Report to the

Oregon Department of Fish and Wildlife
Marine Resources Program

An Approach for Forecasting Oregon's Nearshore Groundfish Landings

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Introduction

Most groundfish species along the US West Coast are subject to annual catch limits, set by the Pacific Fishery Management Council (PFMC) to prevent overfishing from occurring or to rebuild stocks considered to be in an overfished condition. Generally these coastwide limits are allocated to specific fishery sectors and to geographic regions. Fishery managers in Oregon are obliged to manage the pace of local fishing to conform to the limits determined by the PFMC. For fisheries operating primarily within state waters, the nearshore, the Oregon Department of Fish and Wildlife (ODFW) is authorized to impose "trip limits" to slow the rate of removals and to close fisheries before the end of the fishing year. A trip limit is a misnomer in that the limit is not applied to the landings of individual fishing trips but rather to a boat's cumulative landings during a two-month interval (January plus February being the first interval). The ODFW fishery managers' decisions to change trip limits or modify the length of the fishing season are guided by how much landed catch has accumulated relative to the annual allotment (e.g., Fig. 1). One approach that has been used to inform the decision is to forecast to the end of the year the catches that will occur each month and estimate if and when the projected cumulative landings will attain the limit. A forecast is derived from data from past years on the average landings per trip, the number of trips this year relative to past years, and estimates of how the number of trips will change each month during the remainder of the year (personal communication, Mark Karnowski, ODFW, Newport). One major need of the managers is to forecast how future landings will be affected by different trip limit constraints, to provide a basis for selecting a particular value for a new trip limit.

Quantitative forecasting methods are not widely used in fisheries science, although most stock assessments provide forecasts to show the consequences of future harvests on stock abundance and age composition. In other disciplines, however, forecasts are made and updated regularly. Government agencies and private businesses routinely make planning decisions and do so based on formal or informal forecasts of the future. A variety of approaches have been developed to produce quantitative forecasts, including regression models, time-series models, and expert opinion. The web-site *www.forecastingprinciples.com* contains a wealth of information regarding approaches for "evidenced-based principles on forecasting" including descriptions of forecasting approaches, a dictionary of terminology, and suggested best practices.

One standard statistical approach to forecasting is a method of time-series analysis known as ARIMA modeling (Box and Jenkins 1976; Abraham and Ledolter 1983). The website *www.statsoft.com/textbook/sttimser.html* provides a concise and relatively non-technical overview of various time-series methods including ARIMA modeling. The idea underlying an ARIMA model is that a measurement variable that is changing through time (e.g., the monthly landings of a particular species) conforms to an identifiable stochastic process involving a random shock in the current time period and linear combinations of the measurements and random shocks from one or more prior time periods. The AR in ARIMA is short for "autoregressive", the I is short for "integrated", and the MA is short for "moving average". Because the observation from one time period is functionally related to observations from one or more previous time periods, the observed data are not independent of one another; they are said to be autocorrelated. In standard regression models, in constrast, the observations are fully independent of one another; the random errors in the dependent Y-variable are uncorrelated. In standard regression models there are "observation errors" but not "process errors". In time-series models there are process errors but no measurement errors.

The simplest form of autoregressive process is the first-order AR process, given by the equation $Y_t = a_1 * Y_{t-1} + Z_t$, where Y_t is the value observed in period t, a_1 is a fixed (time-invariant) coefficient, and Z_t is a random error term with mean value of zero, constant variance, and the Z_t values are uncorrelated. In an AR process the random shock at a given period becomes embedded in the succeeding observations but its influence gradually decays. The process is described as first-order because it only involves a lag of one time-step. The simplest form of moving average process is the first-order MA process, given by the equation $Y_t = Z_t + b_1 * Z_{t-1}$, were Z_t is the random error term for period t, Z_{t-1} is the random error term for the previous period, and b_1 is a fixed coefficient. In an MA process the random shock at a given period has influence for a fixed duration and then has no further influence. A stochastic process can be a combination of AR and MA processes, in which case it is described as an ARMA process.

Integration in an ARIMA model refers to removing trends by taking differences of adjacent pairs of observed values so that the series of differenced values is stationary, meaning that it has a constant mean value and variance and no regular periodicity. For example, the series $X_t = c + X_{t-1} + Z_t$ will tend to increase by the amount c at each time step; hence the series is not stationary because it does not have a constant mean value. If we define a new variable Y_t to be the difference between adjacent X values, however, we get a new series that is stationary.

$$X_t = c + X_{t-1} + Z_t$$

$$X_{t-1} = c + X_{t-2} + Z_{t-1}$$

$$X_t - X_{t-1} = Y_t = (X_{t-1} - X_{t-2}) + (Z_t - Z_{t-1})$$

$$Y_t = Y_{t-1} + (Z_t - Z_{t-1})$$

For monthly data that show a seasonal pattern, one can eliminate the seasonal trend by creating the differenced series $Y_t = X_t - X_{t-12}$.

The process of fitting an ARIMA model to an observed time series involves determining the amount of differencing (if any) required to remove long-term trends and cycles, and then identifying the appropriate orders (0, 1, 2, ... n) for the AR and MA processes. Having obtained a suitable ARIMA model, one can then use it to forecast the series into the future, including the estimation of approximate confidence limits for the forecast values. The process of model identification can be tedious and is subjective. Many textbooks on time-series analysis state or imply that considerable experience and talent is needed to build reliable time-series models. Like any exercise in statistical modeling, the model builder must use due care to evaluate the adequacy of the model by examining available diagnostics. Computer programs for fitting time-series models are available in many statistics software packages including Minitab, SAS, and SPSS. Many of the programs provide tools for automating the process of model identification and evaluating diagnostics. This report describes my exploration of the potential to use the

ARIMA modeling package called X12-ARIMA to forecast landings in Oregon's nearshore commercial fisheries. This software, available freely from the US Census Bureau (*www.census.gov/srd/www/x12a/*) as a Windows executable file with supporting materials, provides a comprehensive set of tools for building and evaluating ARIMA models for the purpose of forecasting. The Census Bureau and other US and foreign governments agencies use it routinely. X12-ARIMA is based on well-developed theory, has been widely tested, is well documented, and is reasonably easy to use.

Materials and Methods

The rate of landings accumulation for a given species is likely to be affected by several key factors including the abundance of the fish, the number of active fishermen, wind and wave conditions, regulations governing landings, the availability and desirability of other fishing opportunities, and availability and desirability of other economic activities (e.g., a shore-based job). Initially I thought it would be worthwhile to develop a comprehensive model that simultaneously considered these multiple factors. After considering the complexities of the nearshore fishery, however, I concluded that a simpler approach would be more suitable. My exploration began with a review of available landings data for Oregon's commercial marine fisheries.

The Data

Fish ticket landings data for the years 2000 to 2007 (downloaded on 06/25/2008 from the ODFW headquarters data system) was provided by Mark Karnowski. The data set includes information on the gear used, the port of landing, the vessel documentation number, the date of the landing, the dealer making the purchase, the gross overall weight of the landing, and the landing weights by individual (nominal) species and species groups (e.g., all groundfish, all flatfish, all rockfish). During this eight-year interval there were slightly more than 2 billion pounds of marine fish and shellfish landed in Oregon (Table 1). Landings of nearshore groundfish made up a very small fraction (0.23%) of this amount. The annual landings of nearshore species (black rockfish, blue rockfish, other nearshore rockfish, greenling, lingcod, and cabezon) ranged from 541,100 pounds during 2005 to 742,200 pounds during 2002. Most of the nearshore landings (79%) occurred during the months of April through September. The top five ports for commercial landings of nearshore groundfish were Port Orford (34%), Gold Beach (18%), Astoria (9.7%), Brookings (9.2%), and Garibaldi (8.5%). Most of the commercial landings of nearshore groundfish (72%) were taken with hook and line gear.

It was infeasible for this project to consider all of the nearshore species. Instead I focused on the landings of black rockfish and blue rockfish, which together accounted for about 43% of the landings of nearshore groundfish during 2000 to 2007. The combined landings of these two species are managed using a combined trip limit, and the landings undergo close scrutiny by the ODFW nearshore fishery managers. During 2000 to 2007 just over 2 million pounds of black-plus-blue rockfish were landed, with most of the landings (81%) occurring during the months of April through September. The top five ports for commercial landings of black-plus-blue rockfish were Port Orford (38%), Gold Beach (17%), Astoria (14%), Brookings (12%), and Garibaldi (12%). Most of the commercial landings of black-plus-blue rockfish (94%) were taken with hook and line gear.

