Data-Poor Models for Assessing Gulf Curvina and Evaluating Management Alternatives (Supporting a Presentation at Ensenada, BCN, on 11 May, 2011)

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Summary

Using recent unpublished data collected by the Center for Marine Biodiversity and Conservation (CMBC), we developed simple models of curvina golfina to estimate fishing intensity and short-term effects of fishing on the curvina population. The results indicate that it is possible that nearly all of the fish that aggregate in the upper Gulf of California could be caught in the fishery. At the lower bound, the results suggest that few fish escape two years of fishing. The results also suggest that the curvina fishery is nearly saturated; i.e., even if fish were more abundant, larger daily catches would be difficult due to capacity and processing constraints. Under this saturation scenario, we developed a simple model to relate catches to estimated fish abundance which can be used to explore management scenarios such as catch limits, time closures (seasons), and spatial catch limits. The model effectively allocates fish either to catch or to escapement. We ran several time closure scenarios, on the assumption that closures may prove more enforceable and more acceptable to fishermen than catch limits or spatial closures. The results show how escapement (conservation goals) and product flow (social and economic goals) could be achieved by altering the timing and extent of time closures. For example, closing the fishery on the last two days of each tide reduces catch at a time when markets may not buy any more fish, reducing waste. We also simulated strong enforcement of the protected area, which in effect would close the three peak days of the fishery in each tidal period, generating a substantial escapement. The alternative scenarios indicate in general that a large relative increase in escapement to the spawning stock can be achieved with a relatively small decrease in catch, helping to reduce the risk of stock collapse and perhaps also helping to reduce episodic landings gluts and associated waste.

Introduction

The fishery for curvina golfina (*Cynoscion othonoptera*) occurs on a series of spawning aggregations associated with April and May spring tides in the Colorado River Delta in the upper Gulf of California. Data on the fishery and catches have been spotty and unreliable until recently, when a comprehensive monitoring program was undertaken by the Center for Marine Biodiversity and Conservation (CMBC) at the Scripps

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Institution of Oceanography (SIO). The models described here are based mostly on unpublished data from the CMBC program.

The fishery is conducted by hundreds of small shore-launched open boats or “pangas” powered by outboard motors, and employing gillnets. There are typically four spring tides during Lent (when there is a high local demand for edible fish), and the fishery stretches over about eight days during each spring tide as the fish progressively move into the river channel and then disperse after spawning. No other spawning location is known for this species.

A Productivity and Susceptibility Analysis (PSA) suggests that curvina golfina is highly vulnerable to fishing pressure relative to similar sciaenid species and many other fished stocks (Apel and Erisman, 2011); hence, due precaution should be exercised in setting management measures". The following data-poor models supplement independent modeling efforts by INAPESCA, and provide initial guidance regarding the present intensity of the fishery and effects of alternative management options.

1. A Cohort Growth Model

Because no historical catch or abundance data are available for curvina, we treat the catch itself as a cohort[2] and constructed a growth projection model that simulates the size structure and relative abundance of this cohort at past and future times. Figure 1 shows a composite length composition of the catch, based on samples collected by CMBC during 2009 and 2010. The cohort growth model takes this length composition as input and estimates the expected growth of each individual in order to project the length composition of the fish in following years if they were not fished. From these projected distributions, we can gain insight into the probable fishing intensity under current management.

Assuming VonBertalanffy growth, the relationship between fish lengths in successive years is given by Ford’s (1933) equation:

$$\mathbf{L(t+1) = L_{inf}*(1-exp(-k)) + L(t)*exp(-k)}$$

where $\mathbf{t}$ denotes year, $\mathbf{L_{inf}}$ is asymptotic length, and $\mathbf{k}$ is VonBertalanffy growth rate. Parameter values of $\mathbf{L_{inf}} = 117.3$ cmTL and $\mathbf{k} = 0.1635\ yr^{-1}$ were taken from Gherard (2010). Assuming deterministic growth, length groups can be treated as cohorts, and in the absence of fishing are subject only to natural mortality, so that for each cohort

$$\mathbf{N(t+1) = N(t)*exp(-M)}$$

where $\mathbf{N}$ is numerical abundance, and $\mathbf{M}$ is the rate of natural mortality, assumed to be $0.35\ yr^{-1}$, in keeping with standard approaches for estimating natural mortality ($\mathbf{M}$) in

