Final Report to the Oregon Trawl Commission on

Analysis of Data from the At-Sea Data Collection Project

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Abstract

The Enhanced Data Collection Project (EDCP), administered by the Oregon Department of Fish and Wildlife, collected data on discard rates for groundfish species and bycatch rates of prohibited species (salmon and Pacific halibut). From late 1995 to early 1999 EDCP observers collected discard data from 235 fishing trips by 25 trawl vessels that voluntarily participated in the program. Besides these observer data, vessels in the program kept enhanced logbooks that recorded retained and discarded catch. These logbooks had data from 866 trips by 44 vessels, including most of the trips with observers. Provided logbook data are acceptably accurate, collecting discard data using logbooks could be a cost-effective supplement to an observer program for measuring discard rates and total discards. Comparisons of tow-by-tow logbook discards with the corresponding observer discards indicated substantial inaccuracies in the logbook information. However, when averaged across tows, trips, and vessels, the discard rates (discard/catch) from the logbooks were lower than the observer discard rates, but predictably so. Generalized linear models were used to determine the major factors contributing to variability in the discard rates. The models indicated tremendous vessel-to-vessel variability in discard rates. Principal components analysis (PCA) was applied to trip-level landings and species compositions from the entire groundfish trawl fleet to summarize the fleet-wide characteristics of fishing trips. Analyses of the PCA scores from the trips that were in the EDCP compared to the scores from all other trips indicated that the EDCP trips probably were not representative of the fleet at large.

Introduction

In 1995 the Oregon Trawl Commission (OTC) contracted with the Oregon Department of Fish and Wildlife (ODFW) to begin the Enhanced Data Collection Project (EDCP). The major goals of the project were to collect data on trip-limit induced discard rates for primary groundfish species, discard rates for other groundfish species, and bycatch rates of prohibited species such as Pacific halibut and salmon. From late 1995 to early 1999 EDCP at-sea observers collected discard and bycatch data from over 200 fishing trips by trawl vessels that voluntarily participated in the program. In addition to these observer data, boats participating in the program kept enhanced logbooks in which the skippers recorded their retained and discarded catch. These enhanced logbooks have data from over 800 trips, including most of the trips with observers.

For the project described in this report the Commission contracted with Oregon State University to analyze the EDCP databases, which were provided by ODFW on CD-ROM. The analyses compare the discard rates measured by the EDCP at-sea observers with the discard rates reported by the corresponding enhanced logbooks. The overall goal was to examine the feasibility of using logbooks, in conjunction with some observer coverage, to measure discard rates and total discards for use in stock assessments and by management. The main objectives of the analyses were: (a) to evaluate the accuracy of the skippers' estimates of discarded catch; (b) to estimate average discard rates for the major species and determine the factors that contribute to variability in the discard rates; and (c) to evaluate whether the boats that volunteered to participate in the EDCP were representative of the fleet at large.

Description of the EDCP Data

The ODFW staff organized the EDCP data into three primary files. The "*obs_ttow*" file has tow-by-tow data collected by the observers on discards of the main groundfish species and the bycatch of halibut and salmon. It contains data from a total of 2,172 tows from 235 fishing trips by 25 different fishing boats. The "*obs_tckt*" file has trip-by-trip summary data from the observed trips on the total amounts of discards of the main groundfish species and the bycatch of salmon and halibut. This file also contains data from the fish tickets (the official landing receipts) on the retained catches of the main groundfish species. The "*logbook*" file contains the skippers' tow-by-tow estimates of retained and discarded catch of the main groundfish species and the bycatch of salmon and halibut. These enhanced logbook data are available for 7,400 tows from 866 trips by 44 different boats. Enhanced logbook data are available in the database for all but 9 of the observed trips, but 10 boats failed to report discards in their logbooks when there was an observer on board. Evidently the skippers of these boats mistakenly thought that their logbook data were unnecessary given that an observer was monitoring the discards.

During preliminary screening of the database files we uncovered a number of discrepancies in the data including some missing observer discard records (due to incomplete species composition sample information) and some key-punch errors (e.g., halibut lengths entered in inches instead of cm). We notified ODFW staff of the discrepancies, which they investigated using the original EDCP paper records and subsequently rectified.

The preliminary screening and data exploration also identified certain aspects of the data that, if ignored, could lead to incorrect interpretations. For example, notes associated with the observer data records indicated instances where the observers' recorded discards were "visually estimated"; in many cases the amounts record by the observer were identical to the amounts listed in the corresponding logbook. These data grossly overstate the accuracy of the logbook's discard information. Also, the observer notes sometimes indicated that the discard information for specific tow sequences on a trip represented combinations of tows. The discards reported for the last tow of the sequence included the discards from the earlier tow(s), which reported no discards. In preparing the data for analysis we removed these false zeroes from the observer data and combined the logbook data from these tow sequences so that we could correctly match the observer data with the logbook data. A final issue regarding the observer data was the presence of large numbers of data records where the observer reported that "unidentified fish" were discarded. In preparing the data for analysis we included a flag variable to identify observed tows that had discards of unidentified fish.

Data Analysis Methods

The at-sea observers on the EDCP project collected discard data for a wide range of groundfish species, many more than we could reasonably evaluate in our analyses. For this report we limited our detailed statistical analyses to the following species (or groups of species): "All Fish", Dover sole, sablefish, longspine and shortspine thornyheads, English sole, rex sole, petrale sole, sanddab, all *Sebastes*, canary rockfish, Pacific ocean perch, widow rockfish, yellowtail rockfish, lingcod, and Pacific hake. To facilitate data handling we analyzed the species in groups: deepwater complex (Dover sole, sablefish, and longspine and shortspine thornyheads); flatfish (English sole, rex sole, petrale sole, and sanddab), rockfish (all *Sebastes*, canary rockfish, Pacific ocean perch, widow rockfish, and yellowtail rockfish), and other fish (lingcod and Pacific hake). We configured the statistical models to include a *Species ID* factor that allowed us to maintain separate parameter estimates for individual species while analyzing the species collectively.

