Catch-free assessment of Caribbean Yellowtail Snapper

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Abstract
This document illustrates a catch-free assessment model (Porch et al. 2004). As fishery data for yellowtail snapper populations in the Caribbean are sparse, this document will explore a set of hypothetical assumptions about historic fishing effort and historic depletion, and will discuss stock status as implied by those assumptions. This in no way should be interpreted as representing true stock status; rather, it should serve to focus discussions at the assessment workshop as to appropriate ways of dealing with the uncertainty in (or lack of) fishery data and key biological parameters.

Methods

As the name implies, this model framework was created to handle situations where catch data is unavailable. Without information on catch, estimates of absolute levels of abundance are not possible. Instead, the model estimates population sizes relative to virgin levels, where the number of recruits at virgin conditions is 1 and all older ages are calculated relative to that (full details in Porch et al. 2004).

The underlying population equations follow an age-structured production model, which requires information on natural mortality, maturity, fecundity, and spawning time. A spawner-recruit function, which is parameterized in terms of α (maximum reproductive rate; see Myers et al. 1999), must also be specified.

Historic information, anecdotal evidence, or informed opinions can provide guidance on the year that the stock was in a virgin state, y_{virgin}. The time series from y_{virgin} to the last year that data is available, y_{last_data}, is split into a historic and a modern period. The historic period reflects years where there are little data, while the modern period would presumably have some indices of abundance and/or effort.

Application to Yellowtail Snapper Population on the Puerto Rico Platform

Biological inputs

A Beverton-Holt spawner-recruit function was specified, with age 1 recruitment. Although spawning probably occurs year-round, a peak in summer was assumed. A prior for α was developed from the work by Rose et al. (2001), who grouped the meta-analysis of α values from Myers et al. (1999) according to life history strategies. The α grouping selected for this analysis corresponded to periodic strategists. A lognormal fit to those data yielded a mean of 14 and standard deviation of 1.19 (Porch et al. 2004). Maximum ages discussed in the data workshop report ranged from 8-17. A value of M=0.35 was specified in this model application assuming a maximum age of 20, with 99.9% cumulative mortality by that age (M=-ln(0.001/20). To reflect the uncertainty in this value, a lognormal prior was specified with mean 0.35 and CV=0.3. Length at age (mm FL) and weight at age (g) were calculated from the Manooch and Drenon (1987) parameter estimates. Weight at age was used as a proxy for fecundity at age. Maturity was estimated to range from 22-25 cm FL (Table 1a, data workshop report); comparing this with length at age suggests individuals are approximately age 2 at length 22-25 cm. Fish were assumed 50% maturity at age 2 and 100% maturity for ages 3+. All biological inputs are listed in Table 1, and priors are plotted in Figure 1.

Historic fishery inputs

Three surveys of USVI fisheries are documented in Kojis (2004): Fielder and Jarvis (1932), Swingle et al. (1970), and Kojis (2004). A survey on St. John, exclusively, was conducted in 1959 by Idyll and Randall (1959). The effort information available from these studies was in the form of total number of registered commercial fishers and the proportion of those that were full versus part-time (Table 2a). A number of assumptions were made to try to split that information, which was for the USVI as a whole, into platform-specific information (i.e. St. Croix and St. Thomas/St. John). A simple time-series of effort was created by summing the number of full-time fishers and 0.5*(number of part-time fishers). An exponential fit to those points was made, and the fitted equation was used to project back to 1850, when the population was presumed to be in a virgin state (Figure 2). The year 1850 was chosen for this model illustration. Although fishing presumably occurred on the USVI for several hundred years, in the earliest years it was most likely at a subsistence-level. This point could benefit from advice from the group in attendance at the assessment workshop.

In addition to the effort series, a relative index of abundance of was generated to provide a level of stock depletion in 1930, the year of the Fiedler and Jarvis survey. As a starting point for discussion, an assumed depletion of 20% in 1930 was used. In that this was a relatively arbitrary model assumption, a likelihood profile was performed to characterize uncertainty in the level of depletion in 1930.