[2] A **cohort** is a defined group of individuals to which no new members can be added, but from which members can only be lost by mortality. Example cohorts may be a single year-class or a tagged group of fish. Here we treat the catch itself as a cohort for purposes of exploring alternative “what-if” scenarios.

other *Cynoscion* stock assessments (Pauly 1980). The two relationships allow the length composition in Figure 1 (which we will designate as having been taken at time **T**, but which is actually a mixture of fish aged 4, 5 and 6) to be projected to times **T-1**, **T+1** and **T+2**, shown in Figure 2.

Figure 2 allows us to set bounds on probable exploitation rates. Judging by the overlap of the distributions, one year earlier (at time **T-1**), only ¼ of the fish in this cohort were big enough to potentially appear in the fishery (small fish slip though the meshes of the gill nets without being caught). One year later (at time **T+1**) only about 1/3 of the fish in the cohort would be small enough to appear in the fishery (large fish tend to "bounce off" the gill without being caught). And 2 years later, almost no fish would be small enough to appear in the fishery. Despite the restricted length selectivity of gill nets, we suspect that if larger or smaller fish were present, at least some of them would presumably be caught in net tangles which are frequent in this fishery (tangles reduce the size-selectivity of gill nets, and catch a wider size range). These length projections indicate that it is possible that no fish escape even one year of fishing, which gives us an upper bound to fishing intensity. As a lower bound, from the lack of overlap of distributions separated by two years we can conclude that almost no fish escape 2 years of exposure to fishing, otherwise the length distribution would show a "tail" of fish larger than 80cm. At this lower bound of fishing intensity, the fishery still must take at least 80% of the available fish in one year (e.g., if 80% of the available fish are caught each year, the second year of fishing would take 80% of the remaining 20% that survived the first year, for a combined two-year mortality rate of 96%). A more quantitative assessment than this would require several years of catch-at-age samples, allowing estimation of exploitation rates on each age class.

2. Daily abundances: A Virtual Population model

Based on the CMBC sampling, we constructed the idealized daily pattern of a hypothetical 5000 ton fishery (this number exceeds official landings for Santa Clara because it is our best guess of total landings, including unreported catch and catch by the Cucapah tribal fishery) shown in Figure 3 (actual catches are more variable). Peak catches are made on days 4, 5 and 6 of each tidal cycle. Assuming that natural mortality is negligible during the short fishery season, and that interseasonal survival of biomass is 100% because somatic growth nearly offsets numerical losses, we can calculate the virtual population size on each day of the fishery. Under the high exploitation rate assumption, no fish escape being caught, so the abundance of available fish at the beginning of any day consists of the sum of catches from that day to the last day of the fishery. Thus the abundance declines from 5000 tons to zero during the fishing season.

Under the lower exploitation rate scenario, the calculation is similar, except that the final abundance of first-year fish is set at 20% of the initial available abundance, and with 4% surviving at the end of the second year. The solution is to start with 6200 tons of available fish, including 5200 tons of new recruits which is reduced to about 1000 tons at the end of the first year. Of this 1000 tons, about 200 tons survive at the end of the second year of fishing (Figure 4). Notably, the recruitment strength of ca. 5000 tons is nearly identical for the two scenarios.

3. A saturation model of exploitation rates

During the peak periods of fishing, it appears that the fleet's fishing capacity may be nearly saturated. In other words, even if fish abundance were much higher, the fleet could not catch more fish due to limitations of time on the water and transportation bottlenecks both on the water and on land including ability to deliver the fish to the processor before they spoil. A model fishery that recognizes saturation effects could be of use in evaluating the properties of alternative management measures such as closures and TACs.