Evaluating the Accuracy of the Logbook Discard Data

For measuring the accuracy of the discard data reported in the logbooks we created a data file that matched the tow-by-tow logbook discard data with the corresponding observer discard data. We then examined two aspects of these combined data: the proportion of tows for which an observed discard of a given species (or species group) was also reported in the corresponding logbook,

$$\%\text{Agreement} = \frac{\text{No. Logbook Tows with Discard of Species X}}{\text{No. Observed Tows with Discard of Species X}} \times 100\% \ ,$$

and the ratio of the amount of discard reported in the logbook over the amount observed,

$$\text{Log/Obs Ratio} = \frac{\text{Logbook Discard of Species X (lbs)}}{\text{Observed Discard of Species X (lbs)}} \ .$$

This type of evaluation assumes that the observer data are correct, but in many cases (e.g., tows with discards of unidentified fish or discards that were "visually estimated") this assumption is not entirely valid.

The %Agreement proportions were calculated for each species on a trip-by-trip basis for all trips having matched logbook and observer data. The Log/Obs Ratios were calculated for each species on a tow-by-tow basis for all tows with matched logbook and observer data for which both the logbook and the observer reported some discards.

The %Agreement proportions were formally analyzed using logistic regression methods as implemented in the GLIM Release 4 statistical software program (Francis et al. 1993). The logistic regression model can be expressed as

$$\log_e\left(\frac{\%\text{Agreement}}{100\% - \%\text{Agreement}}\right) = \beta_1 \cdot \text{Factor}_1 + \beta_2 \cdot \text{Factor}_2 + \ldots$$

Logistic regression is an accepted method for the analysis of proportions and other forms of binomial data (Cox and Snell 1989). The Log/Obs Ratios were analyzed using the GLIM software based on the following type of regression model,

$$\text{Logbook Discard} = (\text{Log}/\text{Obs Ratio}) \cdot (\text{Observed Discard}) \cdot \text{Factor}_1 \cdot \text{Factor}_2 \cdot \cdots$$

The observed Logbook Discards were treated as normally distributed random variables, as in standard regression or analysis of variance.

To assess the statistical significance of different variables and factors that might influence the dependent variables (the %Agreement proportions and the Log/Obs Ratios) we conducted forward-stepwise analyses (Draper and Smith 1966) that examined the relative improvement in fit that resulted from adding explanatory variables to the statistical model. In GLIM the so-called "deviance" statistic, measures how well a statistical model fits the observed data. If the model is correctly specified (i.e., it includes the correct variables in the correct formulation), then the deviance is approximately distributed as a chi-square random variable and changes in the deviance can be used in an F ratio to evaluate the change in goodness of fit (McCullagh and Nelder 1983),

$$F = \frac{(\Delta \text{ Deviance}) / (\Delta \text{ Degrees of Freedom})}{(\text{Deviance}) / (\text{Degrees of Freedom})} ,$$

where the deviance and degrees of freedom in the denominator are from the more complete model. The F ratio can be compared to the corresponding theoretical F distribution to evaluate the statistical significance of the change. If a change in deviance is large compared to the background variability (as measured by the deviance divided by the degrees of freedom of the more complete model), then the change is unlikely to be due to random chance alone and the P value for the F ratio statistic will be near zero.

For the %Agreement observations we fit a series of three logistic models to each species. The first model had a single parameter representing the overall proportion agreement about discarding, the second had a separate parameter (proportion) for each boat, and the third had a parameter that allowed %Agreement to vary with the size of the observed discard. For the Log/Obs Ratios we fit a model with a single overall ratio, another with a separate ratio for each boat, and a third with a separate ratio for each trip. We examined two additional models: one to evaluate the influence of unidentified fish discards (*Ufish*) and the other to evaluate the influence of questionable data (*Qtow*). The *Ufish* variable for a tow was set to one if the unidentified fish discards were 10% or more of all the fish discards for that tow; otherwise it was set to zero. The *Qtow* variable for a tow was set to one if the logbook discard was exactly the same as the observer discard or if the observer discard amount was evenly divisible by 100 (e.g., exactly 400 rather than 402, or exactly 10,000 rather than 10,013).

Estimating the Discard Rates

Because the observers did not measure the amount of catch retained from each tow, the observer data did not provide any direct measurement of discard rates at the level of individual tows. For our analysis of the observer data we derived discard rates for each groundfish species on a trip-by-trip basis using the ratio

$$\text{Discard Rate} = \frac{\text{Amount Discarded}}{\text{Amount Discarded} + \text{Amount Landed}} .$$

This discard rate measures the fraction of the catch that was discarded (as opposed to the amount of fish discarded per hour of fishing or per trip). We calculated similar discard rates on a trip-by-trip basis from the logbook data. We excluded trips with incomplete discard data, ones with unobserved tows or where the logbook had tows with blank (as opposed to zero) discards. We did not attempt to explore discard rates at the level of individual tows. However, the logbook data could be used for calculating tow-by-tow discard rates because they include tow-by-tow estimates of retained catch.

We analyzed transformed discard rates using the following type of regression model,

$$\arcsin\left(\sqrt{\text{Discard Rate}}\right) = \beta_1 \cdot \text{Factor}_1 + \beta_2 \cdot \text{Factor}_2 + \ldots$$

Prior to running the regression analysis we applied to the discard rates the so-called "angular transformation", as shown in the left-hand portion of the equation, which is a standard technique for converting proportions so that the resulting values have a distribution that is more similar to the normal distribution, on which standard regression methods are based (Zar 1974). We did not consider it appropriate to use logistic regression with the discard rate data because the proportions were based on estimated weights rather than counts.

To evaluate the importance of various factors that might influence the discard rates we conducted forward-stepwise analyses that examined the relative improvement in fit that resulted from adding explanatory variables to the statistical model. In our analysis of the observer discard rates we examined factors for *Boat*, *Port*, *Gear* type (shrimp trawl, sole trawl, bottom trawl, bottom trawl with rollers), *Area* (Pacific Marine Fishery Commission statistical area), *Year*, and season (quarter of the year, *Qtr*). Also, we tested the importance of factors that identified large (>10%) discards of unidentified fish (*Ufish*) and tows with questionable data (*Qtow*), as in our analysis of logbook discard accuracy, and we fit models that included continuous variables (as opposed to discrete factors) for the size of the catch (*Lbs*) and the tow time (*Hrs*). In our analysis of the logbook discard rates we considered factors for boat, year, and quarter, plus a factor to identify trips that had an observer on board (*Obs*) and a continuous variable for the size of the catch (*Lbs*).