The landings of black-plus-blue rockfish during 2000 to 2007 were made by 560 different boats, and there was considerable turnover in the fleet from year to year. The number of different boats operating during any given calendar year ranged from 231 in 2000 to 153 in 2007. Only 29 boats made landings of black-plus-blue rockfish during all eight years, 16 boats made landings during seven years, 30 boats made landings during six year, and 232 boats made landings during only one year. The top-40 producing boats accounted for a total of 57% of the overall landings of black-plus-blue rockfish (Table 2, Fig. 2). Given the large number of different boats that participate in the fishery for black-plus-blue rockfish, and given that there is considerable year-to-year turnover in the fleet, it does not seem feasible to consider building a forecasting model at the level of individual boats, although that is how trip-limits influence the rate at which black-plus-blue rockfish are landed.

Plots of the monthly landings of black-plus-blue rockfish during 2000 to 2007 show marked seasonality, with very low levels of landings during the winter and high landings during the summer (Fig. 3). The pattern of the landings at the northern ports (Coos Bay and north) seems quite different from the pattern of the landings at the southern ports (Bandon and south).

The X12-ARIMA Software

The X12-ARIMA software (version 0.3) from the US Census Bureau is specifically designed to perform "seasonal decompositions" of time-series data (US Census Bureau 2007). That is, time series observations are viewed as being composed a mid- to long-term "trend-cycle" effect, a regular seasonal effect, and an irregular random effect. The software attempts to de-compose the series into these three components. The X12-ARIMA program is an enhanced version of the so-called "X-11 variant of the Census Method II" seasonal adjustment program, developed by the Census Bureau in the 1960s. The X12-ARIMA program can perform automatic model identification and automatic testing for and control of outliers. Further, the program has extensive facilities for building so-called regARIMA models, which are regression models with errors that conform to an ARIMA process. The Windows software for X12-ARIMA includes the executable file (X12a.exe) and a simple Windows interface program (RunX12.exe) that is very effective for manipulating the input text files, running the X12a program, and viewing the resulting output text files. There are also several conversion programs that take the text files output by the X12a program and produce html versions that can be viewed in a web-browser. Installing the software was straightforward, as was operating the software. However, it took me several days of reading the documentation and trial-and-error experimenting with real data sets to learn how to perform specific modeling tasks and interpret the myriad types of information that are produced by the program.

Fitting the Black-plus-Blue Rockfish Monthly Landings Data

To test the X12-ARIMA software (X12a) and evaluate how well it would produce forecasts of nearshore groundfish landings I applied the program to monthly landings data for black-plus-blue rockfish, organized on a statewide basis and regionally (north versus south). The data sets were placed in text files formatted so that the X12a program could read them. The statewide data set file is provided in Appendix A. Operations of the X12a program are controlled by commands in a "specification file", which is also a text file. The program has a rich set of commands and options. An example specification file for fitting an X12-ARIMA model to the statewide black-plus-blue rockfish landings data is provided in Appendix B. This example includes explanatory comments (preceded by a #) and additional optional specifications that have been commented out.

Experiment 1: Additive model versus multiplicative model

As is the case with standard regression models, it is sometimes appropriate to transform the raw data before fitting a time-series model so that the random errors more closely conform to a normal distribution. With seasonal time-series models one would use a log-transformation of the Y-variable for situations in which the underlying model is of the multiplicative form

$$Y_t = TC_t * S_t * I_t ,$$

where TC denotes the trend-cycle effect, S is the seasonal effect and I is the irregular effect, which is an ARIMA process (random and autocorrelated). In this case the trend-cycle effect in a given period scales the seasonal influence for that period. In contrast, in an additive model no transformation is applied and the model has the form

$$Y_t = TC_t + S_t + I_t .$$

In this case the seasonal influence is not proportional to the trend-cycle effect.

In an additive model the predicted Y values could be zero or negative. In a multiplicative model the predicted Y values will always remain positive.

It was unclear to me which form of underlying model would be most appropriate for modeling the black-plus-blue rockfish landings series. While it is impossible for these landings to have negative values, they can be zero, in which case the log-transformation cannot be applied.

The X12a software can be configured to automatically choose between using a log-transformation or no transformation based on a statistical criterion (AICC) but it can only do so if the data series has no zero or negative values (so the log-transform can be applied). To circumvent the problem of having zeroes in the black-plus-blue data series I included a command in the specification file that added the constant one to all the data before fitting the model and doing the analyses. The program automatically subtracts one from each value when it derives the final fitted time series.

In my initial experiment I did three sets of model-fitting runs: with an additive model; with a multiplicative model; and with the model configured to choose between these alternatives. To evaluate performance of the additive versus multiplicative model I compared the fitted time series and reviewed results from the automatic selection process.

Experiment 2: Evaluating forecasts for 2007 using part-year data

To test the forecast accuracy of the X12a software I conducted a series of forecasts for 2007 based on a set of truncated statewide data series. One data series stopped with December 2006, to mimic a forecasting process in which no information is yet available for a new year. The other series stopped at successive months in 2007 starting with May and ending with October, to mimic a forecasting process in which new information accumulates monthly. The fitted values resulting from the different data series were compared visually and the percentage error values of the cumulative predicted landings (relative to the actual cumulative catch) were calculated.

Experiment 3: Evaluating forecasts for simulated data for 2008 using part-year data

As an additional test of the X12a program's forecast accuracy I produced a simulated data series for 2008 by replicating the data from 2004. The landings in 2004 were larger than normal in the early months of the year and the more rapid than expected accumulation of landings resulted in early closure of the fishery. I wanted to test whether the X12a forecasts could predict a fast paced fishery. As in the first experiment, I conducted a series of forecasts for the simulated 2008 data based on a set of truncated statewide data series. One data series stopped with December 2007; the other series stopped at successive months in 2008 starting with May and ending with October. The fitted values resulting from the different data series were compared visually and the percentage error values of the cumulative predicted landings (relative to the actual cumulative catch) were calculated.

Results

The X12a software produces numerous different diagnostics and other forms of output. How to interpret all the values was often obscure to me, despite many hours spent reading the X-12-ARIMA Reference Manual. (I'm certain that one could find other earlier published reports that provide full details of all the X12-ARIMA diagnostics. I did not have sufficient time to do so.) For this report I primarily concentrated on simple plots showing the raw data and the model fits to those data. I do not provide formal statistical evaluations of the different fits, but it would be possible to do so. Also, I concentrate on results from the applications to the statewide black-plus-blue rockfish landings series. Applications to the regional (north versus south) data series produced qualitatively similar results.

Experiment 1: Additive model versus multiplicative model

When the X12a program was configured to choose between fitting an additive model versus fitting a multiplicative model, the program chose the additive model for all three data sets (statewide monthly landings, monthly landings in Coos Bay and north, monthly landings in Bandon and south). Visually there did not appear to be large differences between the fitted values from the additive versus multiplicative models, with the exception of unusually large fitted values from the multiplicative model for the summer months in 2004 and 2007 in the fit to the statewide data (Fig. 4). Plots of the observed versus cumulative landings for these years for this data set made it clear that the two models made very different predictions for these years (Fig. 5). In the cumulative plots for other years the predicted cumulative landings from both models were similar to each other and to the observed cumulative landings. The fishery for black-plus-blue rockfish was shut down early in both 2004 (on September 27th) and 2007 (15-pounds-per-day incidental trip limit imposed on Nov. 1st, closure on November 28th).

Oddly, the linear correlation between the fitted monthly values and the observed data was stronger for the multiplicative model ($R^2 = 0.879$) than for the additive model ($R^2 = 0.849$), which suggests the multiplicative model provides a more accurate fit to the observed data. Also, the average absolute error (AAE = average[| observed - fitted |]) of the fitted values was smaller for the multiplicative model (AAE = 4479) than for the additive model (AAE = 4993), which also suggests that the multiplicative model is the more accurate model.

The multiplicative model has the desirable feature that it cannot produce any predicted monthly landings that are negative, and consequently plots of the cumulative predicted landings are strictly increasing. This is not true of the additive model. However, the multiplicative model clearly produced less reasonable predictions of the cumulative landings in two of eight years for the statewide data series. In light of this the X12a program's choice of the additive model seems very sensible, but exactly how or why the program's statistical model selection process works is unclear to me. The additive model chosen by the program was not identical to the additive model that was specified directly. The process of constructing the former model involved adding one to all the observations (and subtracting one from all the predicted values as a last step), whereas the direct specification involved no such transformation.

In constructing the multiplicative model for the statewide data series the X12a program identified 13 outliers and gave them special treatment. (It is unclear how the program identifies outliers or what it then does with them, but one of the published reports probably provides full details.) Eleven of these outliers were for the months of October through January when the actual monthly landings were quite small. For the additive model the program detected no outliers.

Experiment 2: Evaluating forecasts for 2007 using part-year data

As the statewide monthly landings data from 2007 were gradually added to the data series there were some fairly large changes in the fitted values (Fig. 6, Table 3). The fitted values for February through August 2007 based on the data series that stopped in December 2006 were considerably larger than the actual values and the cumulative predicted landings for the year were 28% larger on average than the actual cumulative landings. The truncated data series that produced the most accurate cumulative fitted values in terms of mean absolute percent error (MAPE) was the series that stopped in August 2007 (MAPE = 9.1%). The fitted values based on the series that had been truncated in 2007 (May through October) showed relatively little change from one series to the next in their fitted values for January through August, but the fitted values for September and subsequent months showed large upward trends as the data from August and September became available to the model (Fig. 7).