In order to obtain a dynamic model in which we can simulate the fishery under alternative management actions, we need to replace the static daily catches in Figure 3 with functions that relate the daily catch to underlying abundance and availability according to the daily sequence in the tidal cycle. For the high exploitation rate scenario, a hyperbolic saturation curve describes the catch data quite well:

$$\mathbf{C(B) = C_{max*}B/(B + B_{half})}$$

where $\mathbf{C}(\mathbf{B})$ is catch at biomass $\mathbf{B}$, $\mathbf{C_{max}}$ is asymptotic maximum catch, and $\mathbf{B_{half}}$ is the biomass at which $\mathbf{C}(\mathbf{B})$ is one half of $\mathbf{C_{max}}$. This curve has many names, but this parameterization is the Michaelis-Menton form. We used least squares to estimate eight separate pairs of parameters, corresponding to each day of the four tidal fisheries (fewer fitted parameters could also be used, for example by combining days 4, 5 and 6). An example fit to the Day 5 catches is shown in Figure 5. When the daily catches for the full season are replaced by the catches predicted from the saturation curves (beginning with an available biomass of 5000 tons), the model fishery is quite similar to the original catch data (Figure 6). A similar fitting procedure was used for the lower exploitation rate scenario, which did not fit the data quite as well (Figure 7). Due to the lack of fit, the modeled first year escapement is 16%. It would be possible to obtain a model with a 20% escapement by successive approximations, but that escapement is only an approximate value and does not justify the additional work for the present purposes.

4. Alternative management scenarios

The two saturation models can be used to explore alternative management actions by modifying the functions on appropriate days (Table 1). We explored the effect of time closures on escapement (how many fish survive the fishery at the end of the season) and the flow of landings on the theory that time closures may be more acceptable to fishermen and easier to enforce than catch limits or spatial closures. Time closures are represented in the model by setting the day's catch to zero. The foregone catch becomes available on following days, tides and years. The model used here assumes that fish are available to the fishery for a maximum of two years, so that escapement in Year 2 is no longer vulnerable to fishing. In general catch lost to closures near the beginning of the season tend to be recovered as catch later in the same season, whereas catch lost due to closures late in the season contributes to escapement, and may be recovered as catch in the second year. The “Low Present Escapement” scenario shows less net effect of closures because the intense fishery is likely to take any foregone catch at a later date. We do not presently know which escapement scenario is more likely to represent the true fishery.

The timing and the nature of the closures (i.e., whether peak days are closed) of course have strong effects on escapement and product flow into markets. The present nominal 5000-ton fishery is estimated to have a Year 2 escapement of 0-90 tons. Closing the first peak day increases escapement by 2-56 tons (an increase of at least 60%) and somewhat evens the distribution of catch among the four tidal periods. Closing all peak days evens the catch out to a great extent and strongly increases escapement (by 121-433 tons, an increase of at least 400%). Closing the fishery on the last two days of each tidal period may reduce discards and waste, since this is a time when markets may not be able to absorb more fish. We simulated a strongly enforced marine reserve as well, by assigning zero catches to the three peak days of each tidal period (during which the bulkof the fishery appears to occur inside the reserve). The results suggest that strong enforcement of the reserve would provide high escapement (2400-3200tons), and catches would be reduced by 50-60%.

References

Apel, A., and B. Erisman. 2011. Productivity and susceptibility analysis: gulf curvina. EDF (San Francisco) document dated June, 2011. 10pp.

Ford, E. 1933. An account of the herring investigations conducted at Plymouth during the years 1924 to 1933. J. Mar. Biol. Assoc. U. K. 19:305-384.

Gherard K. 2010. Age, growth, and batch fecundity of the Gulf Corvina, Cynoscion othonopterus. Masters Thesis, California State University Northridge. 40pp.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer 39:175-192.

Roman Rodriguez, M.J. 2000. Estudio pobacional del chano norteno, *Micropogonias megalops* y la curvina Golfina *Cynoscion othonopterus* (Gilbert) (Pisces: Sciaenidae), especies endemicas del alto Golfo California, Mexico. Instituto del Medio Ambiente y Desarrollo Sustentable del Estado de Sonora. Informe final SNIB-CONABIO proyecto No. L298. Mexico D.F.

