Documentation of the Maximum Sustainable Yield Calculations for the Bottomfish Fishery in the Hawaiian Archipelago[1]

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Purpose: The purpose of this report is to document the steps taken in the most recent update to maximum sustainable yield (MSY) estimates for bottomfish in the Hawaiian Archipelago. These MSY estimates were made in June 2004 and were utilized in stock analyses in 2004 and 2005 -- but lacked complete documentation. Another update of MSY estimates is planned for later in 2005. In the interim, this report details the approach taken and previous findings.

Methods: A dynamic production model was applied to 3 time series of bottomfish catch and effort data for the Hawaiian Archipelago. Commercial fishery data from vessel logbooks and interview data for the Ho'omalu Zone (1987-2001) and the Mau Zone (1987-2001) in the Northwestern Hawaiian Islands (NWHI) were utilized, as well as State of Hawaii commercial catch data for the Main Hawaiian Islands (MHI, 1948-2001). These time series of bottomfish catch were simultaneously fit using nonlinear regression in a simplified 3-parameter model similar to that described by Kobayashi (1996). This approach reduces the number of fitted parameters by utilizing outside information for some parameters and incorporating some shared parameters where applicable. The basic equation for the dynamic production model is from Hilborn and Walters (1992) with a slight modification to the catch formula which prevents catch from exceeding population size at high levels of exploitation (Dr. Richard B. Deriso, Inter-American Tropical Tuna Commission, pers. comm.):

$$\hat{B}_t = \hat{B}_{t-1} + r\,\hat{B}_{t-1}\left(1 - \frac{\hat{B}_{t-1}}{k}\right) - C_{t-1}$$

$$\hat{C}_t = \hat{B}_t\left(1 - e^{-qE_t}\right)$$

$$B_{initial} = \frac{\text{Average of first 3 years CPUE}}{q}$$

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where:

t is time in units of years,

$\hat{B}_t$ is modeled biomass at time t in units of pounds,

$\hat{B}_{t-1}$ is modeled biomass at time t-1 in units of pounds,

r is the intrinsic rate of population increase,

k is the population carrying capacity in units of pounds,

C_{t-1} is the observed catch at time t-1 in units of pounds,

$\hat{C}_t$ is the predicted catch at time t in units of pounds,

q is the catchability coefficient in units of per day,

E_t is the fishing effort at time t in units of days,

$B_{initial}$ is the starting biomass for the time series in units of pounds,

$CPUE$ is the catch per unit of effort in units of pounds per day,

MSY is the maximum long term sustainable catch in units of pounds,

B_{MSY} is the population biomass at MSY in units of pounds,

E_{MSY} is the fishing effort at MSY in units of days, and

$CPUE_{MSY}$ is the catch per unit of effort at MSY in units of pounds per day.

Nonlinear least squares was used to minimize the sum of squared deviations between C_t and $\hat{C}_t$ using the GRG2 algorithm in Excel Solver. The 3 parameters to be estimated were the intrinsic rate of population increase (shared by all 3 regions), the Mau Zone population carrying capacity (with Ho'omalu Zone and MHI values scaled by zone-specific bottomfish habitat multipliers), and an initial value of MHI catchability. Due to the longer history of the MHI fishery (i.e., 50+ years), 4 levels of catchability were utilized in a stepwise fashion to account for increases in fishing power (skill, technology, etc.) over time. The NWHI catchabilities were estimated from bottomfish depletion studies in the Western Pacific as described in Kobayashi (1996).

Results: The results from this analysis are presented in Table 1 and Figure 1. The MSYs and MSY-based values utilized in stock monitoring for the 3 regions are presented in Table 1. The observed and modeled trajectories of catch are shown in Figure 1. The trajectories of modeled current year biomass as percent of virgin (initial) biomass are also shown in Figure 1. One issue may be that the CPUE figures for the Mau zone are nominal values and have not yet been standardized; this will be the subject of a workshop later this year.

References:

Hilborn, R., and C. J. Walters. 1992. Quantitative fisheries stock assessment: Choice, dynamics & uncertainty. Chapman and Hall, New York, 570 p.

Kobayashi, D. R. 1996. An update of maximum sustainable yield for the bottomfish fishery in the Northwestern Hawaiian Islands. NMFS/PIFSC internal document (unpublished), 20 pp.

Table 1. Dynamic production model specifications.

