Preliminary Yield per Recruit Analysis of the Hawaiian Yellowfin Tuna Fishery

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Introduction

The yield per recruit (YPR) is based on the theory of exploited fish populations developed in the 1950s by Beverton and Holt (1957). It is a relatively simple approach requiring only estimates of fishing mortality (F), natural mortality (M), and rate of growth in weight. YPR has fallen into disuse because contemporary stock assessment methods provide more useful biomass-based information for fisheries managers. Nevertheless, YPR can provide insight and guidance regarding potential fishery management interventions. Derivations of YPR often center around development of formulas for calculating YPR based on assumptions of constant F and M over the life of the

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exploited fish. Estimates of age-dependent F and M are often available from agre-structured stock assessments or tagging experiments. These estimates can be easily applied to computing YPR with fewer assumptions. Sparre and Venema (1998) suggest one approach.

Estimates of F and M at age for Hawaiian yellowfin tuna are avaialble from two sources: the 1995-2000 Hawaii Tuna Tagging Programme (HTTP) (Adam et 2003) and the 2014 MULTIFAN-CL (MFCL) stock assessment (Davies et al 2014). Here I apply YPR analysis to evaluate potential effects of changing the minimum size limit in the Main Hawaiian Islands (MHI) yellowfin tuna fishery.

MFCL

The Hawaii Exclusive Economic Zone is split between two regions 2 and 4 in the MFCL analysis (Figure 1). Region 4 extends from 10°S latitude to 20°N latitude and mainly comprises the large-scale equatorial purse seine and longline fisheries. Region 2 extends from 20°N latitude to 50°N latitude and comprises the Hawaii longline fishery. The boundary between these two regions passes through the MHI. The yellowfin landings from the small boat fisheries in Hawaii are not included in the data on which the MFCL assessment is based. Small boat fisheries catch in aggregate more yellowfin than the longline fishery (Figure **??**)*or simple table* .

The 2014 MFCL yellowfin assessment includes data from 1952 through 2012. The stock is assumed to consist of 28 quarterly age classes. MFCL model output routinely includes estimates of mean weight at age, natural mortality by age class, and fishing mortality by year, age and region. The MFCL mortality estimates are shown in Figure 2. The values of M used are the "reference case", i.e., specified values because of problems reliably estimating M. "Natural mortality at age was recalculated for previous assessments using an approach applied to other tunas in the WCPO and EPO." (Davies et al 2014). For the purpose of YPR analysis, I average the fishing mortality at age for each region from 2009 through 2014 (the last 5 years or 20 quarters). Fishing mortality differs sharply between regions 4 and 2. In region 4, F is generally quite high at all sizes of fish with peaks near 5kg and 30kg. The two modes are attributable to the purse seine and longline catches. In region 2, F is an order of magnitude lower with no clear modes. The lack of a mode in the smaller sizes is due to the omission of data from non longline fleets.

The YPR analysis for regions 4 and 2 are presented in Figures 3 and 4 respectively. In region 4, either increasing or decreasing the overall fishing mortality would cause a decrease in yield per recruit for all fisheries. Increasing the size at first capture to around 10 kg increases the yield to the whole fishery from near 1.5 kg/recruit to near 2.0 kg/recruit, and increase of approximately 30%. In region 2, the situation is quite different. Increasing or decreasing the total fishing morality simply increases or decreases the yield. Similarly, increasing the weight at first capture merely decreases the the total yield.

HTTP

Adam et al (2003) used a tag-attrition model to estimate size-dependent fishing mortality, natural mortality and migration rates between six recapture sites from the HTTP yellowfin and bigeye tag recaptures. I used a simplified version of the same model with only one recapture site to estimate size-dependent fishing mortality and natural mortality from the HTTP yellowfin recaptures. The number of age groups was increased in the simplified model from three to eight because there were fewer recapture strata. ‘ The new HTTP mortality estimates are shown in Figure6. These estimates differ from the MFCL estimates in several ways. There are fewer age classes represented because of the relatively low numbers of longline recaptures. The HTTP mortality estimates are generally much higher that the MFCL estimates. The corresponding YPR analyses are shown in Figure 6.

