Resources to manage the catches of five marine species, and are therefore familiar to fishermen.

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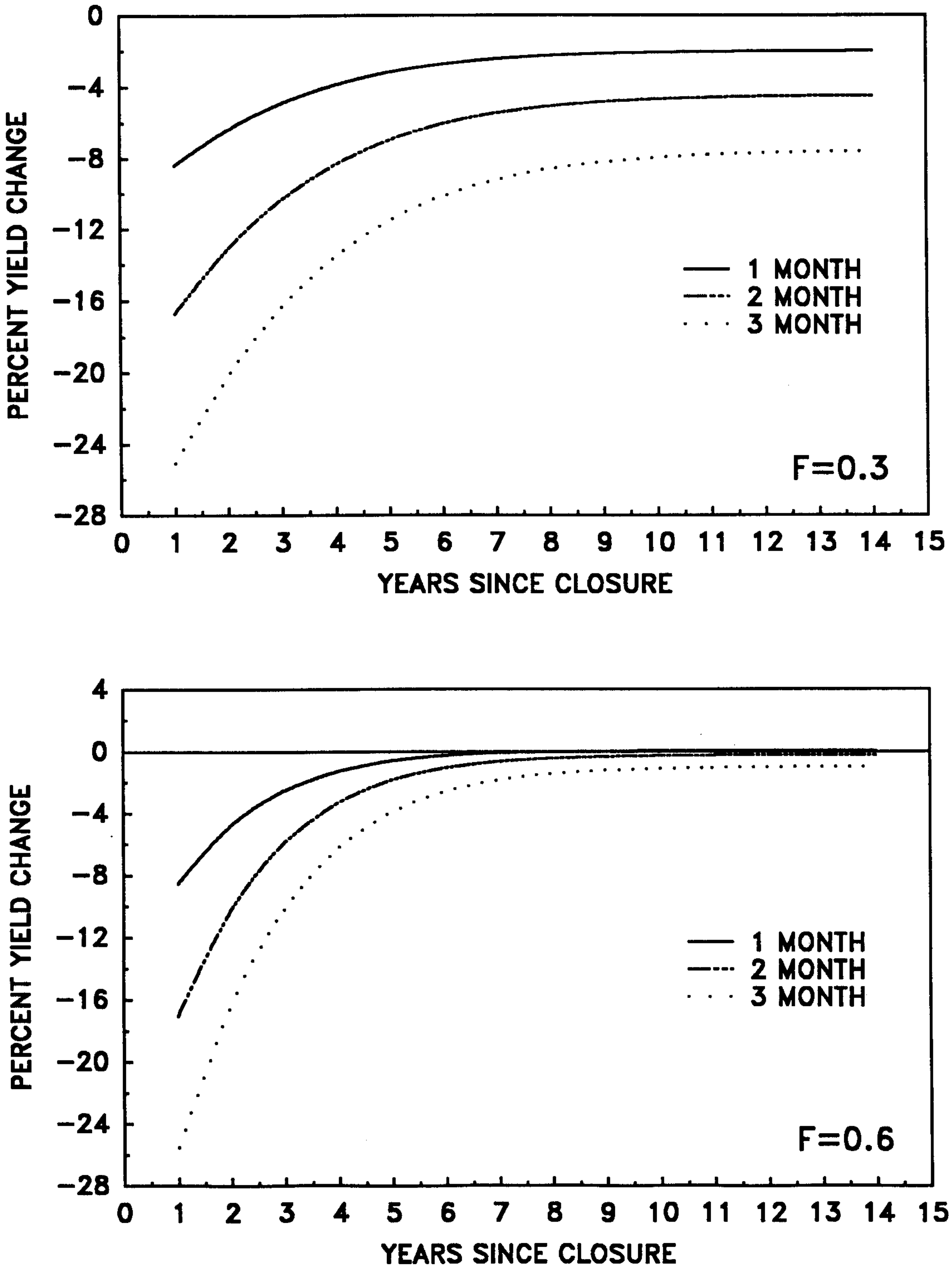

Figure 1.--Change in the yield per recruit over time, expressed as the percentage difference from the initial equilibrium yield per recruit. Individual plots are shown for both levels of initial fishing mortality and for each of the three closure durations.