Figures

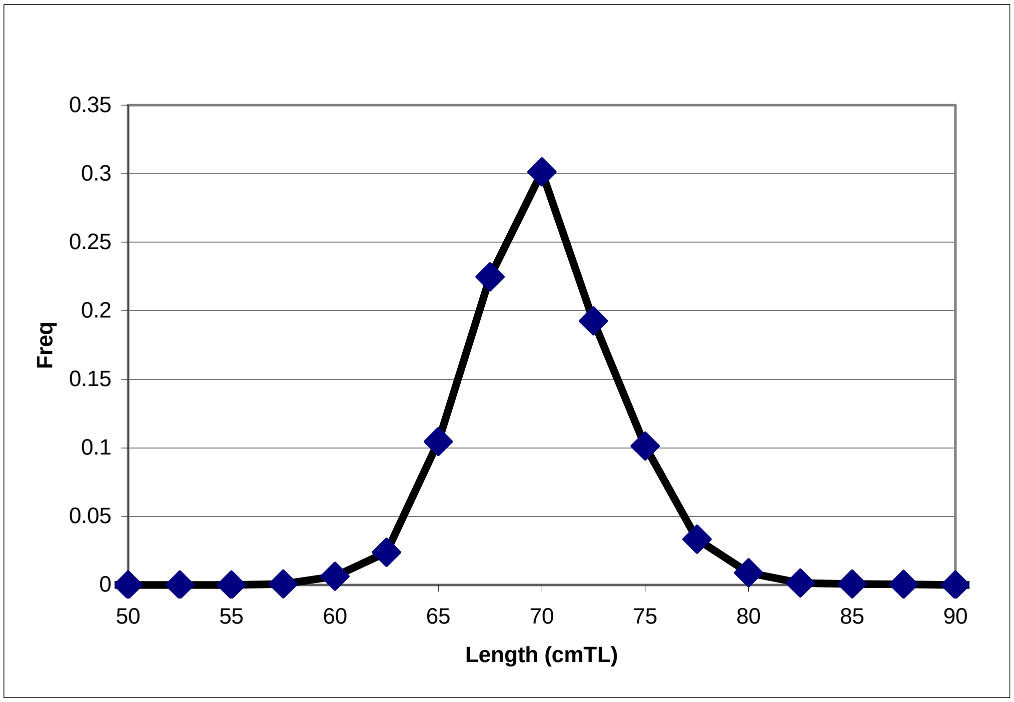

Figure 1. Length composition of curvina catch during 2009-2010.