Experiment 3: Evaluating forecasts for simulated data for 2008 using part-year data

In this experiment I simulated the statewide monthly landings data for 2008 by repeating the data from 2004. The fitted values for February through August 2007 based on the data series that stopped in December 2007 were smaller than the actual monthly landings and the cumulative predicted landings through April were 27% smaller than the actual cumulative landings (Fig. 8, Table 4). The MAPE for the cumulative predicted landings from the model based on the December 2006 data series (13.1%) was not much worse than the MAPE values produced by the series that had been truncated in 2008 (May through October). The truncated data series that produced the smallest MAPE value was the series that stopped in July 2008. The fitted values based on the series that had been truncated in 2008 showed relatively little change from one series to the next in their fitted values for January through August, but the fitted values for September and October showed a large jump up between the August and September series and the fitted values for November and December showed a large jump down between the September and October series (Fig. 9).

Discussion

Results from the initial testing of the X12-ARIMA program to forecast nearshore groundfish landings were very promising in that the forecasts (Experiments 1 and 2) had relatively small errors (10% to 20% relative to known landings). How this compares to the prediction errors of the current process of projecting future landings remains to be evaluated. One aspect of using a time-series program such as X12a is that forecast uncertainty is quantified and the program produces confidence limits for its forecasts. Also, the X12a program has several special features, which I did not have time to explore, that could improve the accuracy of its landings forecasts. Two of these deserve mentioning. The first is a capability to use the "composite specification" feature to produce estimates for the sum of several component data series. For example, one could produce a statewide forecast from the composite of two or more regional forecasts. Given the apparent differences between the northern Oregon versus southern Oregon landings series for black-plus-blue rockfish (Fig. 3), it would be surprising to me if the forecasts derived directly from the statewide series would be as accurate as the forecasts derived as the composite of the separate north and south series. This could be tested very easily.

The second special feature of the X12a program is the capability of using the regression command with user-defined X-variables. For example, it seems likely that landings each month would be influenced by the magnitude of the trip limits in effect that month or the number of days during the month when wave height or wind speed was less than certain threshold values. One could develop monthly data series with the values of potential X-variables and set up a specification file that would have the X12a program estimate coefficients for these X-variables. The program would produce various statistical measures that one could use to evaluate the explanatory power (if any) of these additional sources of information. Also, if trip limits were a "significant" explanatory variable one could use dummy trip limit values in forecasts to predict how different trip limits might influence future landings. Whether this would produce sensible and trustworthy results is anyone's guess, but the modeling capabilities are certainly available in the X12a program.

Another X12a option that I did not have time to explore is the ability to force the predicted annual totals from a model to equal the actual annual totals. While this seems a very desirable property for the forecasts to have, using this option may degrade the accuracy of forecasts. This should be investigated before this option is used on a routine basis.

If the X12-ARIMA program is to be used to inform ODFW management decisions then staff will need to learn more about the potential pitfalls of ARIMA model building and become proficient at interpreting the model diagnostics that the program produces. The program should not be treated as an infallible oracle for predicting the future, but rather as a tool for examining and exploring patterns in time series.

References

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Table 1. Summary of landings (1000s of pounds) reported on Oregon fish tickets, 2000 to 2007.

	No. trips *	Gross weight	All grndfish	Black rockfish	Blue rockfish	Other nr shore rf	green-ling	lingcod	cabezon	Pacific halibut	Pacific salmon	sardine	shrimp	tuna	Ocean crab
By year															
2000	27625	263838	188788	240.1	8.6	45.6	42.8	141.2	68.8	331	3132	21005	25462	8757	11163
2001	28608	233815	147698	327.4	8.6	58.2	63.7	148.6	102.1	253	5266	28176	28482	8986	9673
2002	30964	210224	91050	280.5	6.9	54.4	117.9	181.1	101.4	529	6118	50069	41584	4365	12412
2003	29231	225723	104166	259.2	9.7	27.9	44.3	152.8	59.5	342	6722	55683	20546	9166	23916
2004	33613	294288	154753	261.9	10.9	23.1	51.3	162.3	61.1	345	5934	79610	12207	10754	27248
2005	27606	312508	161181	224.6	7.4	16.1	46.1	183.1	63.9	357	4682	99450	15784	8087	17708
2006	25687	300644	160756	214.3	6.3	18.6	32.0	263.6	48.6	251	1778	78634	12195	8536	33295
2007	25176	271082	123511	228.6	4.3	18.6	40.4	258.0	48.2	244	1352	92911	20125	10468	17006
By month															
Jan	16264	63510	15204	36.7	1.4	7.9	19.8	24.2	19.1	0	0	0	0	0	46792
Feb	15470	45146	18379	69.7	3.7	11.1	30.9	30.1	30.7	0	50	0	0	0	24334
Mar	17068	28900	15639	93.9	4.8	12.2	41.6	13.8	32.6	0	1182	0	0	0	10520
Apr	17984	49323	20144	205.9	7.2	19.8	52.2	48.0	60.8	46	1903	66	18337	0	5779
May	24995	60139	21018	306.6	5.2	36.7	60.5	234.7	90.4	37	4186	119	27903	1	3480
Jun	23440	329619	265658	295.4	5.5	36.5	34.2	240.1	56.8	728	3416	23669	30101	687	1490
Jul	22727	642531	471683	277.7	5.6	30.4	32.6	279.1	55.6	1234	1933	116767	27466	16552	1025
Aug	26553	466287	200046	287.6	7.1	38.8	48.4	223.4	65.1	536	5454	193633	33044	27025	560
Sep	28029	263180	59193	295.0	10.7	37.0	60.2	217.4	69.2	73	11635	141931	28919	16122	1
Oct	17985	75303	20766	98.0	5.4	18.3	25.5	126.1	40.5	1	5034	27195	10615	8334	23
Nov	4905	18797	14752	36.9	4.0	8.8	18.7	35.9	19.3	0	169	1685	0	396	24
Dec	13090	69386	9421	33.2	2.1	5.0	14.0	17.9	13.6	0	21	474	0	3	58393

* For counting purposes a "trip" is a unique Land_date+Docnum (or License if no Docnum).

Table 1. Summary of landings (1000s of pounds) reported on Oregon fish tickets, 2000 to 2007. (continued)

		Gross weight	All grndfish	Black rockfish	Blue rockfish	Other nr shore rf	green-ling	lingcod	cabezon	Pacific halibut	Pacific salmon	sardine	shrimp	tuna	Ocean crab
By port															
001	Columbia R	16364	3	0.0	0.0	0.0	0.0	0.0	0.0	0	13755	0	0	0	0
002	Astoria	1079778	447209	15.5	0.0	4.8	0.0	447.0	0.3	914	1597	504804	53837	20683	38691
005	Gearhart	286	0	0.1	0.0	0.0	0.0	0.2	0.0	0	10	0	0	4	3
006	Cannon Bch	45	0	0.0	0.0	0.0	0.0	0.0	0.0	0	40	0	0	2	0
008	Nehalem	50	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	26
010	Garibaldi	24585	1372	288.5	5.9	1.5	3.2	49.1	64.0	52	1535	447	9756	1768	8454
012	Netarts	60	1	0.5	0.0	0.0	0.0	0.0	0.1	0	0	0	0	0	0
016	Pacific City	462	319	251.6	2.7	2.0	0.9	54.0	4.3	0	33	0	0	30	34
020	Siletz	1	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
022	Depoe Bay	1749	30	5.6	1.4	0.4	0.1	18.8	3.0	17	81	0	0	52	547
024	Newport	716050	566530	64.8	0.5	0.8	0.2	262.5	3.0	1139	8894	230	56042	30948	46006
026	Waldport	348	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	3
030	Florence	2448	702	0.0	0.0	0.0	0.0	2.2	0.0	58	491	0	3	479	696
032	Winchester B	6312	256	1.0	0.0	0.3	0.0	3.7	0.0	63	601	56	0	1075	4118
034	Coos Bay	208014	95556	25.5	0.3	4.7	2.5	245.5	13.5	330	6343	1	50817	13395	31456
036	Bandon	207	18	6.2	0.2	0.4	0.1	2.0	0.2	2	133	0	7	43	2
038	Port Orford	13922	4487	769.4	29.0	152.4	238.9	195.6	278.4	64	819	0	0	148	6018
040	Gold Beach	1791	894	352.5	10.5	79.8	172.2	126.8	128.8	6	80	0	0	23	158
042	Brookings	38518	14526	255.4	12.2	15.3	20.8	83.1	58.3	10	572	0	5923	469	16210
other		1129627	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 1. Summary of landings (1000s of pounds) reported on Oregon fish tickets, 2000 to 2007. (continued)