Halibut Bycatch Rates

The observers on the EDCP project almost always recorded the number of halibut caught and discarded. The observers were instructed to give this task, along with the recording of bycatch of salmon, the highest priority. During most tows with halibut bycatch the observers measured and recorded the individual lengths, and sometimes the weights, of a sample of the halibut. If small numbers of halibut were caught, all were measured. In the EDCP "*halibut*" file the ODFW staff included a field with the estimated weights of those individual fish for which length data were available, and another field with the estimated total weights of the entire halibut catch, including fish that were not measured. In the enhanced logbooks used with the EDCP program the skippers were allowed to record their halibut bycatch either in terms of the numbers or pounds of fish. Some reported both measures, but they reported halibut bycatch in terms of weight more frequently than in terms of numbers of fish.

During preliminary examinations of the data we determined that the estimated halibut weights tended to overstate the weights of those halibut that had been weighed. For example, the estimated weight of a 110-cm fish was on average about 2.4 kg heavier than the weight of the 110-cm fish observed during the EDCP project. We used the individual halibut length and weight data from the *halibut* file to derive coefficients for a length-weight relationship, which we then used to estimate individual halibut weights for those fish with length measurements. From the individual halibut weights for each tow we estimated an average halibut weight for each tow. We estimated the total halibut weight for each tow by multiplying the number of halibut caught on the tow times the estimated average halibut weight for that tow. For the 37 observed tows that caught halibut but none were measured, we used an overall average halibut weight.

Because trawl-caught halibut cannot be retained legally, it is not meaningful to define a halibut bycatch rate in terms of the catch of halibut. All of the catch is always discarded. For our analysis of halibut bycatch we defined two measures for the trip-level bycatch rate, one based on the hours of trawling,

$$\text{Halibut Bycatch Rate}_1 = \frac{\text{No. or Pounds of Halibut Caught}}{\text{Hours of Trawling}}$$

and the other based on the weight of all the landed fish,

$$\text{Halibut Bycatch Rate}_2 = \frac{\text{No. or Pounds of Halibut Caught}}{\text{Pounds Landed of All Fish}}$$

Histograms of the halibut bycatch data indicated appreciable numbers of tows and trips that caught no halibut. As a consequence, in our formal analysis of the halibut bycatch we modeled the catch rates using the so-called "delta-distribution" (Pennington, 1983, 1996). The proportion of trips that caught halibut was treated separately from the magnitude of the halibut catch (in numbers or pounds of halibut), and the overall bycatch rate was simply the product of the two components. We used logistic regression methods to formally analyze tabulations of the proportions of trips that caught halibut. To analyze the ratios of halibut catch over hours of trawling (or pounds of fish landings) we first logarithmically transformed the ratios and then applied standard regression methods.

To evaluate the importance of various factors that might influence halibut bycatch, either the proportion of trips catching halibut or the magnitude of the non-zero halibut catches, we conducted forward-stepwise analyses that examined the relative improvement in fit that resulted from adding explanatory variables to the statistical models. In our analysis of the observer data we examined factors for boat, port, gear type, area, year, and a flag to identify tows with questionable data (*Qtow*), and continuous variables for the size of the fish landings (*Lbs*) and the tow time (*Hrs*). In our analysis of the logbook data we considered factors for boat, year, and quarter, and a factor to identify trips that had an observer on board and a continuous variable for the size of the fish landings (*Lbs*). We excluded from the analyses observer data from trips that had unobserved tows and logbook data from trips for which there were missing logbook discards, unrecorded trawl hours, or no landings of fish.

Evaluating Whether the EDCP Data are Representative

The fishing boats that participated in the EDCP program did so on a voluntary basis. As a consequence, they cannot be considered a random sample of the trawl fleet at large; it may be inappropriate to extrapolate the results from the EDCP program to the entire fleet, despite the pressing need for reliable estimates of discards. To evaluate whether the boats and fishing trips covered by the EDCP program were representative of the trawl fishery in general, we compared traits of the trips covered by the EDCP program with the traits of the rest of the groundfish trawl trips that landed their catch in Oregon. We obtained fish ticket files from ODFW for the period covered by the EDCP program (16 Nov. 1995 through 31 Dec. 1999) and tabulated on a trip-by-trip basis the total fish landings and the proportions landed by species. The tabulations included the following 21 species or species groups: Pacific hake, English sole, petrale sole, Dover sole, rex sole, sanddab, arrowtooth flounder, small rockfish, large rockfish, Pacific ocean perch, widow rockfish, yellowtail rockfish, canary rockfish, shortspine thornyheads, longspine thornyheads, grenadier, sablefish, lingcod, Pacific mackerel, jack mackerel, and skate). We then applied Principal Components Analysis (PCA) to these landings and species composition data to derive PCA scores, which we treated as summary statistics to characterize each trip. Because the species composition numbers are proportions (restricted to the range 0 to 1) we transformed them using the angular transformation prior to application of PCA. In an auxiliary file we included flag variables that identified trips covered by EDCP observers or EDCP logbooks. We compared the PCA scores of the EDCP trips with the PCA scores of the rest of the trips.

Because we did not have ready access to fish ticket information for trips that landed their catch in California or Washington, our analysis was restricted to trips that landed in Oregon. Also, the fish ticket files that we obtained from ODFW did not include shrimp trawl landings of groundfish, but relatively few of the EDCP trips were aboard boats using shrimp trawls.