Modern fishery inputs

Two nominal indices of catch per unit effort for commercial landings in STT/STJ were used as an additional tuning index for the model – one for lines, and one for lines/traps. The series spanned the years 1997-2003 (SEDAR8-DW-Table 7). The commercial fishery appears to dominate landings on yellowtail for the Puerto Rico "platform", which includes STT/STJ (SEDAR8-DW-Figure 21). It is therefore assumed that this fishery would track fluctuations in population abundance. A logistic selectivity was assumed, with guidance on the age of 50% selectivity gleaned from Figures 12, 13, and 18 (SEDAR8-DW final report). It appeared that handlines selected slightly older fish than traps, so the age of 50% selectivity was assumed to be 3.5 for the lines index, and 2.5 for the lines/traps index. The index of relative depletion, which reflects the vulnerable biomass, was assumed to have an age of 50% selectivity somewhere between those for the two commercial gears, and an age of 3.0 was chosen (Figure 3).

Results

Given the various modeling assumptions about historic effort and an assumed depletion of 20% in 1930, model results indicate that the stock is not overfished (SSB/SSB_{msy} = 1.96) nor is overfishing occurring (F/F_{msy}=0.49). The model estimated that the stock is currently 51% depleted (SSB_{2003}/SSB_{virgin} = 0.49), with a fishing mortality rate of 0.18. Relative population benchmarks are given in Table 3.

Estimated trajectories for fishing mortality (F) and spawning stock biomass (SSB) appear reasonable given the model assumptions. A linear increase in F was estimated for the period preceding the nominal CPUE (first year of data is 1997), and then a scalar multiple of F in 1996 was estimated for the period 1997-2003, with annual deviations (Figure 4).

Fits to the two nominal abundance indices adequately capture the mean trend, although the last years appear to consistently overestimate the observed values (Figure 5). The fit to the relative depletion index is reasonable (Figure 6).

Likelihood profiles on natural mortality (M) and maximum reproductive rate (α) are plotted with their priors (Figure 1). For natural mortality, the mode of the posterior is the same as the prior, although the distribution is shifted slightly to the left; this may be due to the upper boundary being set at 0.6. Most likely, there is no information in the data from which to estimate M. The mode of the posterior is greater than the prior for α, although again it appears the upper boundary of 70 had some constraint on the estimated distribution.

The likelihood profile suggests that the most likely level of depletion in 1930 is 38% (i.e. relative biomass in 1930 is 0.62). An estimated 95% confidence interval for relative biomass in 1930 is [0.4, 0.87]. The present model illustration assumed 20% depletion, or a relative biomass of 0.8 in 1930. While this value is contained in the 95% confidence interval, it is more probable that the stock was twice as depleted (Figure 7). This may relate to the bias in fits to the nominal indices.

Discussion

While time did not permit a full exploration of the model assumptions, this paper serves to illustrate the catch-free methodology. Given the paucity of data, several key model assumptions may drive the model results and should be carefully considered by the group before proceeding further. In particular, discussion of inputs to this model should focus on the following:

1. a year when virgin conditions can be assumed;
2. a level of depletion in 1930 (or another year could be used as a reference, if its value could be determined with greater certainty than 1930);
3. the assumptions made in calculating historic effort and in filling gaps in that time series;
4. appropriateness of key biological parameters, namely natural mortality and α.

While this paper presents an illustration for the Puerto Rico platform, the same data issues apply to the St. Croix platform, and similar discussion should be made with respect to the above four points.

Acknowledgements

Nancie Cummings provided useful guidance in navigating the information contained in the data workshop report.

References

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Porch, C.E., A.-M. Ecklund, and G.P. Scott. Catch-free stock assessments with application to Goliath Grouper (*Epinephelus itijara*) off southern Florida. ICCAT Col. Vol. Sci. Pap., SCRS/2004/110.

Rose, K.A., J.H. Cowan, Jr., K.O. Winemiller, R.A. Myers, and R. Hilborn. 2001. Compensatory density dependence in fish populations: importance, controversy, understanding, and prognosis. Fish and Fisheries 2:293-327.

Table 1. Biological inputs to catch-free model for an application to the Puerto Rico yellowtail snapper population.