Ho'omalu q =	0.000262	per day
Mau q =	0.000991	per day
MHI <=1967 q =	0.000166	per day
MHI 1968-1984 q =	0.000190	per day
MHI 1985-1991 q =	0.000238	per day
MHI 1992-2001 q =	0.000285	per day
r =	0.412722	
Ho'omalu k =	3292562	pounds
Mau k =	948865	pounds
MHI k =	3425403	pounds
Ho'omalu MSY =	339728	pounds
Mau MSY =	97904	pounds
MHI MSY =	353435	pounds
Ho'omalu E_{MSY} =	789	days
Mau E_{MSY} =	208	days
MHI E_{MSY} =	868	days
Ho'omalu $CPUE_{MSY}$=	431	pounds per day
Mau $CPUE_{MSY}$=	470	pounds per day
MHI $CPUE_{MSY}$=	407	pounds per day
Ho'omalu B_{MSY}=	1646281	pounds
Mau B_{MSY}=	474433	pounds
MHI B_{MSY} =	1712702	pounds

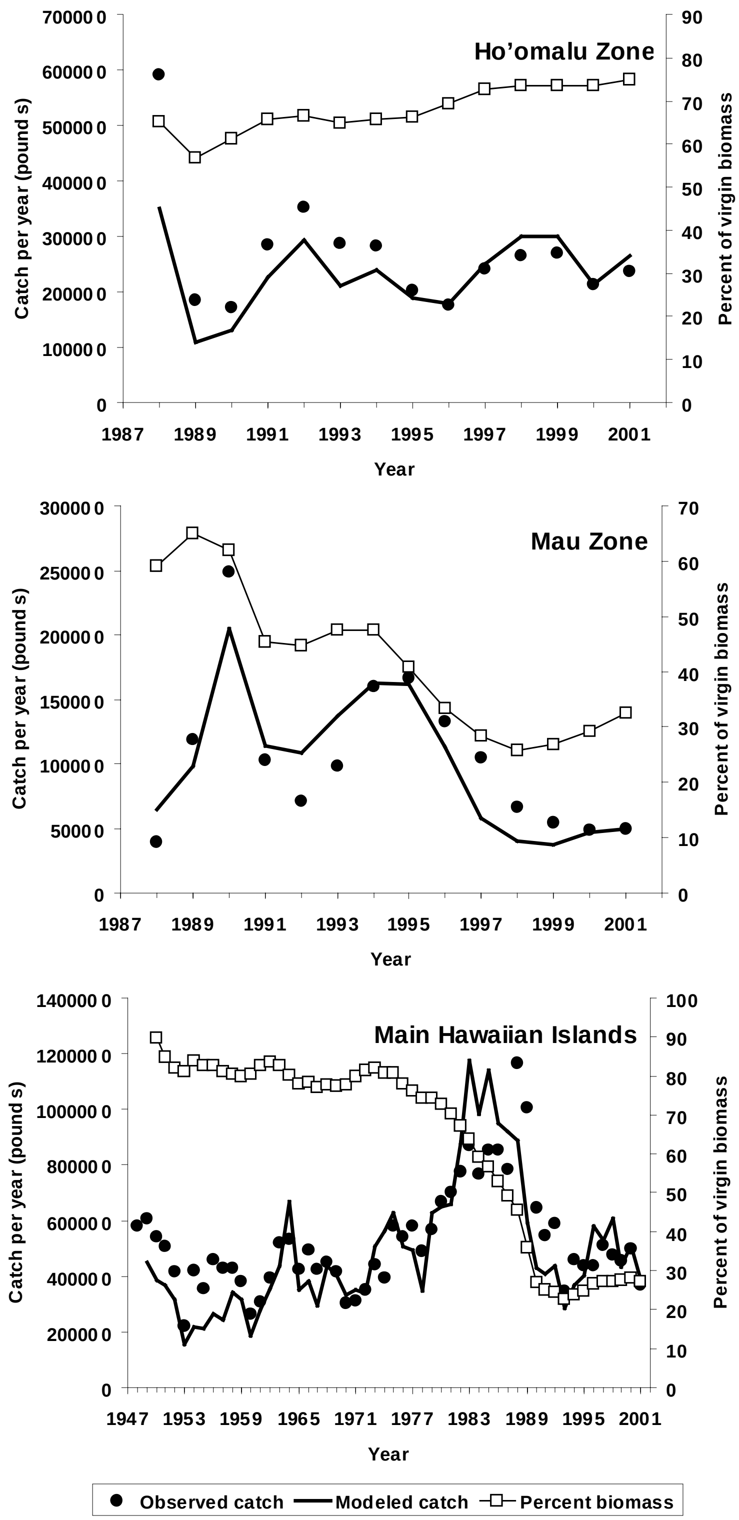

Figure 1. Trajectories of observed catch, modeled catch, and modeled percent of virgin (initial) biomass for aggregate bottomfish stocks in 3 regions of the Hawaiian archipelago.