		Gross weight	All grndfish	Black rockfish	Blue rockfish	Other nr shore rf	green-ling	lingcod	cabezon	Pacific halibut	Pacific salmon	sardine	shrimp	tuna	Ocean crab
By gear type															
110	CSTGILL	12	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
120	TROLL	90021	154	16.9	0.5	1.3	0.0	68.0	0.0	115	21155	0	0	68572	0
140	PELGILL	6	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	3	0
170	TUNABAIT	430	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	430	0
210	COLRGILL	14171	3	0.0	0.0	0.0	0.0	0.0	0.0	0	11928	0	0	0	0
230	TRTYGILL	2034	0	0.0	0.0	0.0	0.0	0.0	0.0	0	1795	0	0	0	0
240	DIPNET	61	0	0.0	0.0	0.0	0.0	0.0	0.0	0	29	0	0	0	0
250	SETLINE	37	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
300	FISHPOT	14098	8740	1.4	0.0	0.5	1.7	26.3	57.9	1	0	0	0	0	0
320	SHRIMPOT	34	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
330	SQUIDNET	3	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
340	HOOKLINE	3606	3589	1925.4	54.5	203.3	421.3	489.4	409.7	0	0	0	0	0	0
350	LONGLINE	12814	10162	77.4	7.8	52.0	15.4	94.7	81.8	2531	0	0	0	1	0
360	MIDWATER	939566	936135	0.3	0.0	0.0	0.0	37.2	0.0	6	73	37	0	0	1
370	SSHRIMP	5944	23	0.0	0.0	0.0	0.0	2.0	0.0	0	0	0	5721	0	0
380	DSHRIMP	171439	734	0.0	0.0	0.0	0.1	48.4	0.0	0	0	0	170651	0	0
390	BOTTOM	1282	1242	0.0	0.0	0.0	0.0	2.0	0.6	0	0	0	0	0	0
391	LGFTROPE	123475	117204	1.3	0.0	0.0	0.0	190.3	0.2	0	0	0	13	0	0
392	SMFTROPE	37864	33249	6.9	0.0	3.5	0.0	285.5	0.4	0	0	0	0	0	0
393	SELFLAT	23115	20664	6.4	0.0	1.8	0.0	246.6	0.3	0	0	0	0	0	0
400	CRABPOT	152578	4	0.4	0.0	0.1	0.0	0.3	2.7	0	0	0	0	0	152418
410	CRABRING	190	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	2
420	CLAMRAKE	440	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
430	DREDGE	7	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
440	SHRMPUMP	501	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
450	BAITNET	511413	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	505501	0	0	0
460	CLAM	75	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
470	HANDTOOL	6001	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
480	CRAYTRAP	607	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
490	SHELLHL	2	0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0	0
	Other	295	0	0	0	0	0	0	0	0	4	0	0	112	0

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Table 2. Landings (pounds) of black-plus-blue rockfish during 2000 to 2007 by the top-40 boats.

Year =	2000	2001	2002	2003	2004	2005	2006	2007	Total	Overall
N Boats =	231	211	202	178	178	178	183	153	560	Percent
Boat 1	7463	15520	19208	9882	9000	3596	276	601	65546	3.1%
Boat 2	4180	18256	6589	7055	3568	3763	5286	6133	54830	2.6%
Boat 3	5422	11425	7034	3162	9066	6913	4830	4719	52571	2.5%
Boat 4	5443	4017	6935	7908	9009	4923	4278	3683	46196	2.2%
Boat 5	11319	15463	10867	2810	3276	2223			45958	2.2%
Boat 6	4236	6292	8440	7716	6457	3038	4601	4479	45259	2.2%
Boat 7	3417	11309	2819	11175	4752	2501	3925	3960	43858	2.1%
Boat 8	10636	19884	5996	2334	4		3291	745	42890	2.0%
Boat 9	7137	18835	158	4119	1597	3514	4615	1847	41822	2.0%
Boat 10	7384	10964	16312						34660	1.7%
Boat 11		13873	6071	6904	6583	766			34197	1.6%
Boat 12	1962	1486	4534	5940	7256	3091	4157	5637	34063	1.6%
Boat 13	3777	3474	5103	3078	5834	5085	2775	2864	31990	1.5%
Boat 14				9991	5880	4475	5895	5263	31504	1.5%
Boat 15	1261	9508		2285	6897	3734	4615	3187	31487	1.5%
Boat 16			8228	3477	1365	5271	5887	5994	30222	1.4%
Boat 17			3095	4002	7039	4059	6014	5782	29991	1.4%
Boat 18	3110	3428	403	5986	5516	4214	1589	3863	28109	1.3%
Boat 19		561	8787	5172	6496	3626	2356	858	27856	1.3%
Boat 20		7823	7531	6255	3884	1647			27140	1.3%
Boat 21	4109	7793	4649	1373	2538	1191	1998	3286	26937	1.3%
Boat 22	6154	12237	6691						25082	1.2%
Boat 23	387	276		2336	7732	4105	5306	4624	24766	1.2%
Boat 24	5111	3002	3324	1338	2732	4416	421	3428	23772	1.1%
Boat 25	552	3111	1924	4623	5024	4452	2958	621	23265	1.1%
Boat 26	5954	2902	1592	4169	4192	2686	1065		22560	1.1%
Boat 27	6222	4569	3792	1661	3404	971	508	745	21872	1.0%
Boat 28	1007	885	2916	908	2706	3956	5081	4175	21634	1.0%
Boat 29		7016				4109	5584	4684	21393	1.0%
Boat 30			4722	4907	3309	3174	2991	1913	21016	1.0%
Boat 31	2326	5372	3985	1710	1329	2861	803	2065	20451	1.0%
Boat 32			2960	2571	3271	2886	4223	4388	20299	1.0%
Boat 33					6139	5457	4458	3924	19978	1.0%
Boat 34			66	2481	6940	3710	4816	959	18972	0.9%
Boat 35		242	1296	1786	3668	4262	2652	4880	18786	0.9%
Boat 36				2610	9763	4145	1506		18024	0.9%
Boat 37	2733	6536	321	767	1203	1838	2352	2149	17899	0.9%
Boat 38	3345	1882	4718	2189				4943	17077	0.8%
Boat 39	682	1110	2199	3943	2109	1231	2656	2726	16656	0.8%
Boat 40			1631	3258	2326	1894	1351	5716	16176	0.8%

Table 3. Cumulative landings of black-plus-blue rockfish for 2007, actual and predicted from truncated data series.

		- - - - - - - - - - - - Predictions based on data through: - - - - - - - - - - - -						
	Actual	Dec-06	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07
Cumulative landings for 2007 (1000s pounds)								
Jan	4.48	4.09	2.45	2.49	2.46	2.65	3.11	3.03
Feb	6.67	12.20	7.30	7.49	7.44	7.32	9.97	9.71
Mar	14.52	22.46	13.16	13.47	13.44	12.70	18.02	17.60
Apr	26.56	48.18	30.93	31.21	31.26	30.02	37.54	37.26
May	62.44	84.45	63.69	63.76	63.90	62.57	72.02	71.87
Jun	94.07	119.72	98.40	96.64	96.95	95.78	106.19	106.30
Jul	124.72	152.59	130.65	127.39	126.32	126.56	137.59	138.46
Aug	161.82	186.15	163.55	159.53	158.40	160.44	171.79	173.30
Sep	208.10	219.96	196.69	192.23	191.08	197.65	214.15	216.93
Oct	231.89	228.09	204.14	199.38	198.21	209.10	230.07	236.09
Nov	232.86	230.54	205.91	200.92	199.74	214.84	238.01	248.03
Dec	232.86	232.33	207.02	201.83	200.64	219.90	244.16	256.21
Percentage error for predictions of 2007 cumulative landings.								
Jan	4.48	-8.6%	-45.3%	-44.3%	-45.1%	-40.9%	-30.5%	-32.4%
Feb	6.67	83.0%	9.5%	12.3%	11.7%	9.8%	49.6%	45.6%
Mar	14.52	54.7%	-9.4%	-7.2%	-7.5%	-12.6%	24.1%	21.2%
Apr	26.56	81.4%	16.5%	17.5%	17.7%	13.0%	41.4%	40.3%
May	62.44	35.3%	2.0%	2.1%	2.3%	0.2%	15.3%	15.1%
Jun	94.07	27.3%	4.6%	2.7%	3.1%	1.8%	12.9%	13.0%
Jul	124.72	22.3%	4.8%	2.1%	1.3%	1.5%	10.3%	11.0%
Aug	161.82	15.0%	1.1%	-1.4%	-2.1%	-0.9%	6.2%	7.1%
Sep	208.10	5.7%	-5.5%	-7.6%	-8.2%	-5.0%	2.9%	4.2%
Oct	231.89	-1.6%	-12.0%	-14.0%	-14.5%	-9.8%	-0.8%	1.8%
Nov	232.86	-1.0%	-11.6%	-13.7%	-14.2%	-7.7%	2.2%	6.5%
Dec	232.86	-0.2%	-11.1%	-13.3%	-13.8%	-5.6%	4.9%	10.0%
Mean abs. % error =		28.0%	11.1%	11.5%	11.8%	9.1%	16.7%	17.4%

Table 4. Cumulative landings of black-plus-blue rockfish for 2008 (2004 data repeated), actual and predicted from truncated data series.