Results

The fishing trips that had enhanced logbooks and reported discards landed a total of 11.6 million pounds of fish, caught during 5,134 non-zero tows (Table 1). The logbooks for these trips reported total fish discards of 4.7 million pounds (exclusive of halibut and salmon), most of which was Pacific hake (24.8%), shark (17.8%), or sablefish (10.6%). The rockfish species as a group were 12.8% of the reported discards. The observers reported fish discards (exclusive of halibut and salmon) totaling 2.8 million pounds, from 2,102 tows. The largest category of observed discards was unidentified fish (29.8%). Most of the identified discards were Pacific hake (15.4% of all fish discards), shark (11.3%), and sablefish (7.6%). Rockfish species were 11.9% of the observed discards.

Evaluating the Accuracy of the Logbook Discard Data

More than half of the tows for which observer data were available could not be matched to corresponding logbooks, primarily because nine boats never reported discards when they had an observer on board. However, matched logbook and observer discard data were available from 15 boats for 919 tows during 118 fishing trips (Table 2). Discards of fish were reported in the logbooks or observed on 916 of the tows, and the logbooks reported fish discards for 889 of the 913 tows (97.4% agreement) for which the observer reported fish discards. With respect to identifying that individual species had been discarded on a tow, there was in general a fairly poor level of agreement between the logbooks and the observers, except for "high-profile" species such as sablefish (61.4% agreement), canary rockfish (52.2% agreement), and Pacific hake (53.9% agreement). Some species were rarely identified as discards in the logbooks. For example, only 2.7% of the tows with Pacific ocean perch discards and only 2.8% of the tows with English sole discards were correctly identified in the logbooks.

Oddly, the logbooks reported fish discards for three tows for which the observer reported none (Table 2, the column labeled "Lg no Ob"). These may represent reporting errors on the part of the skipper. For a substantial number of tows the logbooks reported discards of unidentified rockfish or unidentified fish that the observer was apparently unable to apportion to individual species. However, the moderate numbers of logbook reports of sablefish, Pacific hake, and shark discards that were not seen by the observers are difficult to explain. For our analysis we assumed that the observer records were correct and that the logbooks contain fair numbers of false-positive records of discards.

The ratios of the discards reported in the logbooks over the discards reported by the observers (Table 2) provides another measure of the accuracy of the logbooks (assuming the observer data are completely accurate). When summed over all tows, including those where the logbooks and observers disagreed that there were discards, the total logbook discards for all fish was only 0.79 of the observer discards. For most individual species the discards reported in the logbooks were considerably smaller than the discards reported by the observers. When the discard amounts were limited to those tows where the logbooks and observers agreed that there were discards, the ratios of logbook discards over observer discards were generally much closer to 1.0, as it would be if the logbook discards (and observer discards) were perfectly accurate.

Our formal analysis of the %Agreement between logbooks and observers that discards occurred (Table 3) in general indicated significant variability amongst the boats. Even with the "All Fish" discards, for which the overall %Agreement was almost 100%, there was one boat that had 0% agreement and another with only 50% agreement (Figure 1). At the level of individual species there was even more variation in the %Agreement values for the different boats. Except for the "All fish" category, there were significant improvements in the fits of the logistic regression models when they included a term for the size of the observed discards (the rows labeled "Boat + ObsDisc" in Table 3). Furthermore, the coefficients on the ObsDisc term were positive for all species except sanddabs (where the coefficient was not significantly different from zero), indicating that the %Agreement tended to increase as the observed discards increased. Large discards were more likely to be reported in the logbooks than small ones.

The formal analysis of the Log/Obs ratios, for tows that had non-zero discards reported by both the logbooks and observers, also indicated highly significant variation amongst the boats for the "All fish" category as well as for the individual species, except for those in the flatfish group (Table 4). Furthermore, there was very significant variation in the Log/Obs ratios at the trip-to-trip level for individual boats (Table 4, the rows labeled "Trip | Boat"). When factors were added to identify tows with more than 10% of the observed discards reported as unidentified fish (*ufsh*), there was a significant improvement in fit for "All Fish", the Deepwater Complex group and the Rockfish group (Table 4, the rows labeled "Ufsh.ObsDisc"). Also, the Log/Obs ratios for the tows with unidentified fish were in general larger than the ratios for the other tows. This result is consistent with the idea that the unidentified fish discards included quantities of the focal species, so that the reported discards of the focal species were too small. When factors were added to identify tows with questionable observer data (exactly the same as the logbook data or discards that were simple multiples of 100), there was a significant improvement in fit for the "All Fish" category but not for the other groups (Table 4, the rows labeled "Qtow.ObsDisc"). For the "All Fish" model the Log/Obs ratio for the tows without questionable data was 0.67, whereas the ratio for the tows with questionable data was 0.93. Most of the questionable tows were ones having logbook discards that were exactly the same as the observer discards, and many of these also were simple multiples of 100.

Estimating the Discard Rates

Over the course of the entire EDCP program there were 416 trips with complete logbook data (no tows with missing discard information) and there were 205 trips that were fully observed (no tows with missing discard information). We used the discard data from these trips to derive trip-level estimates of discard rate averages and standard deviations (Table 5). In general, the discard rates based on the logbooks were smaller than the rates based on the observers (Figure 3) by a factor of 0.92. The ratio of the logbook discard rate over the observer discard rate was variable among the different species, ranging from a low of 0.16 for petrale sole to 1.7 for widow rockfish. The discard rates from the logbooks were generally more variable than the rates based on the observer data, with the coefficients of variation from the logbook data being about 1.2 times larger than the coefficients of variation from the observer data.

Our formal analysis of the transformed discard rates derived from the observer data (Table 6) indicated highly significant variation among the boats for the "All Fish" category and for all of the individual species groups. The factors *Port* and *Area* were also important and significant explanatory variables. The factors for trips having tows with unidentified fish (*Ufsh*) and those having tows with questionable data (*Qtow*) were often significant, but had much less explanatory power than other variables, as measured by the rank of the adjusted R^2 statistic. The variables for the size of the total catch (*Lbs*) and the tow time (*Hrs*) were also significant but low ranking explanatory variables. We examined interactions between *Boat* and the other factors to evaluate in greater detail the importance of the other factors (Table 6, right-hand columns). This analysis indicated a strong *Gear* effect on the boat-specific discard rates for the "All Fish" category, a strong seasonal effect (*Qtr*) on the rates for the deepwater complex and flatfish species, a strong *Area* effect on the rates for the rockfish species, and a strong *Year* effect on the rates for the other species (lingcod and Pacific hake).