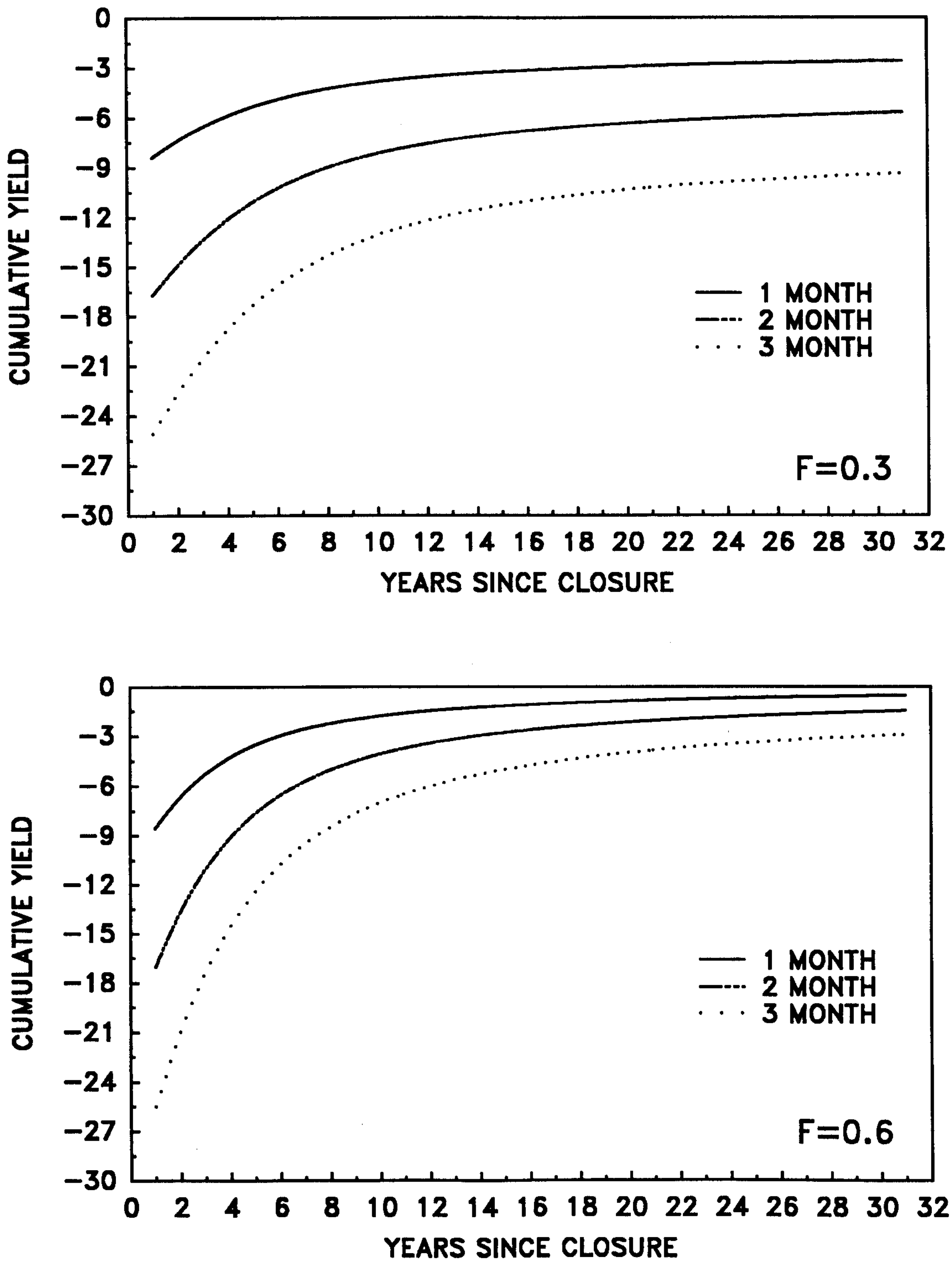

Figure 2.--Change in the cumulative yield over time, expressed as the percentage difference from the cumulative yield that would have been obtained without the seasonal closure. Individual plots are shown for both levels of initial fishing mortality and for each of the three closure durations.