		- - - - - - - - - - - - Predictions based on data through: - - - - - - - - - - - -						
	Actual	Dec-07	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08
Cumulative landings for 2008 (simulated, 1000s pounds)								
Jan	3.03	2.84	4.61	4.57	4.52	4.54	4.38	4.74
Feb	10.58	11.08	13.85	14.01	13.94	13.96	13.79	14.45
Mar	27.35	22.96	29.96	30.84	30.61	30.61	30.20	31.05
Apr	67.76	49.38	61.10	63.98	62.93	62.68	61.74	62.31
May	111.96	88.24	105.34	110.00	107.93	107.46	106.15	106.82
Jun	157.99	125.80	145.52	154.21	150.60	149.73	148.82	149.57
Jul	191.47	161.19	182.19	193.78	185.30	183.87	184.63	185.17
Aug	224.44	198.02	219.64	232.67	221.20	218.55	222.16	222.22
Sep	272.85	236.23	258.16	271.90	258.96	254.88	268.07	266.60
Oct	272.85	249.15	271.24	285.33	271.67	266.89	285.90	283.50
Nov	272.85	254.26	276.42	290.69	276.67	271.55	293.37	282.69
Dec	272.85	258.68	280.87	295.22	281.03	275.75	298.92	284.39
Percentage error for predictions of 2008 (simulated) cumulative landings.								
Jan	3.03	-6.1%	52.5%	51.0%	49.6%	50.0%	44.9%	56.5%
Feb	10.58	4.7%	30.9%	32.4%	31.7%	31.9%	30.2%	36.6%
Mar	27.35	-16.0%	9.5%	12.7%	11.9%	11.9%	10.4%	13.5%
Apr	67.76	-27.1%	-9.8%	-5.6%	-7.1%	-7.5%	-8.9%	-8.0%
May	111.96	-21.2%	-5.9%	-1.8%	-3.6%	-4.0%	-5.2%	-4.6%
Jun	157.99	-20.4%	-7.9%	-2.4%	-4.7%	-5.2%	-5.8%	-5.3%
Jul	191.47	-15.8%	-4.9%	1.2%	-3.2%	-4.0%	-3.6%	-3.3%
Aug	224.44	-11.8%	-2.1%	3.7%	-1.4%	-2.6%	-1.0%	-1.0%
Sep	272.85	-13.4%	-5.4%	-0.3%	-5.1%	-6.6%	-1.8%	-2.3%
Oct	272.85	-8.7%	-0.6%	4.6%	-0.4%	-2.2%	4.8%	3.9%
Nov	272.85	-6.8%	1.3%	6.5%	1.4%	-0.5%	7.5%	3.6%
Dec	272.85	-5.2%	2.9%	8.2%	3.0%	1.1%	9.6%	4.2%
Mean abs. % error =		13.1%	11.1%	10.9%	10.3%	10.6%	11.1%	11.9%

Figure 1. Daily cumulative commercial landings of black rockfish plus blue rockfish in Oregon, 2004 to 2008. Graph provided by Steve Kupillas and Mark Karnowski (ODFW).

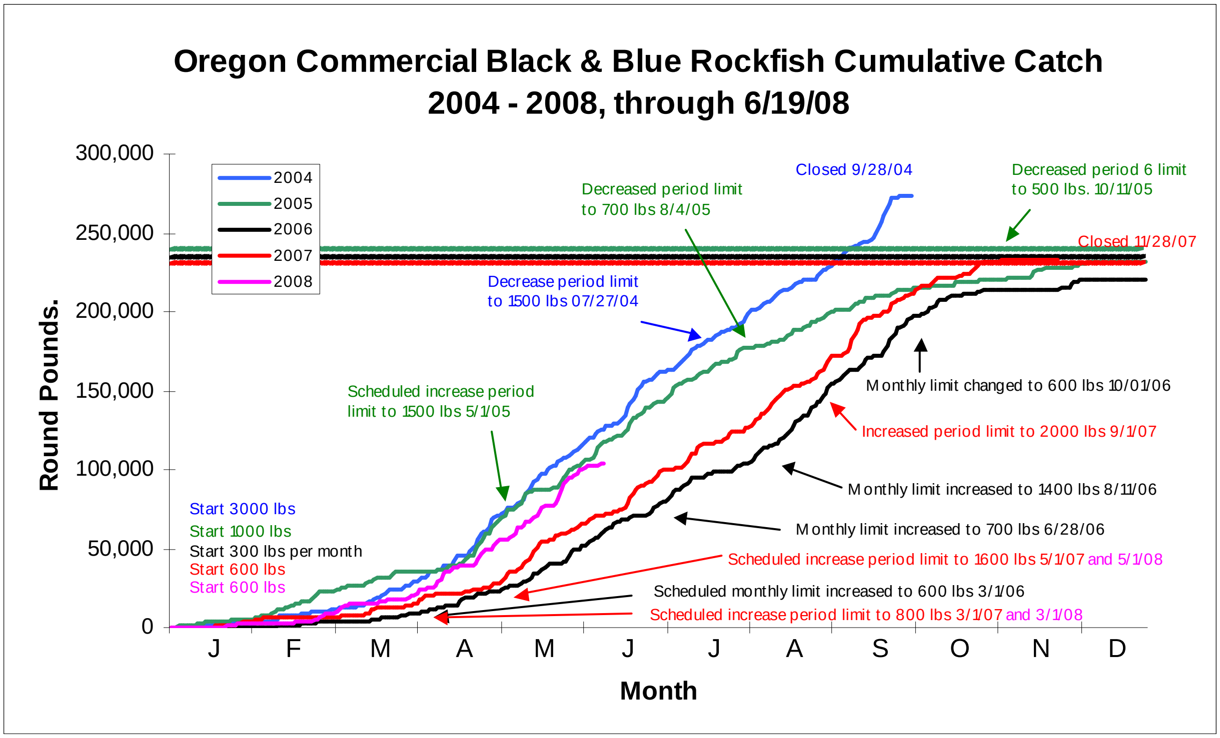


Figure 2. Ranked boat-by-boat contributions to the 2000 through 2007 cumulative landings of black-plus-blue rockfish in Oregon.

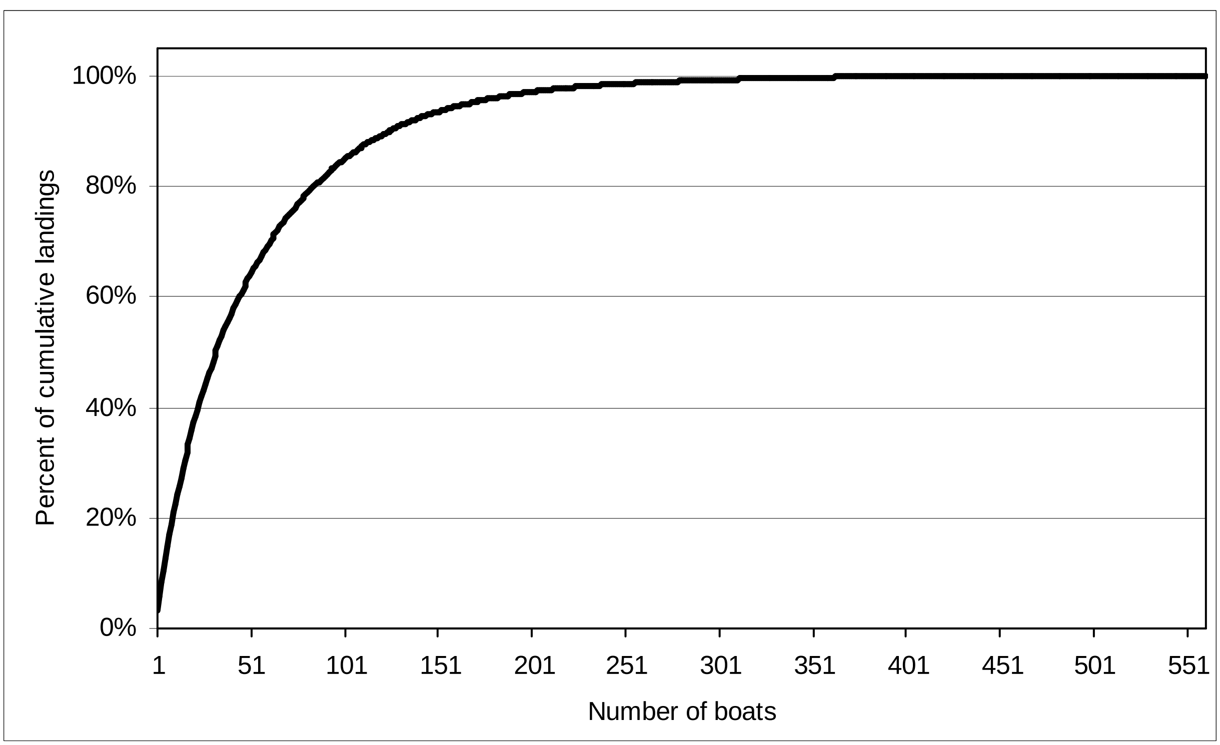


Figure 3. Monthly Oregon landings of black-plus-blue rockfish during 2000 through 2007. Northern ports are Coos Bay and north; southern ports are Bandon and south.