The analysis of the transformed discard rates derived from the logbook data (Table 7) also indicated highly significant variation among the boats for the "All Fish" category and for all of the individual species groups. Our analysis of interactions between *Boat* and the other factors indicated a strong *Year* effect on the boat-specific discard rates for the "All Fish" category and all the individual species groups except rockfish, for which the seasonal effect (*Qtr*) ranked higher than the *Year* effect. The factor identifying trips with observers on board (*Obs*) was generally significant, either as a main effect or as an interaction with *Boat*, which suggests that skippers and crews may have altered either their discarding practices or discard reporting practices when an observer was present.

Halibut Bycatch Rates

Weight and length data were available from 711 individual halibut measured by the EDCP observers. From these data we derived the following weight - length relationship, which we used for estimating weights for halibut with observed lengths but no weights,

$$\text{Weight (kg)} = 0.0000057389 \cdot \text{Length (cm)}^{3.1582}$$

For halibut with no observer length or weight data we used the overall average halibut weight, 7.65 kg (16.86 lb).

During the entire EDCP program halibut were caught on 733 of the 1,859 observed tows (39%) and were reported in logbooks for 690 of the 2,956 tows (23%) from the 395 trips that had complete logbook information on discards and hours of trawling (Table 8). Interpretation of the halibut bycatch data in the logbooks is complicated because some fishers reported their halibut bycatch as numbers of fish whereas others reported it as total weight of halibut. From those trips where both observers and logbooks reported halibut bycatch it was possible to make direct tow-by-tow comparisons of the numbers of halibut caught (Fig. 5a) and the weight of the halibut bycatch (Fig. 5b). When the logbooks reported halibut bycatch, the reported numbers of fish caught were almost identical to the numbers counted by the observers (78.4% agreement to within one fish), but on 152 of the 319 tows (48%) where the observers reported halibut bycatch, the corresponding logbooks listed zero halibut bycatch. The non-zero bycatch weights reported in the logbooks were much more variable than the corresponding bycatch numbers and in general were underestimates (57.2% too small) of the weights based on the observer data.

Our formal analysis of the halibut bycatch rates indicated that boat-to-boat variations were the dominant source of variability in the proportions of tows that caught halibut, both for the observer data (Table 9) and the logbook data (Table 10). The factor *Boat* was also the main source of variability in the logbook data for the four variables that we used to measure the positive halibut bycatch rates (numbers of halibut per trawl hour, weight of halibut per trawl hour, numbers of halibut per weight of gross fish landings, and weight of halibut per weight of gross fish landings). With the observer data the factor *Boat* was identified as the primary explanatory variable for the bycatch rates based on trawl hours, whereas *Area* was the primary explanatory variable for the bycatch rates based on the weight of the fish landings and *Boat* was the 2nd most influential variable. The factor *Port* was also an important source of variability in both data sets and for all five of the dependent (Y) variables examined. Oddly, the variable for trawl hours (*Hrs*) was not a significant explanatory variable for the proportions of tows that caught halibut, although one would expect that long tows would more frequently encounter halibut. As measured by the mean squared error (deviance/degrees of freedom), the most precise measure of the overall positive halibut bycatch rate was the one based on the numbers of halibut per pound of fish landings for the observer data and the one based on pounds of halibut per pound of fish landings for the logbook data.

Evaluating Whether the EDCP Data are Representative

To facilitate our analysis of fishing trip characteristics and whether the trips covered by the EDCP were representative, we divided the trip-level groundfish trawl landings in Oregon during the study period into three categories. "Hake" trips landed more than 10,000 pounds of fish that were at least 50% Pacific hake; "big" trips landed more than 10,000 pounds of fish that were less than 50% hake; and "small" trips landed less than 10,000 pounds of fish (Table 11). EDCP logbooks or observers covered none of the hake trips, but ODFW samplers regularly monitor the shore-based fishery for hake in Oregon for discards and bycatch. The hake trips accounted for 79% of the overall landings of fish in Oregon and 31% of the groundfish trips. In terms of their overall landings of fish and groundfish the trips covered by EDCP logbooks or observers tended to be *big* trips more than *small* trips, especially for the trips covered by logbooks. There was equal coverage by observers of big- and small-trip landings of the deepwater complex (Dover sole, thornyheads, and sablefish); observers covered the small-trip landings of rockfish more than the big-trip landings.

Principal Components Analysis (PCA) was applied to the trip-level data on overall landings and species composition (percent by weight) to derive a small number of summary statistics for each trip. The PCA for the data from the *big* trips (Fig. 6a) was moderately successful at simplifying the data, with the first three PCA axes accounting for 15.4%, 12.0%, and 8.0% of the variability in the data. Ideally, the first two or three principal components would account for 50% or more of the variability in the data being analyzed, but for these data the first three components only "explained" 35% of the variability. Similarly, the PCA applied to the data from the small trips (Fig. 6b) was only somewhat successful. The first principal component accounted for 13.7% of the variance, the second for 10.4%, and the third for 9.0%. Although the two data sets (*big* trips versus *small* trips) were analyzed separately, both analyses produced similar groupings of trips (lower panels of Fig. 6a and 6b). For example, trips that were dominated by the deep-water species had large positive scores for PCA1 and PCA2.

We calculated simple t-statistics to formally compare the PCA scores from the trips that were part of the EDCP with those that were not. For the *big* trips we found statistically significant differences ($P<0.01$) between the PCA1 scores from the trips that had enhanced logbooks versus those that did not, and between the PCA3 scores from the trips covered by observers versus those that were not. These results indicate that the among the trips making *big* landings of groundfish in Oregon, the trips covered by the EDCP made landings that had different species compositions than the landings by trips that were not covered under the EDCP. For the *small* trips we found statistically significant differences ($P<0.01$) between the PCA1 scores and PCA3 from the trips that had enhanced logbooks versus those that did not, as well as for the trips covered by observers versus those that were not. Among the trips making *small* landings of groundfish in Oregon, the trips covered by the EDCP made landings that had different species compositions than the landings by trips that were not covered under the EDCP. These results provide no support for the presumption that the trips covered by the EDCP were representative of the fleet at large.