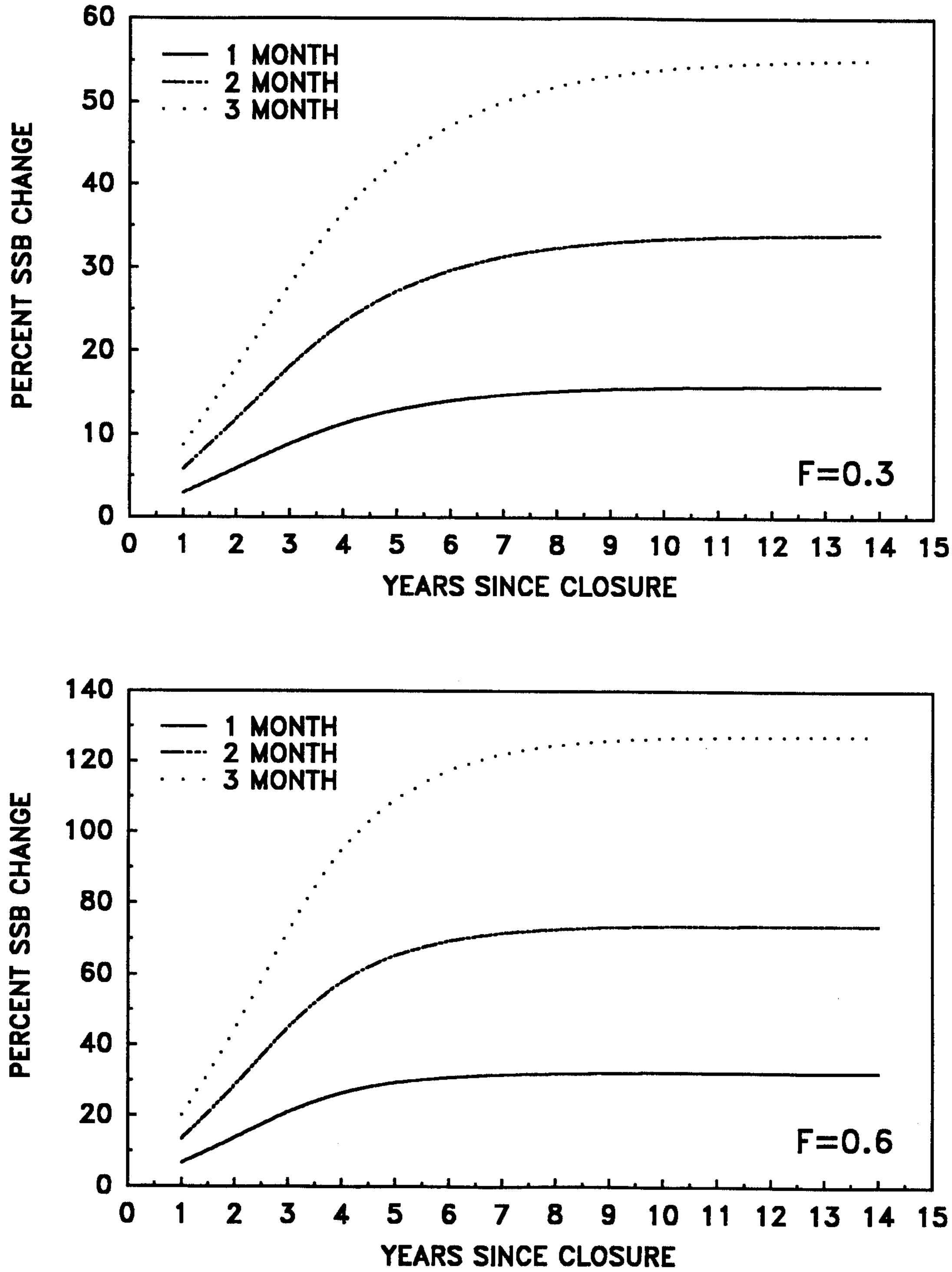

Figure 3.--Change in the spawning stock biomass (SSB) over time, expressed as the percentage difference from the initial equilibrium spawning biomass. Individual plots are shown for both levels of initial fishing