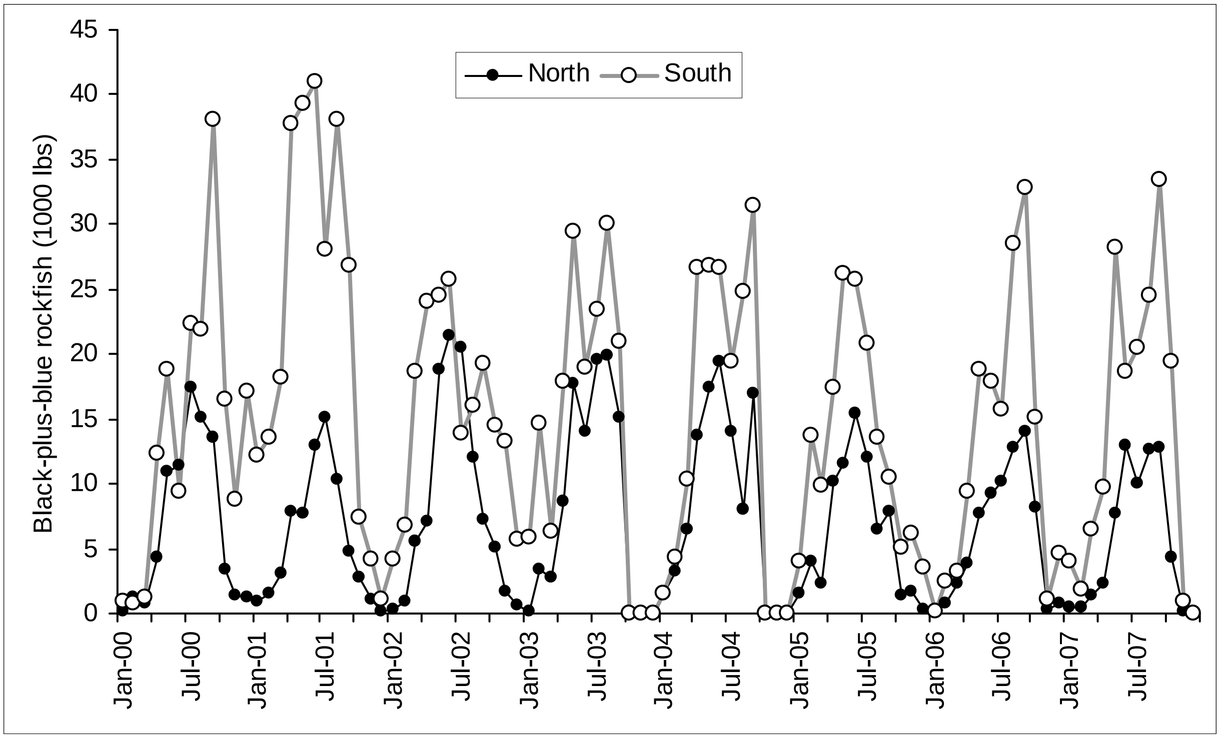


Figure 4. Fitted values from the additive versus multiplicative models applied to the monthly black-plus-blue rockfish landings in Oregon during 2000 through 2007.

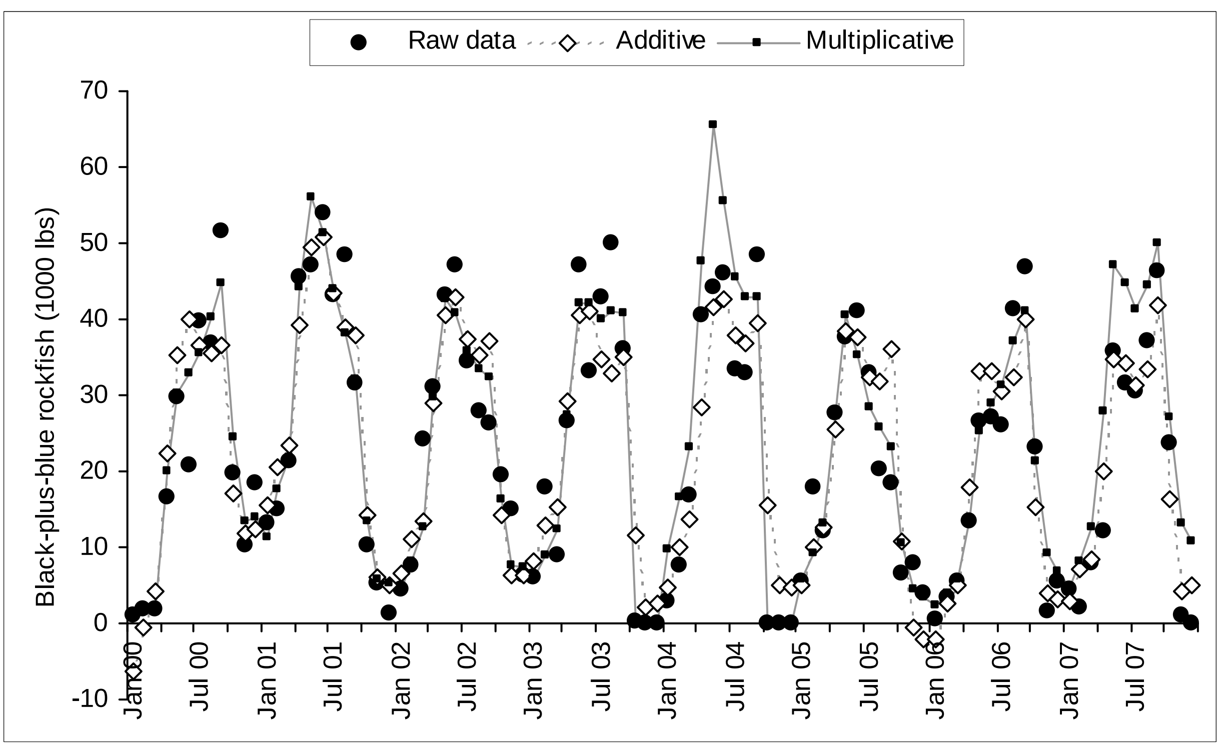


Figure 5. Cumulative observed and fitted monthly landings of black-plus-blue rockfish in Oregon during 2004 and 2007.