Discussion

The MFCL stock assessment is not intended to inform management of fisheries in the North Pacific. Division of the Hawaii EEZ between two regions makes application to problems in Hawaii difficult. Furthermore exclusion of a significant tonnage catch of smaller fish exacerbates the problem. Nevertheless, the situation in region 4 is instructive. Fishing mortality on yellowfin is higher for small-sized fish than for larger fish, as is the suspected case in the MHI. By analogy, it is possible that increasing the age at recapture in Hawaii could increase the total yield to the fishery. The general level of F in Hawaii is considered to be much smaller than in region 4, so conclusions about MHI fisheries based on region MFCL 4 are purely speculative.

Yield per recruit analysis only provides information about the effects of management actions on the yield to the fishery. YPR does not provide insight into stock conditions and does not offer any guidance in establishing biomass-based reference points.

Still working on it.

Conclusions

Working on it.

Math Stuff

Working on it.

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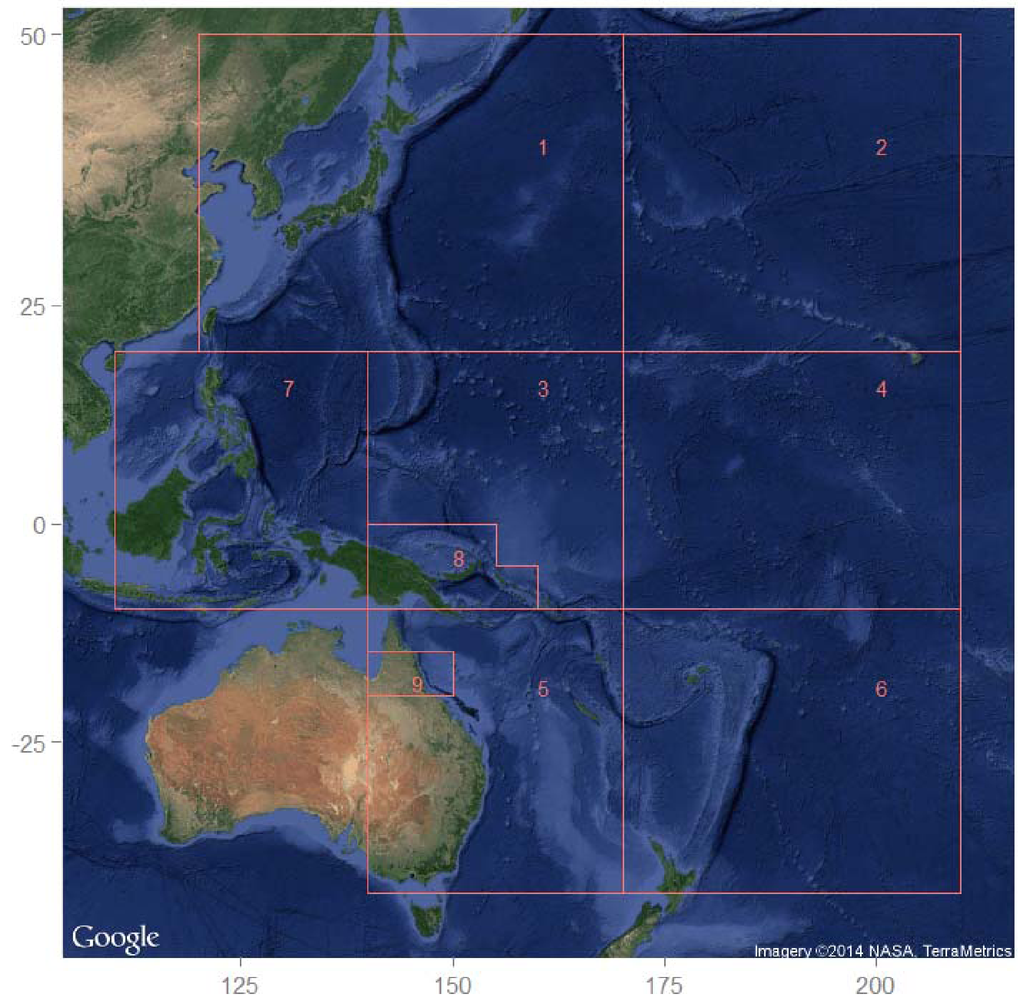

Figure 1: Regions used in the 2014 MFCL stock assessment; from Davies et al, 2014.