Discussion

Collecting information on discards and bycatch is a time-consuming and costly process. However, unless reasonably accurate information is available on fishery removals (landings plus discards), it is very likely that stock assessments will produce estimates of exploitable stock size that are biased, or at least highly uncertain. Logbooks provide a relatively inexpensive mechanism for the collection of large quantities of data on discards. Our direct comparisons of the logbook discard data with the observer discard data, however, generally indicated that the enhanced logbooks were not very accurate either in terms of their identification of discards or their estimates of the amount discarded. Non-reporting of discards seemed especially to be a problem with unimportant species such flatfish, which are routinely discarded when they are of unmarketable size. Non-reporting of discards of Pacific ocean perch was also a particular problem, presumably because fishers have been discarding small amounts of this species for so long that they are no longer even aware of the practice. Given the intensity of debate in recent years over the catch quotas and trip limit regulations for thornyheads, the non-reporting of discards of the two thornyhead species was surprisingly large (62% non-agreement for longspine thornyheads, 70% non-agreement for shortspine thornyheads).

The estimates of discarding derived from the logbook data were not accurate at the level of individual tows (e.g., Fig. 1 and 2). However, the discard rates derived from the logbook data by averaging across tows and trips were fairly comparable to those based on the observer data (e.g., Fig. 3), although they were generally biased low. It certainly should be feasible to develop bias adjustment factors that could be used to inflate the logbook discard rates so that they more closely resembled the discard rates recorded by the at-sea observers. Extensive collections of discard data from logbooks would greatly increase the sample size and thus could provide much more precise estimates of discard rates. Because the discard rate estimates from the logbook data were generally more variable than the discard rates derived from the observer data (Table 5), it will take two or three trips with logbook data to achieve the same degree of precision as a single observed trip. Except for Pacific hake (discard rate ≈ 100%), the discard rates from both the logbook and observer data were extremely variable, with coefficients of variation ranging from 98% (sanddab) to 791% (petrale sole) for the logbook data, and from 76% (sablefish) to 611% (widow rockfish) for the observer data. Such high levels of variability imply that to obtain reliable estimates of discard rates it will be necessary to sample discards from very large numbers of trips.

Large boat-to-boat variations in the data were a dominant feature in the results from all of our analyses. This was the case in the accuracy of the logbooks discards and the estimates of discard rates derived from the logbook data and the observer data. Data collected from a one set of boats could be markedly different from the data collected from a different set of boats, which implies that large numbers of boats will need to be sampled in any program that monitors discards.

If future programs use fishers' logbooks to record discards the programs should provide the fishers with more training and practice to identify species and estimate discard amounts. In our tow-by-tow comparisons of the logbook data with the observer data it appeared that discrepancies between the two sometimes were the result of differences in species identification, for example, with the skipper reporting discards of miscellaneous rockfish while the observer reported several individual rockfish species. Also, a training program could encourage the fishers to be more aware of discarding so that small discards do not go unnoticed, as apparently occurred with the EDCP logbooks. Finally, the training program should help the fishers learn how to estimate discard amounts, especially with those species that are not landed. With species that are routinely discarded (e.g., dogfish) the fishers never receive any feedback to help them learn whether they correctly estimated the weight of the fish they discarded. With retained marketable species they have an opportunity to learn from their bad estimates, for example, when the processor pays them for 1000 pounds of fish but they thought they caught 2000 pounds.

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References

Cox, D.R. and E.J. Snell. 1989. *Analysis of binary data*, Second Edition. Chapman and Hall, London. 236 p.

Draper, N.R. and H. Smith. 1966. *Applied regression analysis*. John Wiley, New York. 407 p.

Francis, B., M. Green, and C. Payne. 1993. *The GLIM sytem, release 4 manual*. Clarendon Press, Oxford. 821 p.

McCullagh, P. and J.A. Nelder. 1983. *Generalized linear models*. Chapman and Hall, London. 261 p.

Pennington, M. 1983. Efficient estimators of abundance, for fish and plankton surveys. Biometrics 39:281-286.

Pennington, M. 1996. Estimating the mean and variance from highly skewed marine data. Fish. Bull. 94:498-505.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, NJ. 620 p.

Table 1. Summary of landings and discards by species reported in the enhanced logbooks and by the observers.