Parameter	**Value**	**Prior**
Spawning	Peak mid-summer	(constant)
Maturity	Age 1: 0 Age 2: 0.5 Ages 3+: 1.0	(constant)
α		
Natural Mortality	0.35	LN(0.35, 0.011)
L∞	483.8 (cm FL)	(constant)
K	0.17	(constant)
t0	-1.87	(constant)
L-W scalar	1.17E-4	(constant)
L-W exponent	2.6504	(constant)
Fecundity	Weight used as proxy	(constant)

Table 2a. Estimates of historic effort from Table 58 in Kojis(2004). Yellow highlighted cells were calculated by assuming a halving in number of full-time fishers (NFT), as occurred in roughly the same period of time from 2003 back to 1968.

Year	N FT	%	N PT	%	N fishers-comm	USVI pop	% pop commercially fishing
1930	61	15	344	85	405	22012	1.8
1968	120	30	280	70	400	55000	0.73
2003	215	67	108	33	383	108612	0.3

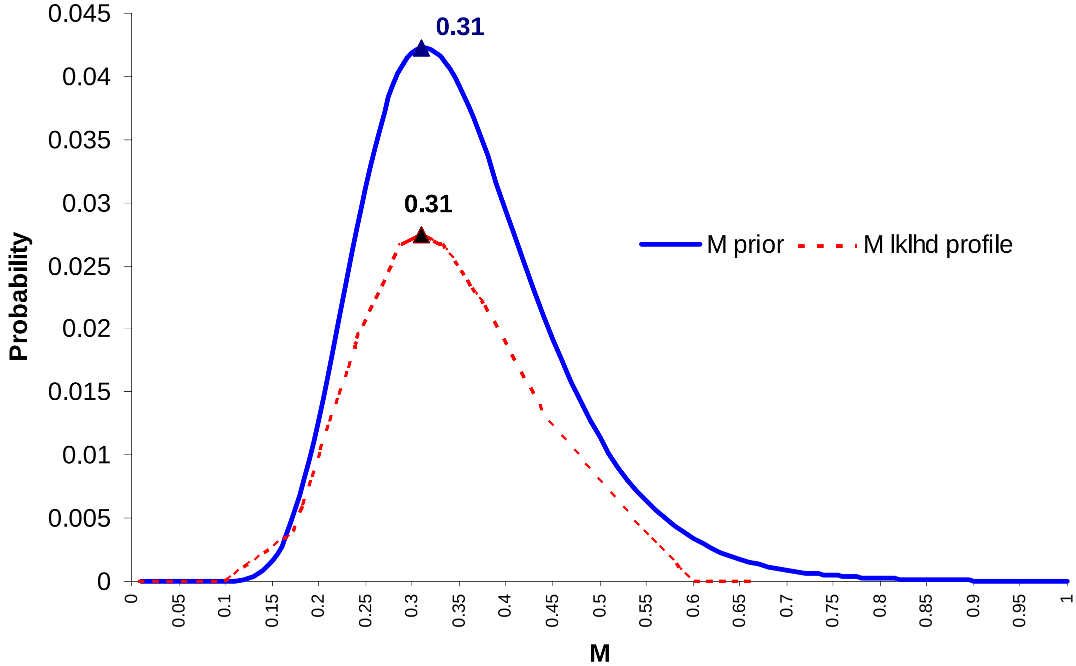
Table 2b. Attempt to split historic effort information into platform specific information (ST X = St. Croix; STT/STJ = St. Thomas, St. John). Yellow highlighted cells were arrived at by assuming constant fractions in the split between STX and STT/STJ number of commercial fisher, and constant fractions in the split of number of full time fishers. A linear interpolation was used to arrive at the USVI population in 1959.

	ST X					**STT/STJ**							
Year	N FT	*% FT*	N PT	*% PT*	N. comm. fishers	N FT	*% FT*	N PT	*% PT*	N. comm. fishers	USVI N comm fishers	USVI pop	% pop comm. fishing
1930	25	*11*	211	*89*	236	36	*21*	134	*79*	169	405	22012	1.8
1959	37	*16*	196	*84*	233	52	*31*	115	*69*	167	400	47187	0.85
1968	50	*21*	183	*79*	233	70	*42*	97	*58*	167	400	55000	0.73
2003	87	*61*	136	*39*	223	124	*77*	36	*23*	160	383	108612	0.3

Table 3. Relative benchmarks.