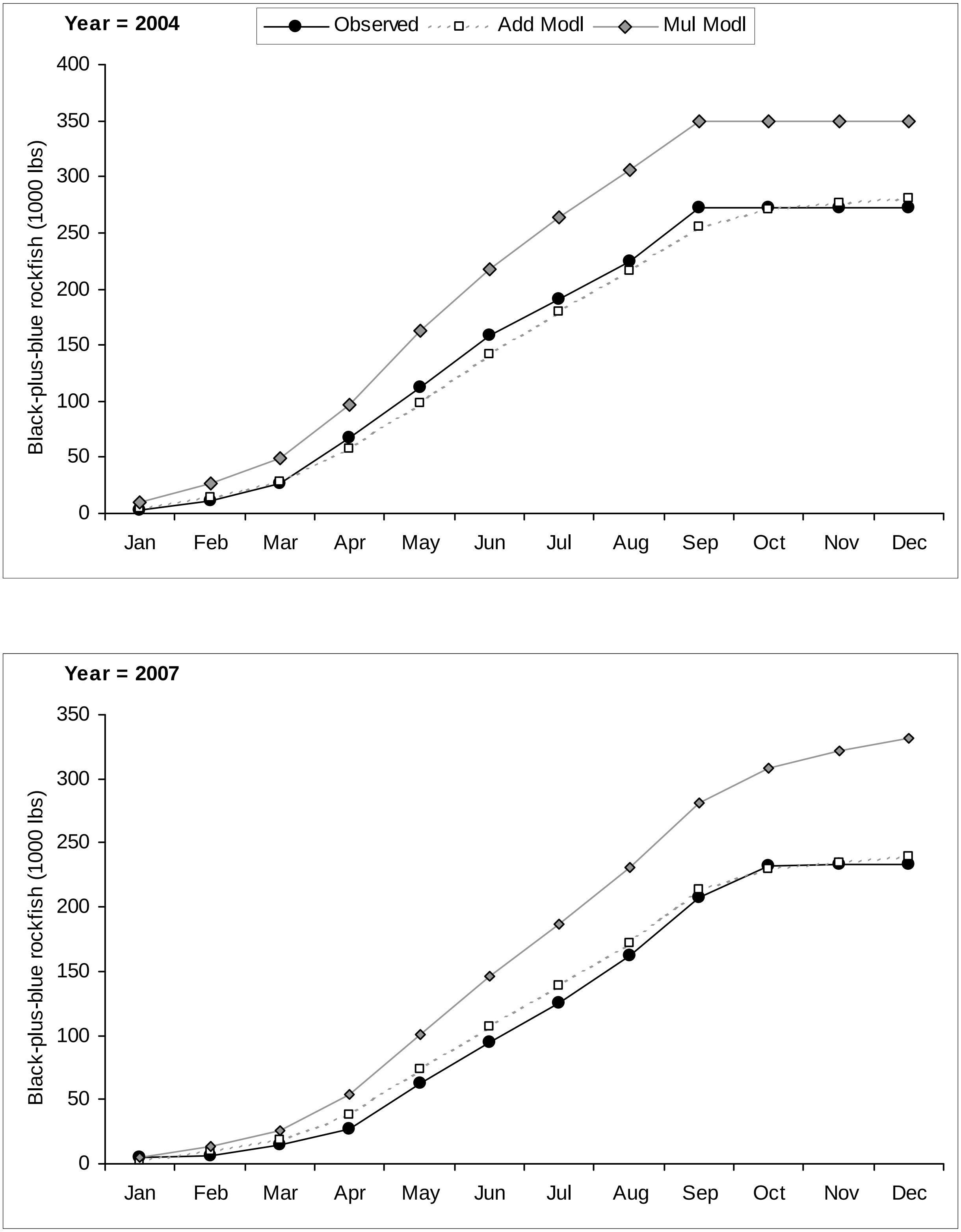


Figure 6. Actual monthly landings and predicted values based on truncated versions of the statewide data series. The "Dec-06" data series stopped with the data from December 2006.

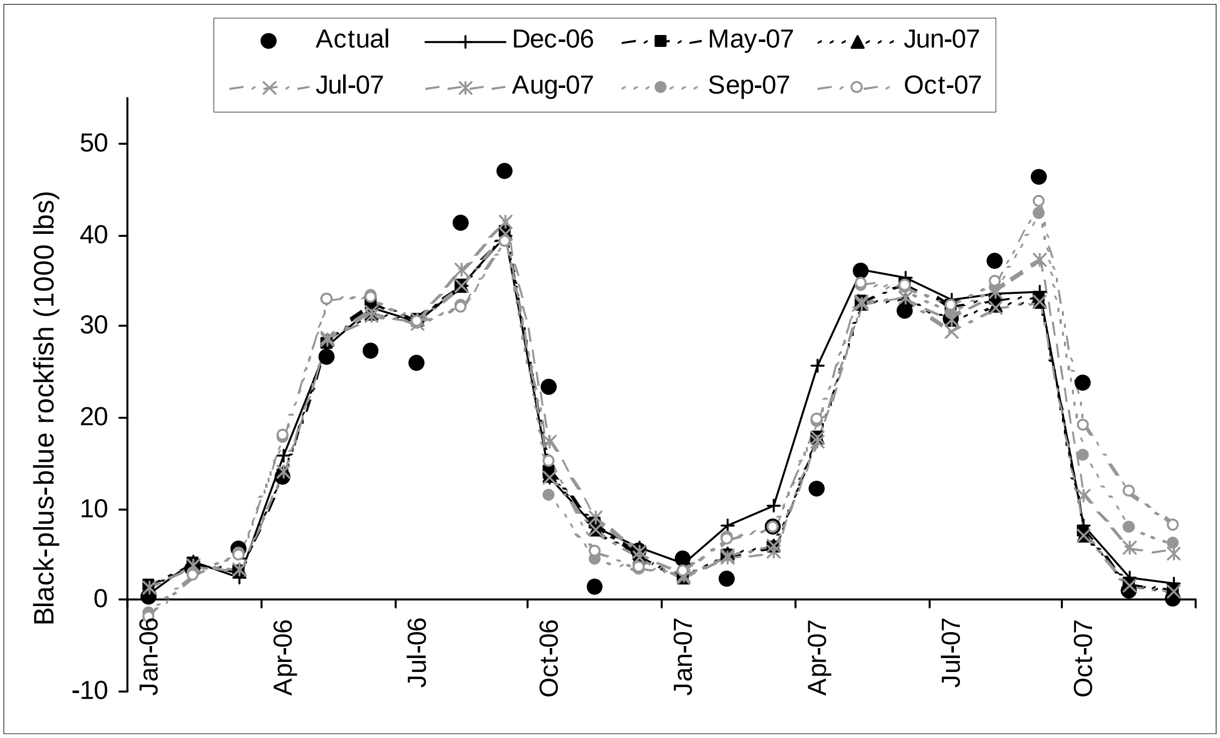


Figure 7. Actual monthly landings and predicted values based on truncated versions of the statewide data series, for 2007 only.

The solid circles are the actual data. The sets of small open circles show the sequence of predicted values for each month from the May 2007 series, then the June 2007 series, and so on through October 2007.

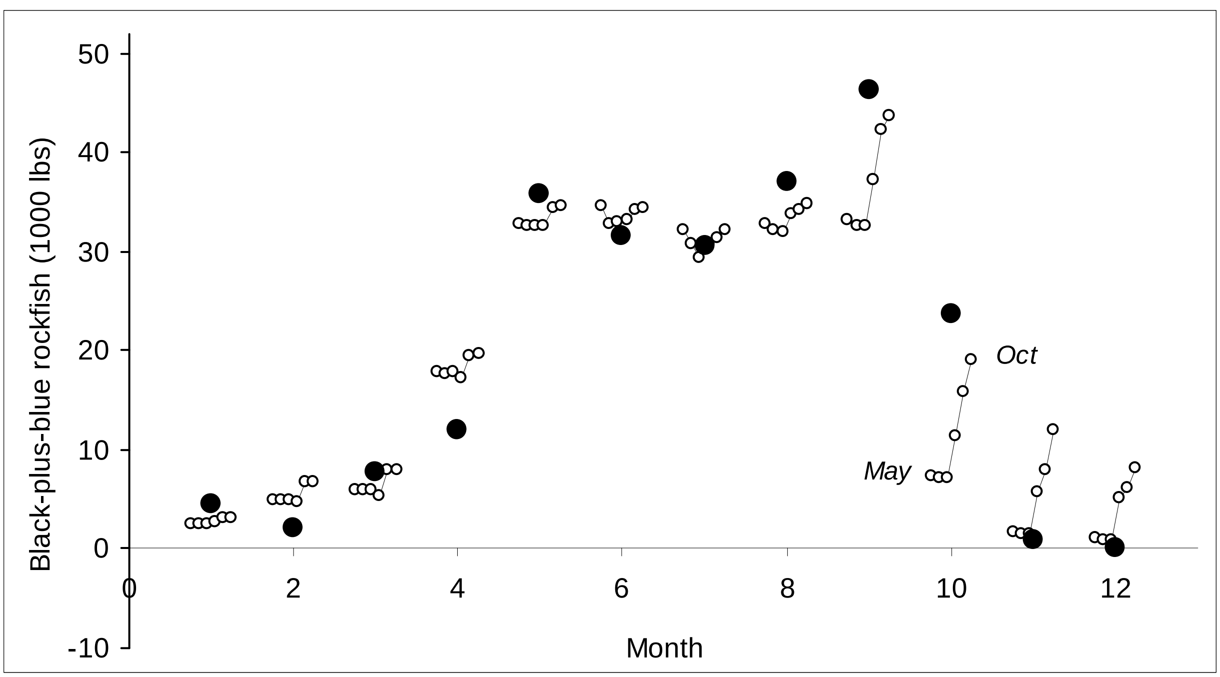


Figure 8. Simulated monthly landings and predicted values based on truncated versions of the statewide data series. The "Dec-07" data series stopped with the data from December 2007.