Species		-------------------- Logbook data --------------------					------------- Observer data -------------			
Code	Name	No. Tows	Landings*	Discards*	%Gross	Rank	No. Tows	Discards*	%Gross	Rank
GROSS	All Fish (ex. halibut & salmon)	5134	11597.2	4705.7	100.0%	1	2102	2869.4	100.0%	1
DOVR	Dover Sole	3276	2573.6	229.5	4.9%	8	798	84.3	2.9%	11
SABL	Sablefish	3311	922.9	500.1	10.6%	5	969	219.5	7.6%	6
LSPN	Longspine Thornyheads	1717	1114.8	76.5	1.6%	16	424	50.5	1.8%	13
SSPN	Shortspine Thornyheads	2440	332.0	89.0	1.9%	14	583	45.5	1.6%	14
THDS	Thornyhead Unidentified	344	0.0	38.0	0.8%	20	2	0.4	0.0%	32
ARTH	Arrowtooth Flounder	2159	869.7	108.1	2.3%	11	592	54.6	1.9%	12
CNRY	Canary Rockfish	1743	233.5	27.7	0.6%	23	53	14.3	0.5%	20
POP	Pacific Ocean Perch	582	183.0	9.9	0.2%	28	148	13.9	0.5%	21
WDOW	Widow Rockfish	1297	1594.4	79.7	1.7%	15	52	9.7	0.3%	22
YTRK	Yellowtail Rockfish	1373	696.8	189.9	4.0%	10	172	131.0	4.6%	9
SBTSG	All Sebastes	3774	1687.7	603.0	12.8%	4	1062	341.7	11.9%	4
BCAC	Bocaccio Rockfish	73	14.1	7.3	0.2%	30			0.0%	40
BLCK	Black Rockfish	14	0.8	0.0	0.0%	42			0.0%	40
LGRK	Large Rockfish	2065	293.6	17.3	0.4%	27	73	0.6	0.0%	31
SMRK	Small Rockfish	2108	378.0	337.5	7.2%	6	844	170.0	5.9%	8
ORCK	Other Rockfish	249	71.0	23.3	0.5%	24	180	25.7	0.9%	16
EGLS	English Sole	2338	223.1	18.2	0.4%	26	359	6.8	0.2%	23
PTRL	Petrale Sole	2353	530.9	2.7	0.1%	32	227	4.4	0.2%	25
REX	Rex Sole	2542	175.2	33.9	0.7%	21	844	39.8	1.4%	15
SDAB	Pacific Sanddab	268	100.1	50.5	1.1%	17	235	25.4	0.9%	17
BSOL	Butter Sole	58	0.2	0.2	0.0%	35	2	0.0	0.0%	38
CSOL	Curlfin Sole	14	0.3	0.0	0.0%	42	4	0.0	0.0%	36
RSOL	Rock Sole	96	1.1	0.0	0.0%	41	3	0.0	0.0%	37
SSOL	Sand Sole	105	13.2	0.2	0.0%	36	14	0.1	0.0%	34
STRY	Starry Flounder	67	5.9	0.1	0.0%	40	1	0.0	0.0%	39
OFLT	Other Flatfish	55	0.6	7.3	0.2%	29	689	17.1	0.6%	19

* Thousands of pounds.

Table 1. Summary of landings and discards by species reported in the enhanced logbooks and by the observers. (continued)

Species		Logbook data					Observer data			
Code	Name	No. Tows	Landings*	Discards*	%Gross	Rank	No. Tows	Discards*	%Gross	Rank
LCOD	Lingcod	1898	367.5	47.2	1.0%	18	277	21.5	0.8%	18
PWHT	Pacific Hake	2020	12.2	1168.4	24.8%	2	1180	441.3	15.4%	3
PCOD	Pacific Cod	780	53.4	0.1	0.0%	37	101	1.8	0.1%	27
SHRK	Shark unidentified	947	31.2	839.5	17.8%	3	1104	324.7	11.3%	5
SKAT	Skate unidentified	2923	386.4	206.0	4.4%	9	1108	116.7	4.1%	10
CMCK	Chub Mackerel (Pacific)	48	2.2	0.4	0.0%	33	83	1.7	0.1%	28
JMCK	Jack Mackerel	35	2.6	0.4	0.0%	34	85	2.9	0.1%	26
NSM	Nearshore Mixed Fish	33	0.0	45.3	1.0%	19			0.0%	40
OCTP	Octopus Unspecified	301	1.8	0.1	0.0%	39	118	1.3	0.0%	30
SQID	Squid Unspecified	213	18.7	6.3	0.1%	31	257	6.3	0.2%	24
STGR	Sturgeon	7	0.2	0.1	0.0%	38			0.0%	40
MISC	Miscellaneous Fish	1624	274.6	299.8	6.4%	7	1403	180.0	6.3%	7
UFLT	Flatfish Unidentified	200	0.0	21.5	0.5%	25	20	0.3	0.0%	33
URCK	Rockfish Unidentified	399	117.7	106.2	2.3%	12	39	1.6	0.1%	29
UFSH	Flatfish Unidentified	407	0.0	89.1	1.9%	13	317	854.9	29.8%	2
UMCK	Mackerel Unidentified	44	0.0	28.6	0.6%	22	10	0.0	0.0%	35
Shrmp	Shrimp						68	0.7		

* Thousands of pounds.

Table 2. Accuracy of logbook discard records based on matched logbook and observer tows. The "Discards (Lg>0 & Ob>0)" columns are the discard amounts for those matched tows where both the logbook and the observer reported non-zero discards for the given species.

			------- Tows w Discard -------				----- Discards (all tows) -----			Discards (Lg>0 & Ob>0)		
Species	N Trips	N Tows	Lg no Ob	Lg+Ob	Obs	%Agree	Log*	Obs*	ratio	Log*	Obs*	ratio
All Fish	118	919	3	889	913	97.4%	906.55	1151.91	0.79	906.48	1141.71	0.79
Dover sole	112	644	20	66	398	16.6%	24.37	29.75	0.82	19.48	20.53	0.95
Sablefish	112	657	39	310	505	61.4%	81.90	110.39	0.74	73.84	97.77	0.76
Longspine	89	332	13	96	253	37.9%	15.98	24.46	0.65	14.41	13.73	1.05
Shortspine	103	511	27	94	313	30.0%	17.39	26.19	0.66	14.25	11.91	1.20
Thornyheads	29	81	81	0	0		10.29	0.00				
Canary rk	56	111	5	12	23	52.2%	14.95	8.70	1.72	8.05	8.47	0.95
Pac oc perch	52	146	1	2	75	2.7%	2.30	2.96	0.78	2.00	1.84	1.09
Widow rk	58	147	2	6	25	24.0%	6.41	9.08	0.71	5.33	3.82	1.40
Yellowtail rk	56	193	7	22	52	42.3%	28.30	38.25	0.74	26.65	32.41	0.82
All Sebastes	109	607	32	188	481	39.1%	156.58	157.80	0.99	114.46	126.14	0.91
English sole	83	198	1	4	142	2.8%	0.17	2.05	0.08	0.16	0.10	1.62
Petrale sole	93	230	4	3	97	3.1%	0.25	1.20	0.21	0.01	0.05	0.28
Rex sole	96	441	7	42	406	10.3%	9.26	28.52	0.32	7.17	6.41	1.12
Sanddab	35	97	2	10	94	10.6%	9.98	17.97	0.56	8.38	13.97	0.60
Lingcod	82	231	3	16	101	15.8%	1.66	3.52	0.47	1.49	2.05	0.73
Pac hake	108	614	41	309	573	53.9%	180.19	182.83	0.99	129.44	151.29	0.86
Shark	109	541	33	104	508	20.5%	140.23	85.03	1.65	54.45	70.75	0.77
Skate	113	625	31	177	558	31.7%	22.41	46.96	0.48	19.00	29.17	0.65
UnID flatfish	20	54	43	4	11	36.4%	8.72	0.07	121.28	0.53	0.04	12.59
UnID rockfish	30	100	100	0	0		44.35	0.00				
UnID fish	82	306	209	31	97	32.0%	56.62	278.53	0.20	14.53	49.43	0.29

* Thousands of pounds.