Type	F	Y/R	SSB	SPR	Recruits
VIRGIN	0.00E+00	0.00E+00	1.00E+00	1.00E+00	1.00E+00
MSY	**3.63E-01**	**1.44E+02**	**2.51E-01**	**3.02E-01**	**8.29E-01**
MAX YPR	1.09E+00	1.64E+02	7.68E-03	7.63E-02	1.01E-01
F0.1	3.50E-01	1.42E+02	2.62E-01	3.13E-01	8.37E-01
20% SPR	5.45E-01	1.56E+02	1.41E-01	2.00E-01	7.03E-01
30% SPR	3.67E-01	1.44E+02	2.48E-01	3.00E-01	8.27E-01
40% SPR	2.58E-01	1.29E+02	3.55E-01	4.00E-01	8.89E-01
50% SPR	1.83E-01	1.11E+02	4.63E-01	5.00E-01	9.26E-01
60% SPR	1.28E-01	9.12E+01	5.70E-01	6.00E-01	9.50E-01

(a)



(b)

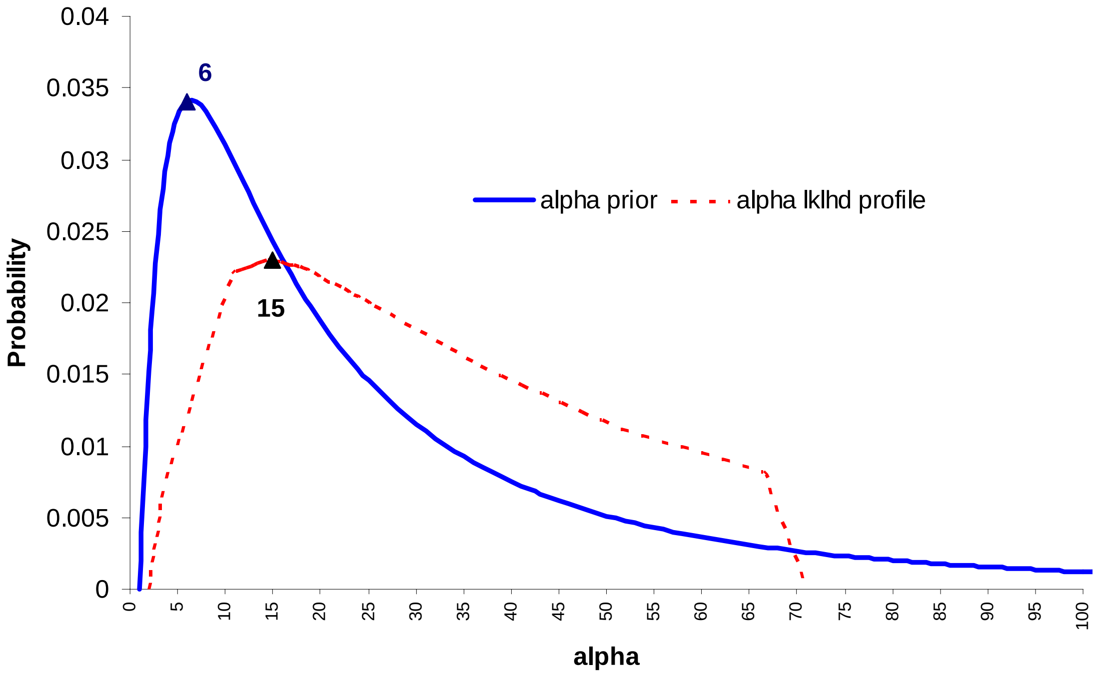


Figure 1. Prior probability distributions and likelihood profiles for natural mortality (a) and maximum reproductive rate (b). The value of the mode is indicated by the triangle.