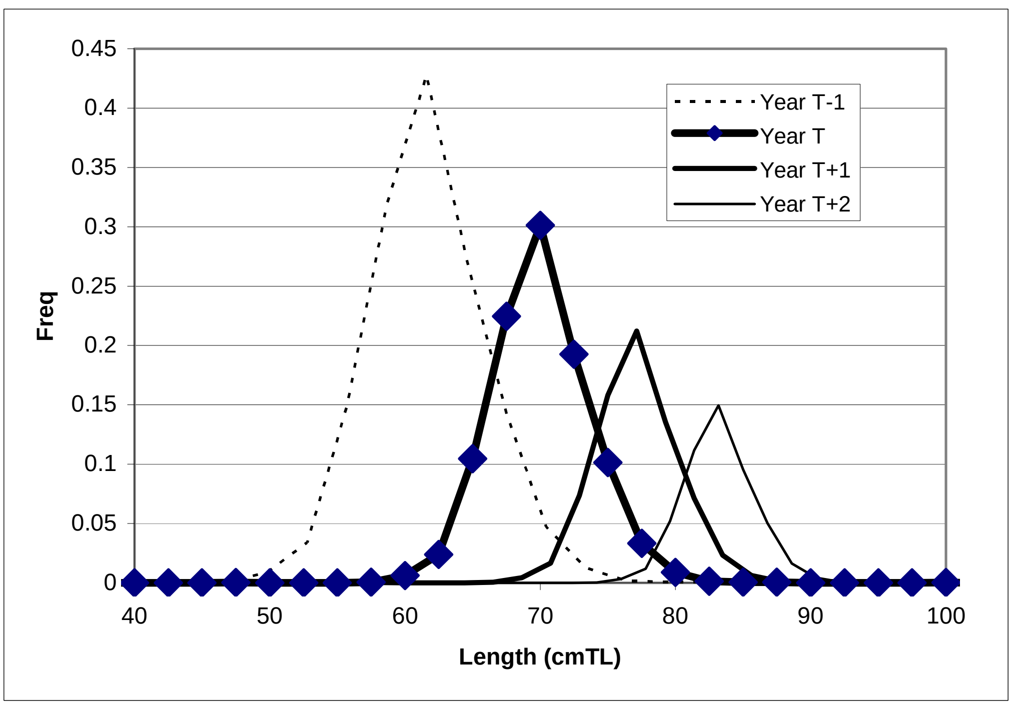

Figure 2. Projected length compositions to earlier and later years. Frequencies are relative to those at time/age T.

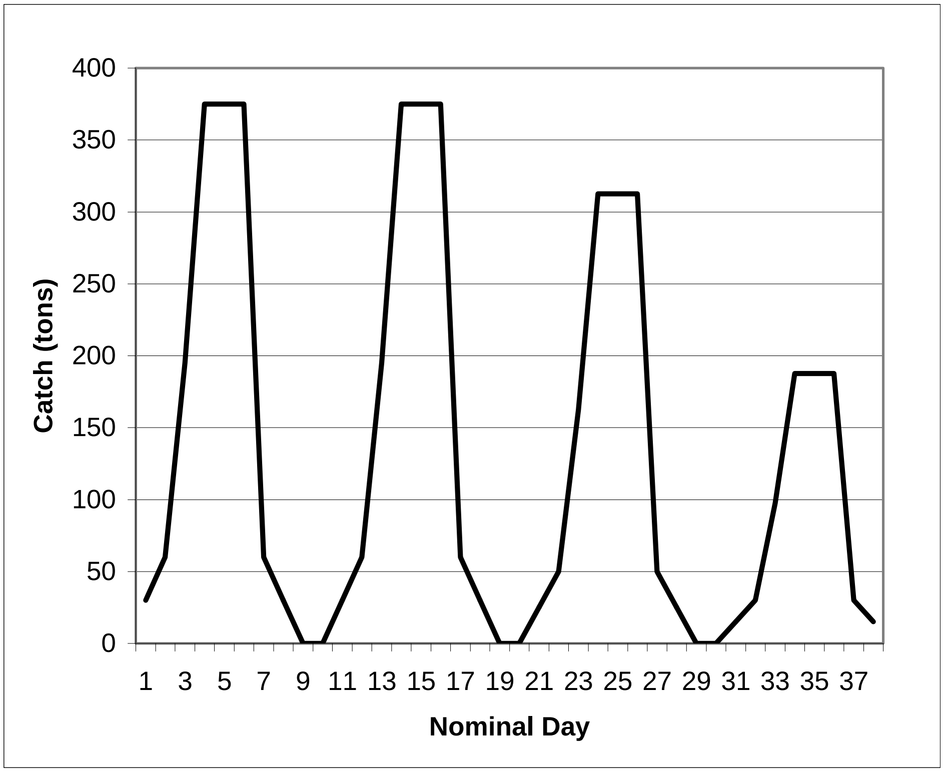

Figure 3. Idealized daily catch pattern for a 5000 ton fishery.