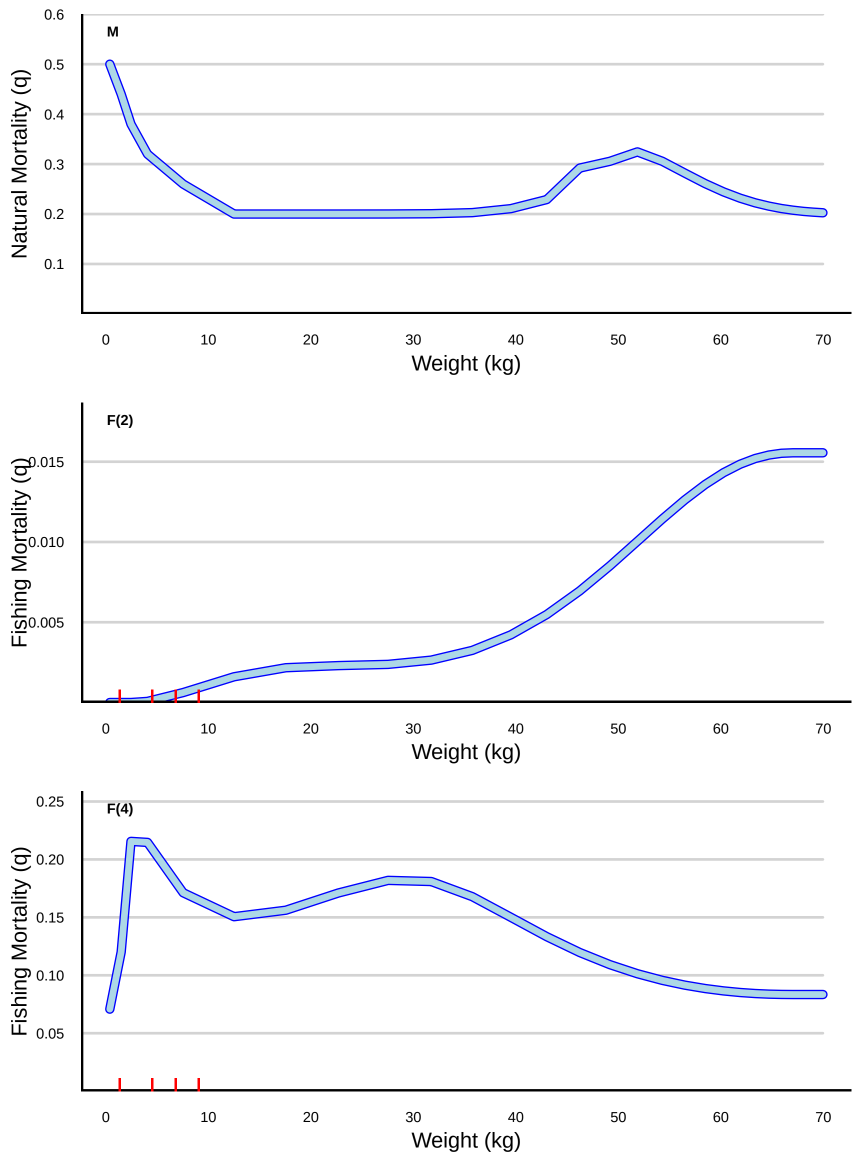

Figure 2: Natural and fishing mortality from the 2014 MFCL yellowfin stock assessment. The upper panel (M) shows the "reference case" natural mortality at age plotted against mean weight at age. The lower two panels, F(2) and F(4), show the MFCL estimated fishing mortality for regions 2 and 4 respectively, averaged over the period 2009 through 2014. The red marks on the abscissa are placed at the current lower catch weight limit and at three other weight limits sometimes discussed; that is at 3, 10, 15, and 20 pounds.