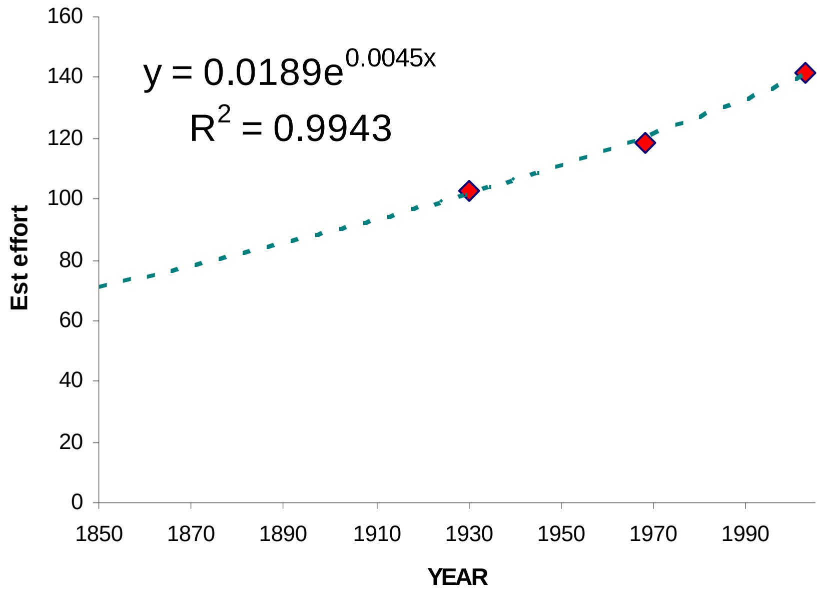


Figure 2. Exponential fit to estimated effort for STT/STJ from values in Table 2b (effort = NFT+0.5*NPT). The fitted equation was used to project back to 1850, when the population was assumed to be in a near-virgin state.

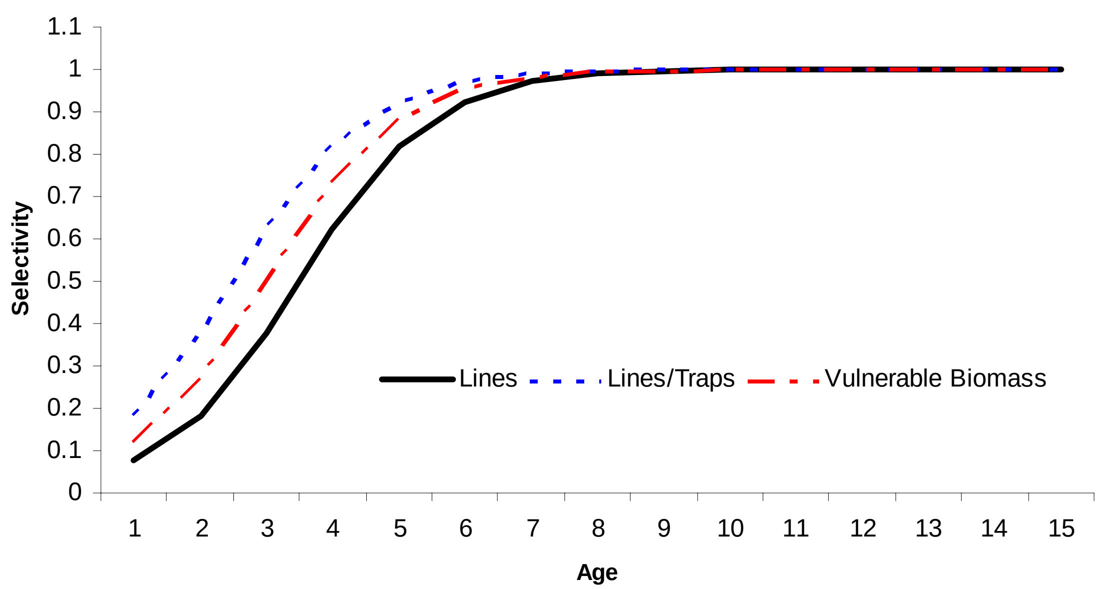


Figure 3. Selectivity assumed for nominal indices of abundance (Lines, Lines/Traps) and an assumed index of relative depletion (Vulnerable Biomass).