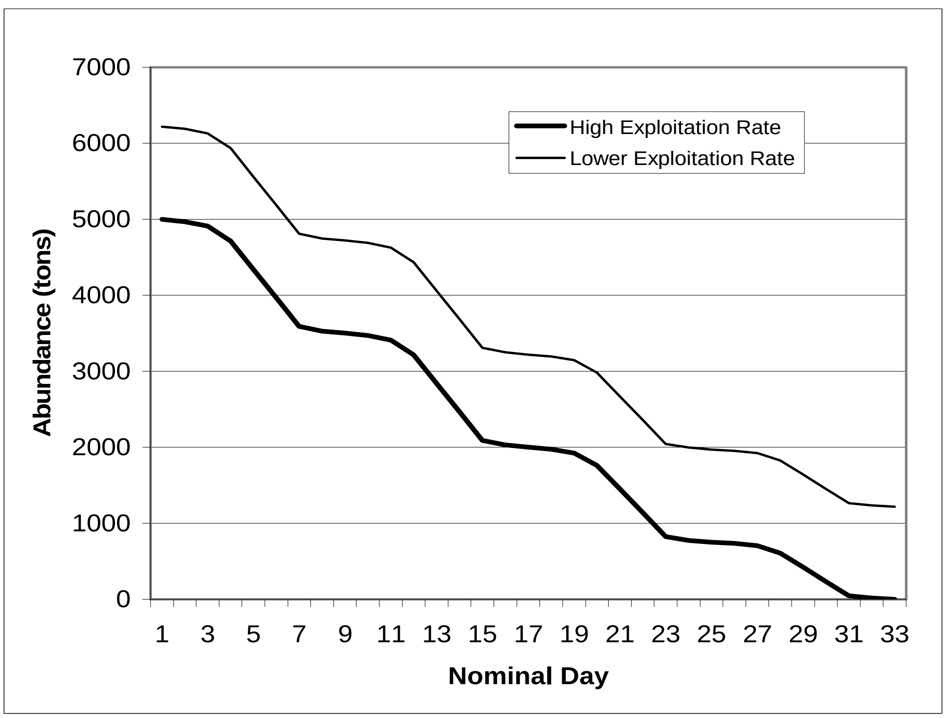

Figure 4. Virtual population abundance for a 5000-ton fishery under two exploitation rate scenarios.

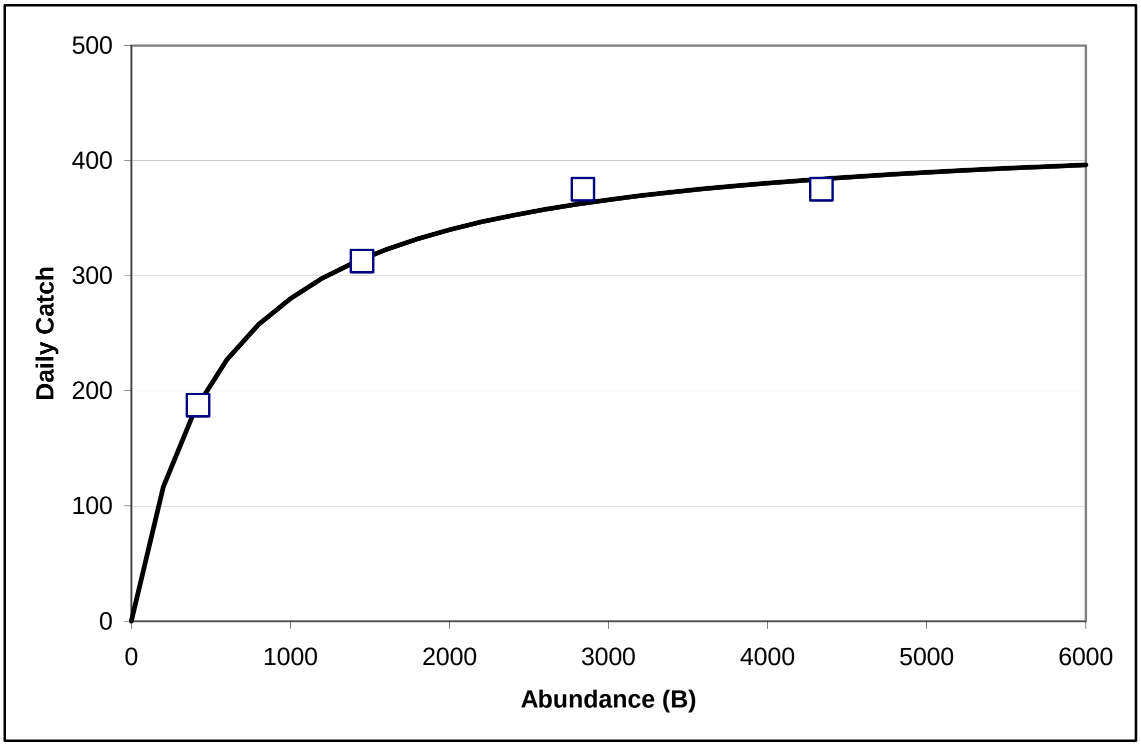

Figure 5. Catches and saturation curve fit for fishery Day 5.