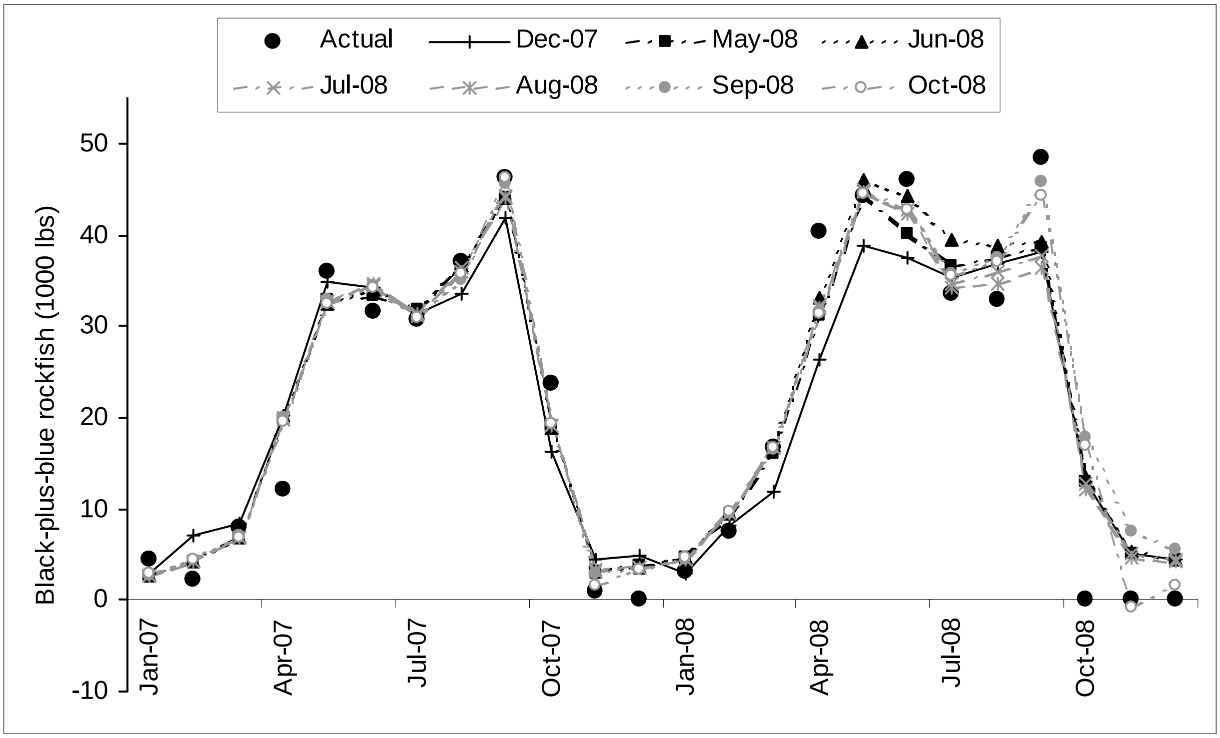
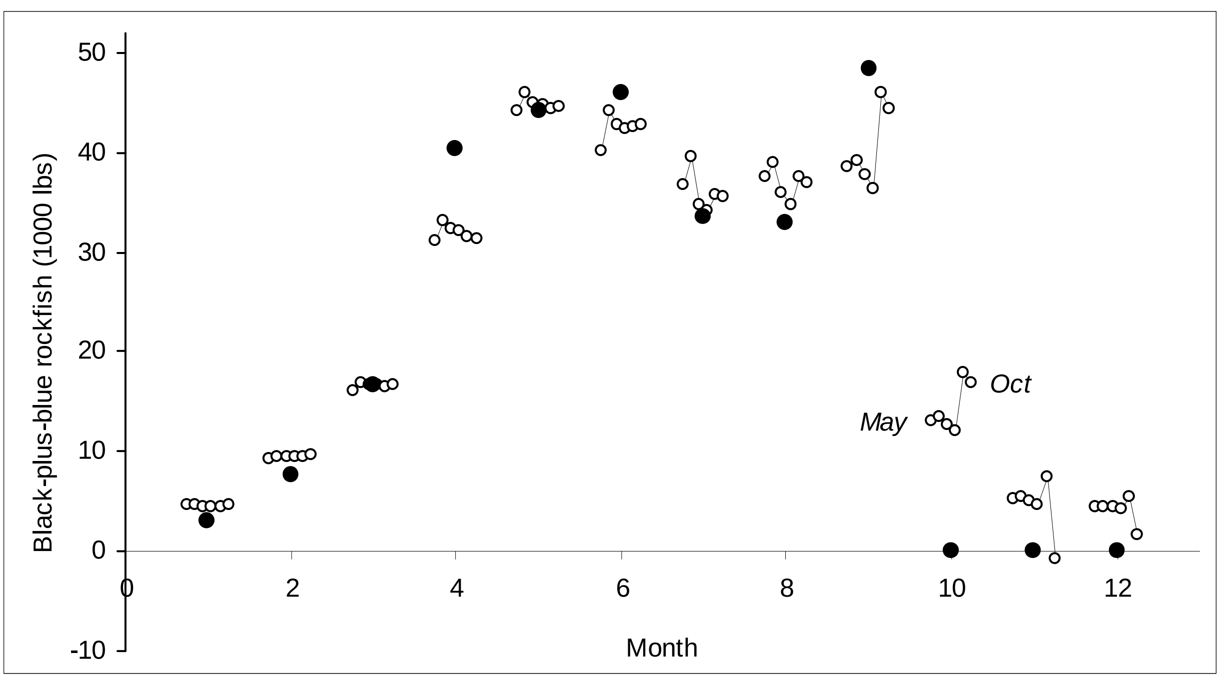


Figure 9. Simulated monthly landings and predicted values based on truncated versions of the statewide data series, for 2008 only.

The solid circles are the actual data. The sets of small open circles show the sequence of predicted values for each month from the May 2008 series, then the June 2008 series, and so on through October 2008.



Appendix A. X12a data file with monthly Oregon landings (lbs) of black-plus-blue rockfish, 2007 to 2007. To conserve space the information below is organized as three columns, each with data for the year, month, and pounds. An actual data file would be organized as a single column.

2000	1	1022
2000	2	1908
2000	3	1906
2000	4	16578
2000	5	29828
2000	6	20793
2000	7	39759
2000	8	36888
2000	9	51548
2000	10	19866
2000	11	10230
2000	12	18352
2001	1	13193
2001	2	15038
2001	3	21262
2001	4	45493
2001	5	47023
2001	6	53912
2001	7	43218
2001	8	48419
2001	9	31661
2001	10	10188
2001	11	5369
2001	12	1206
2002	1	4488
2002	2	7632
2002	3	24170
2002	4	31112
2002	5	43251
2002	6	47089
2002	7	34374
2002	8	27994
2002	9	26411
2002	10	19526
2002	11	14966
2002	12	6390
2003	1	6016
2003	2	17909
2003	3	9042
2003	4	26563
2003	5	47185
2003	6	33110
2003	7	42974
2003	8	49876
2003	9	36078
2003	10	201
2003	11	13
2003	12	0
2004	1	3025
2004	2	7559
2004	3	16766
2004	4	40410
2004	5	44200
2004	6	46030
2004	7	33484
2004	8	32967
2004	9	48407
2004	10	2
2004	11	0
2004	12	0
2005	1	5466
2005	2	17845
2005	3	12135
2005	4	27575
2005	5	37730
2005	6	41170
2005	7	32944
2005	8	20171
2005	9	18472
2005	10	6608
2005	11	7868
2005	12	3956
2006	1	395
2006	2	3340
2006	3	5518
2006	4	13324
2006	5	26642
2006	6	27171
2006	7	25922
2006	8	41306
2006	9	46880
2006	10	23259
2006	11	1488
2006	12	5398
2007	1	4478
2007	2	2188
2007	3	7857
2007	4	12034
2007	5	35881
2007	6	31634
2007	7	30646
2007	8	37106
2007	9	46276
2007	10	23791
2007	11	971
2007	12	0

Appendix B. X12a specification file for fitting an ARIMA model to the statewide black-plus-blue rockfish monthly landings data.

```
series{
   title= 'Black-plus-blue rockfish monthly landings'
   file=  'BLKBLU.dat'
   format= 'Datevalue'
   period=12
   decimals=2
   modelspan=(,2005.DEC)    # change end-date to test forecasts
   savelog=peaks
}
transform{
   function=none
#     constant=1          # to allow possible log-transform
#     function=log        # log-transform will force positive values
#     function=auto       # auto test of log-transform versus no transform
}
regression{
#    variables=lom        # length of month
}
outlier{
  types=(AO LS TC)
  lsrun=3
}
automdl{                  # automatically pick the ARIMA model
   savelog=(b5m amd)
}
estimate{
   print=(roots regcmatrix residuals)
   savelog=(aicc afc)
   save=(residuals mdl)
   outofsample=yes
}
check{
   print=all
   savelog=(nrm lbq)
}
x11{
   savelog=(M1 M7 M8 M9 M10 M11 Q Q2)
   save=(d10 d12 d13)           # output files with the Seasonal, Trend-Cycle, and Irregular effects
}
forecast{
   maxlead=12
   print=none
}
```