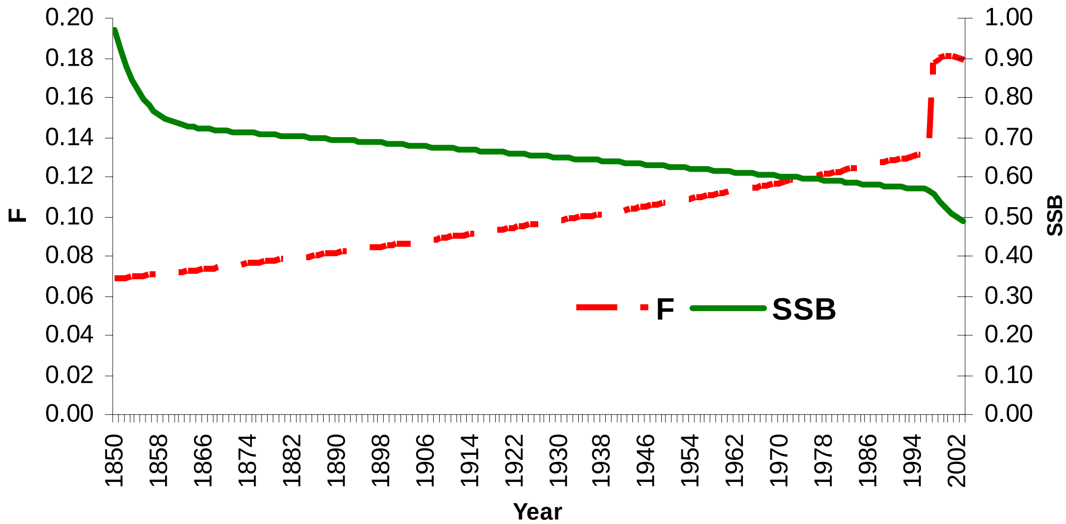


Figure 4. Model estimates of fishing mortality (F) and relative SSB over time.

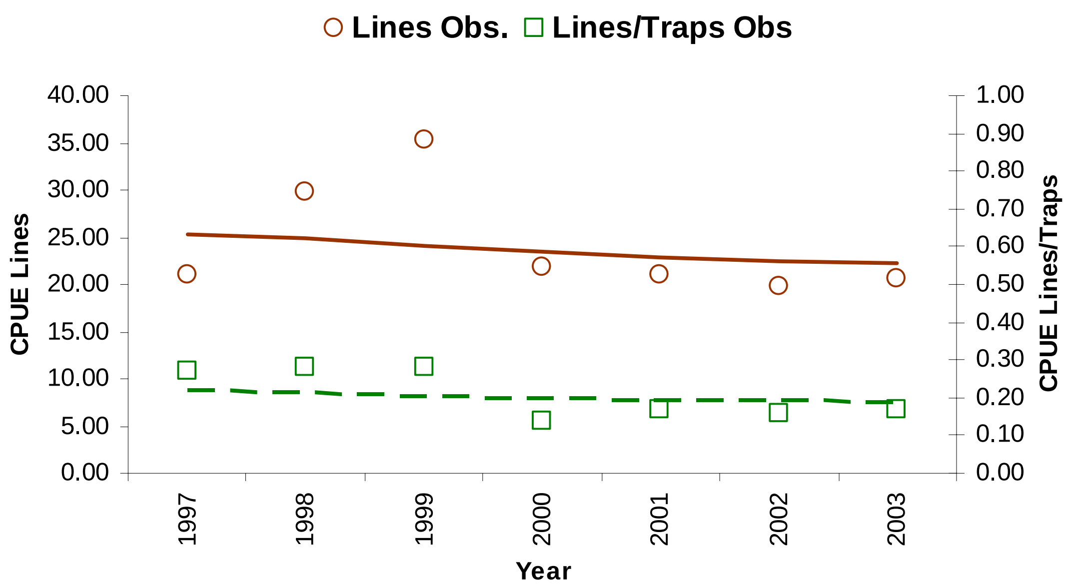


Figure 5. Fits to nominal CPUE series.