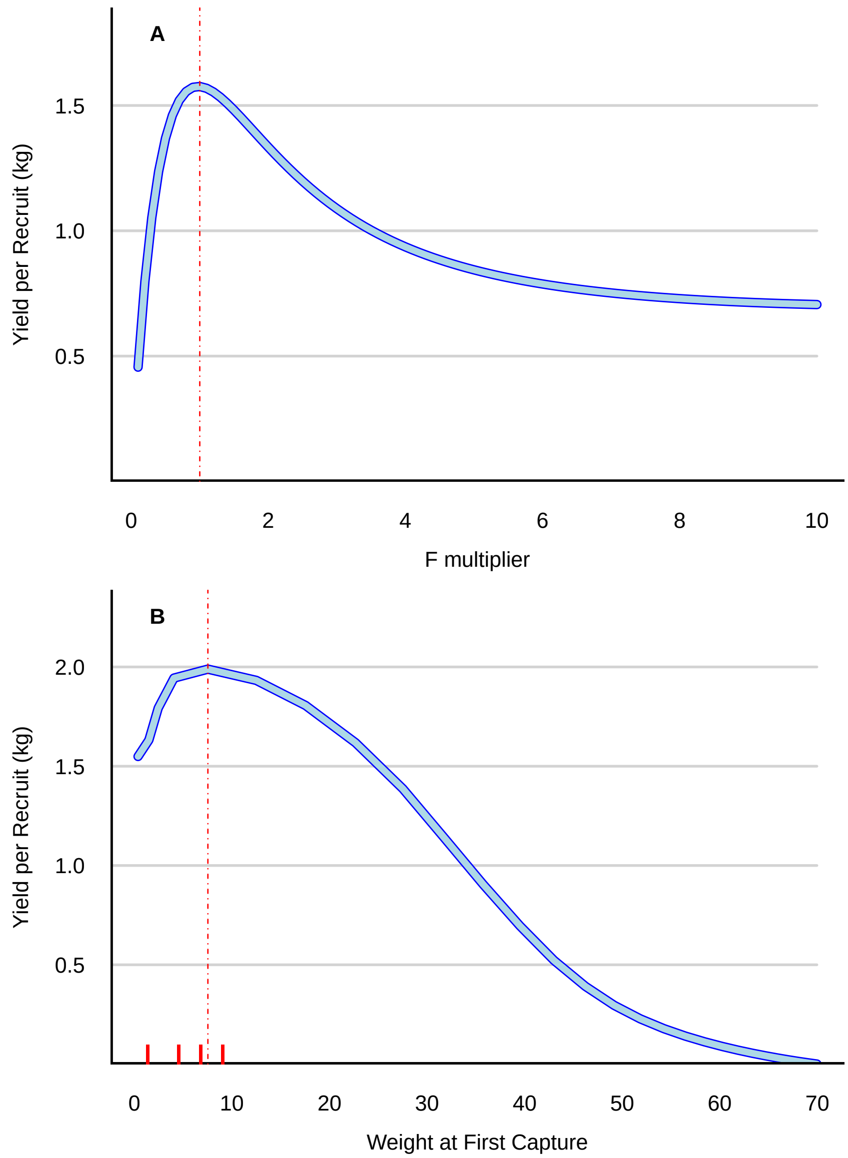

Figure 3: Yield per recruit in MFCL region 4 as a function of fishing mortality and age at first recapture. Panel A shows the change yield per recruit due to multiplying the fishing mortality at all ages by constant factor ranging from 0 to 10, that is from essentially closing all fisheries to expanding all fisheries by a factor of 10. The dashed vertical red line is drawn at 1, the current fishing mortality. Panel B shows the change in yield per recruit of increasing the minimum size limit in the fishery from 0kg to 70kg. The dashed vertical red line is drawn at the weight producing the highest yield per recruit.