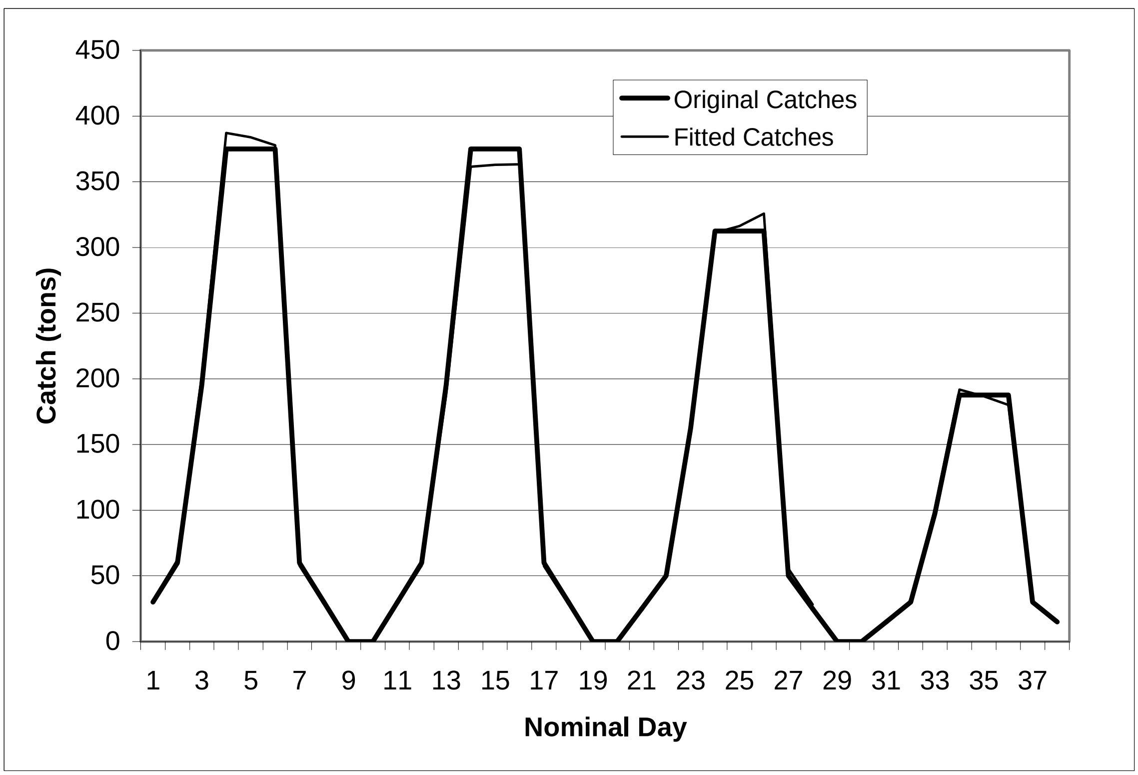

Figure 6. Comparison of catch data and modeled catches from saturation model (high exploitation)..