mortality and for each of the three closure durations.

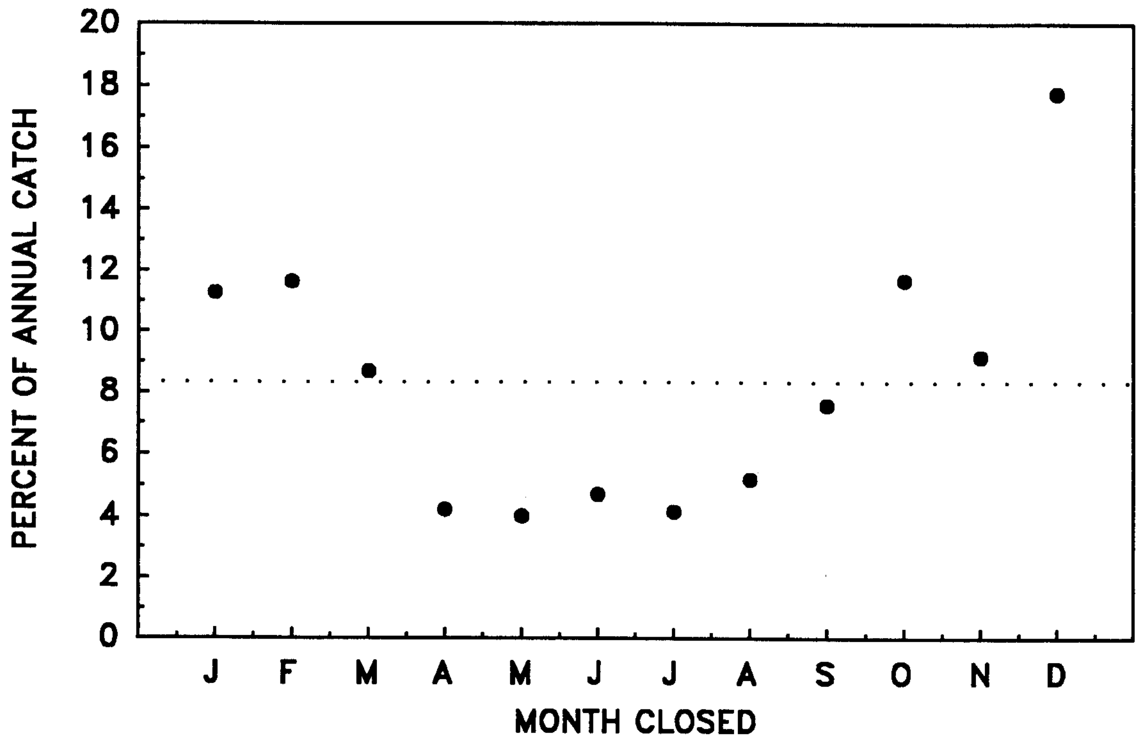

Figure 4.--Monthly variation in the catch of opakapaka expressed as monthly percentages of total annual catch. Monthly mean (1/12) is indicated with a dotted line.