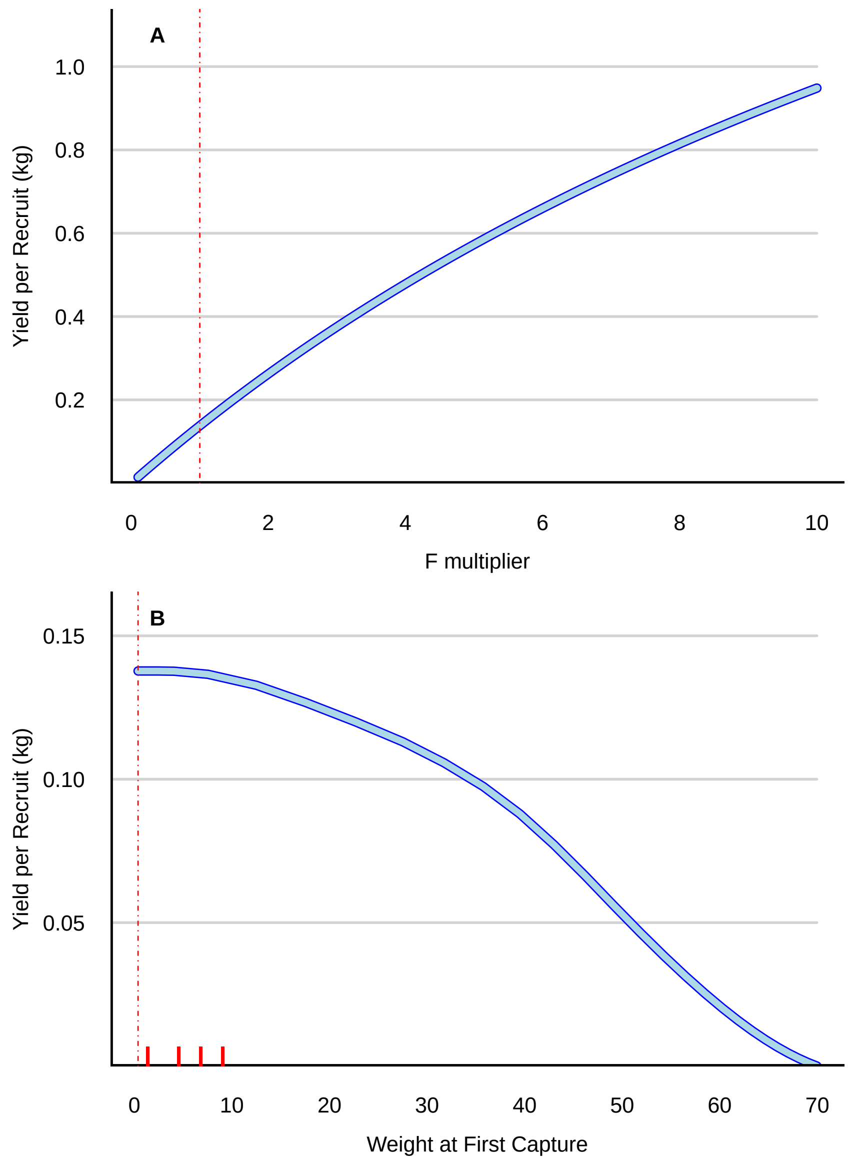

Figure 4: Yield per recruit in MFCL region 2 as a function of fishing mortality and age at first recapture. See caption in Figure 3 for details.