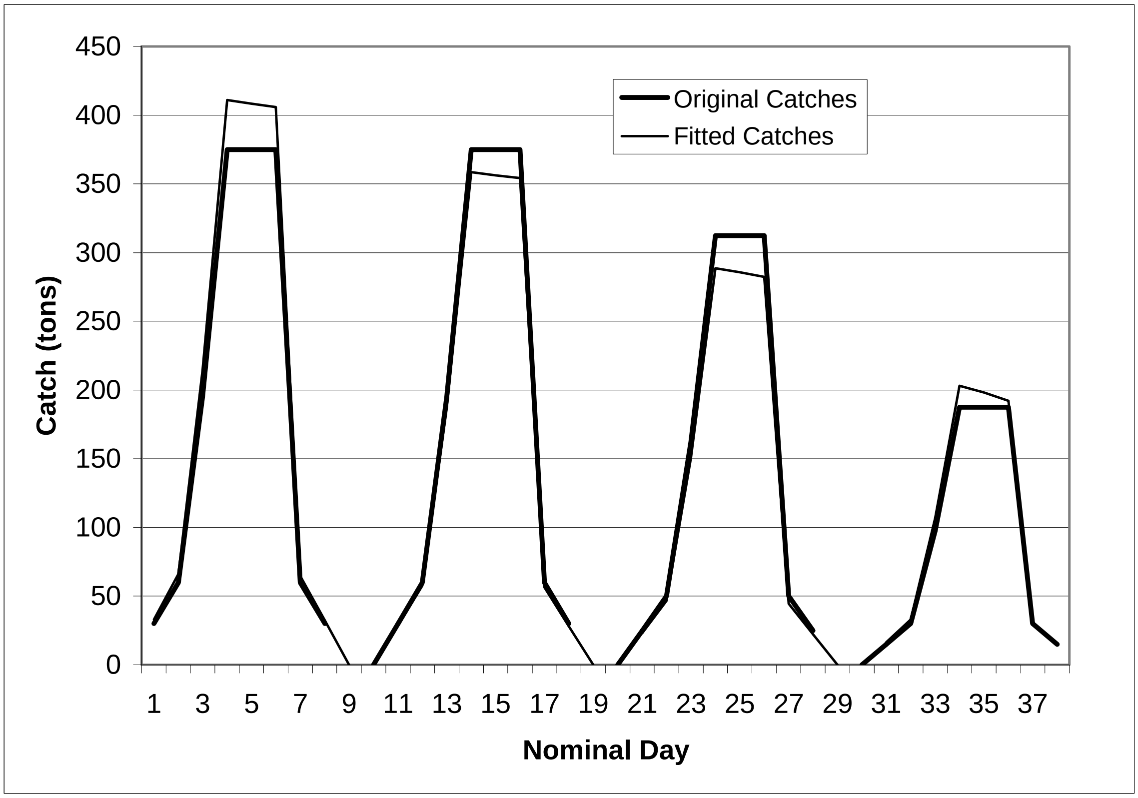

Figure 7. Comparison of catch data and modeled catches from saturation model (lower exploitation).

Tables

Table 1. Projected fishery performance under example alternative fishery closures.

		Escapement		Catch				
	Case	Year 1	Year 2	Total	Tide 1	Tide 2	Tide 3	Tide 4
0	Present Fishery (data)			5000	1500	1500	1250	750
	Low Present Escapement							
0	Present Fishery (model)	0.5	0	5000	1530	1448	1272	751
1	Close First Peak Day	93	1.7	4998	1170	1501	1357	971
2	Close All Peak Days	777	121	4879	1327	1280	1205	1067
3	Close First Tide	751	113	4887	0	1760	1665	1463
4	Close Last Tide	751	113	4887	1760	1665	1463	0
5	Close Last 2 Days Each Tide	128	3.3	4997	1480	1403	1249	864
6	Close Peak 3 Days Each Tide	3502	2452	2548	649	642	633	624
7	Close Last 2 Tides	2023	818	4182	2149	2033	0	0
	Medium Present Escapement							
0	Present Fishery (model)	675	90	5000	1635	1427	1144	794
1	Close First Peak Day	863	146	4943	1253	1510	1255	925
2	Close All Peak Days	1632	523	4566	1304	1213	1098	952
3	Close First Tide	1618	514	4575	0	1722	1547	1306
4	Close Last Tide	1618	514	4575	1722	1547	1306	0
5	Close Last 2 Days Each Tide	871	149	4940	1557	1382	1147	854
6	Close Peak 3 Days Each Tide	4051	3225	1865	476	470	463	456
7	Close Last 2 Tides	2858	1605	3485	1813	1672	0	0