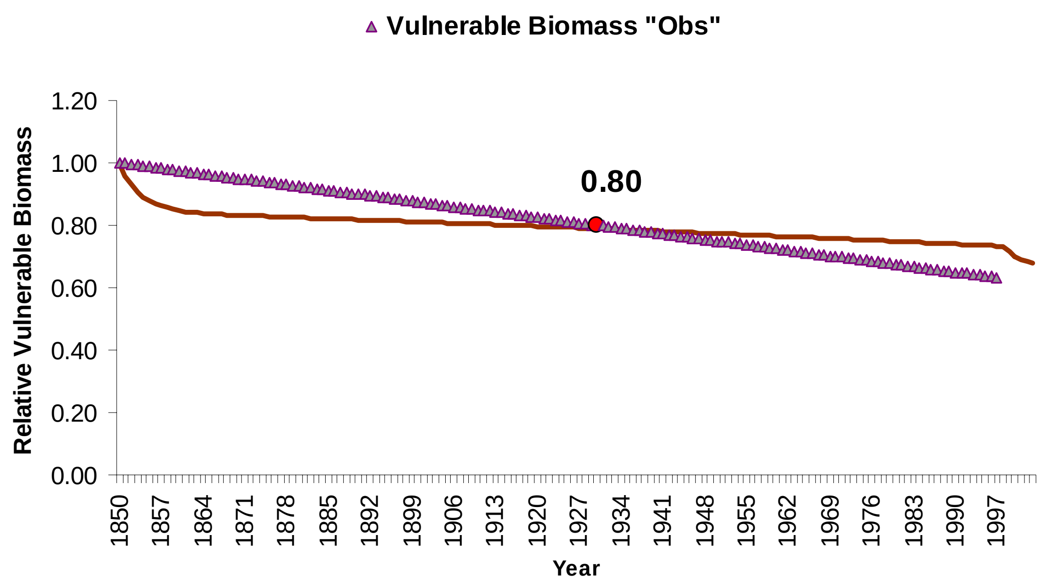


Figure 6. Fit to relative index of depletion (generated to give a depletion of 20% in 1930).

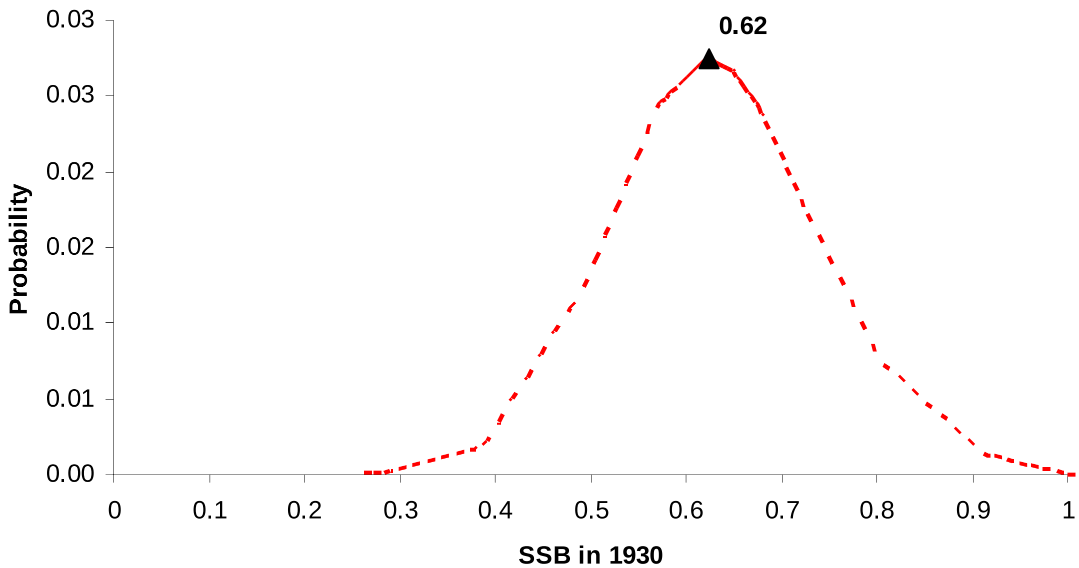


Figure 7. Likelihood profile of relative spawning stock biomass in 1930.