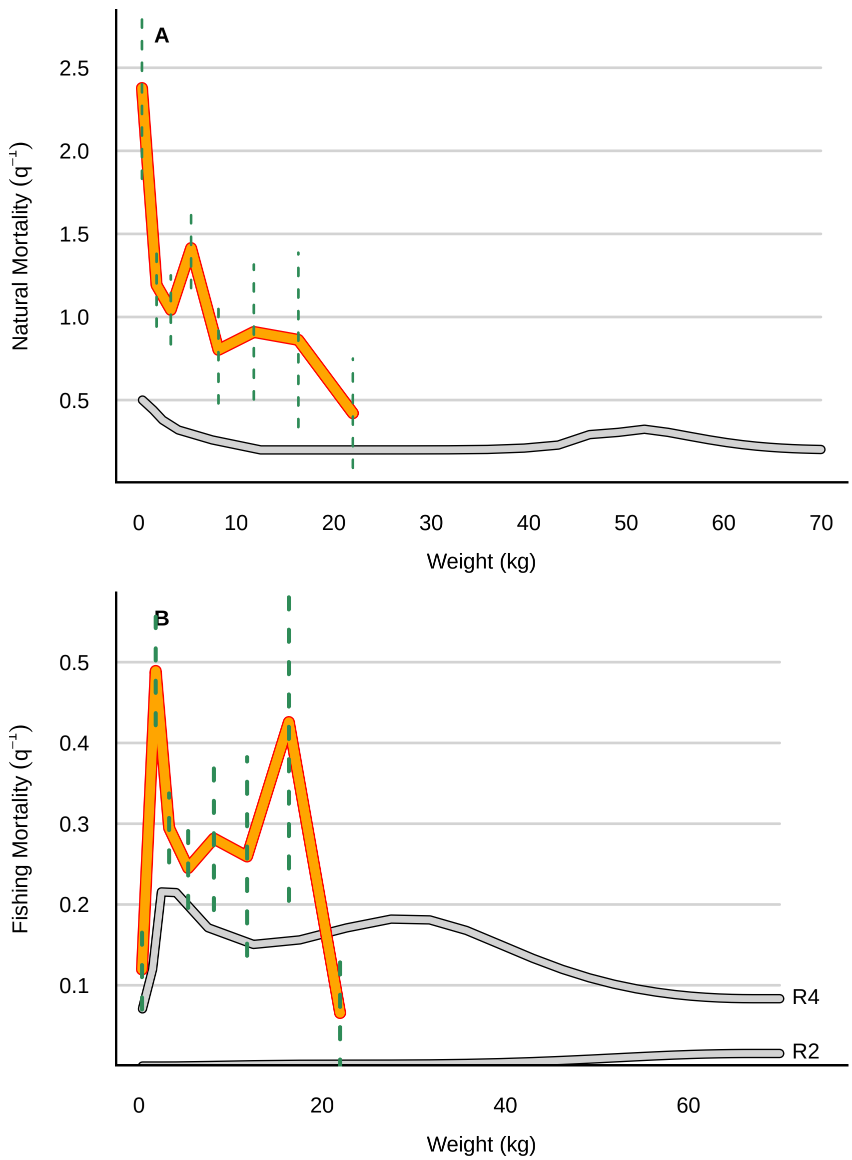

Figure 5: Natural mortality (A) and fishing mortality (B) estimates from the HTTP tag recaptures. Mortality estimates (per quarter) are shown in orange. The green bars are the point estimates ± two standard deviations. The light gray lines are MFCL estimates shown for comparison.

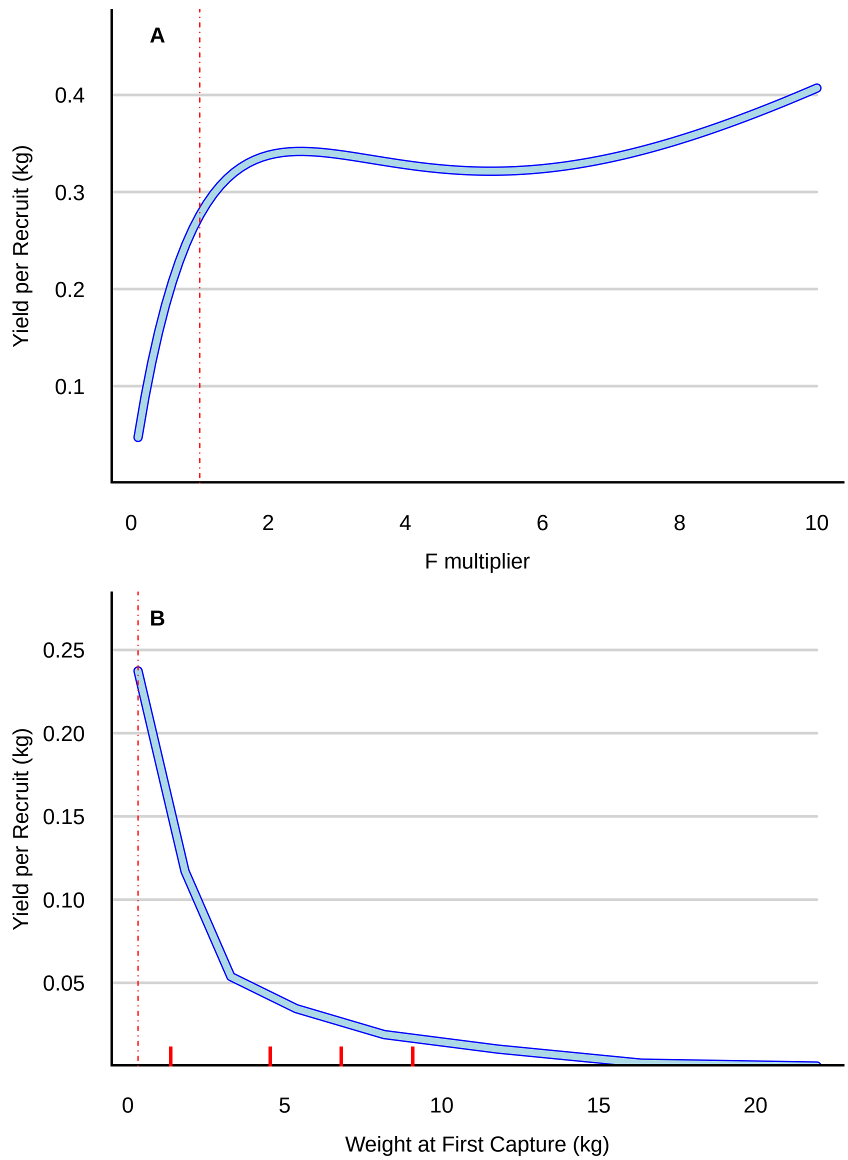

Figure 6: Yield per recruit in the Main Hawaiian Islands based on HTTP mortality estimates. See caption in Figure 3 for details.