Table 3. Analysis of the %Agreement between logbooks and observers that discarding occurred.

Model	Deviance	deg.free.	Δ Dev	Δ d.f.	F ratio	P value	R^2	Adj. R^2
All fish								
overall	105.58	117						
Boat	50.78	103	54.80	14	7.94	0.000	51.9%	45.4%
Boat + ObsDisc	50.53	102	0.25	1	0.50	0.479	52.1%	45.1%
Deepwater complex								
overall	953.87	348						
Boat	658.64	300	295.23	48	2.80	0.000	31.0%	19.9%
Boat + ObsDisc	591.51	296	67.13	4	8.40	0.000	38.0%	27.1%
Rockfish								
overall	396.92	172						
Boat	269.24	137	127.68	35	1.86	0.006	32.2%	14.8%
Boat + ObsDisc	194.73	132	74.51	5	10.10	0.000	50.9%	36.1%
Flatfish								
overall	102.54	129						
Boat	36.83	101	65.71	28	6.44	0.000	64.1%	54.1%
Boat + ObsDisc	29.74	98	7.09	3	7.79	0.000	71.0%	61.8%
Other fish								
overall	394.77	150						
Boat	258.10	124	136.67	26	2.53	0.000	34.6%	20.9%
Boat + ObsDisc	232.04	122	26.06	2	6.85	0.002	41.2%	27.7%

Table 4. Analysis of the accuracy of non-zero logbook discards versus observer discards.

Model	Deviance	deg.free.	Δ Dev	Δ d.f.	F ratio	P value	R^2	Adj. R^2
All fish								
overall	3341.70	888						
ObsDisc	740.26	888					77.8%	77.8%
Boat.ObsDisc	505.15	875	235.11	13	31.33	0.000	84.9%	84.7%
Trip.ObsDisc	312.48	773	427.78	115	9.20	0.000	90.6%	89.3%
Trip | Boat			192.67	102	4.67	0.000		
Ufsh.ObsDisc	645.25	887	95.01	1	130.60	0.000	80.7%	80.7%
QTow.ObsDisc	639.07	887	101.19	1	140.44	0.000	80.9%	80.9%
Deepwater complex								
overall	108.97	562						
ObsDisc	37.15	562					65.9%	65.9%
Boat.ObsDisc	21.46	526	15.69	36	10.68	0.000	80.3%	79.0%
Trip.ObsDisc	7.44	378	29.71	184	8.21	0.000	93.2%	89.8%
Trip | Boat			14.02	148	4.81	0.000		
Ufsh.ObsDisc	33.29	560	3.86	2	32.46	0.000	69.4%	69.3%
QTow.ObsDisc	37.15	560	0.01	2	0.04	0.962	65.9%	65.8%
Rockfish								
overall	398.38	225						
ObsDisc	43.71	225					89.0%	89.0%
Boat.ObsDisc	33.37	210	10.35	15	4.34	0.000	91.6%	91.0%
Trip.ObsDisc	18.01	161	25.70	64	3.59	0.000	95.5%	93.7%
Trip | Boat			15.36	49	2.80	0.000		
Ufsh.ObsDisc	41.45	223	2.26	2	6.08	0.003	89.6%	89.5%
QTow.ObsDisc	43.71	225	0.00	0			89.0%	89.0%
Flatfish								
overall	21.46	14						
ObsDisc	5.21	14					75.7%	75.7%
Boat.ObsDisc	5.20	8	0.01	6	0.00	1.000	75.8%	57.6%
Trip.ObsDisc	3.89	6	1.32	8	0.25	0.961	81.9%	57.7%
Trip | Boat			1.31	2	1.01	0.419		
Ufsh.ObsDisc	5.21	14	0.00	0			75.7%	75.7%
QTow.ObsDisc	5.21	14	0	0			75.7%	75.7%
Other fish								
overall	266.11	323						
ObsDisc	40.45	323					84.8%	84.8%
Boat.ObsDisc	28.95	306	11.50	17	7.15	0.000	89.1%	88.5%
Trip.ObsDisc	20.34	237	20.11	86	2.72	0.000	92.4%	89.6%
Trip | Boat			8.61	69	1.45	0.021		
Ufsh.ObsDisc	40.45	322	0.00	1	0.02	0.884	84.8%	84.8%
QTow.ObsDisc	40.29	322	0.16	1	1.24	0.265	84.9%	84.8%

Table 5. Discard rates from trips with logbooks versus trips with observers. These tabulations do not include trips with tows that were unobserved or for which logbook discards were missing.

Species	No. Trips	Landings*	Logbook Discards*	Discard Rate	St. Dev.	Coef. Var.
Complete logbook trips						
All Fish	416	6997.02	2551.50	0.2672	0.1914	0.7162
Dover	385	1468.35	98.49	0.0629	0.1583	2.5170
Sablefish	383	562.79	282.96	0.3346	0.3271	0.9774
Longspine	284	714.44	51.51	0.0673	0.1016	1.5091
Shortspine	327	201.55	55.24	0.2151	0.2962	1.3770
English	297	156.66	12.63	0.0746	0.0953	1.2769
Petrale	320	349.86	0.92	0.0026	0.0206	7.9077
Sanddab	48	53.13	45.07	0.4589	0.4528	0.9867
Lingcod	274	174.38	19.02	0.0983	0.2417	2.4589
Pac. Hake	303	2.33	657.29	0.9965	0.0503	0.0505
Sebastes	368	905.87	318.73	0.2603	0.2855	1.0967
Canary	202	125.57	16.05	0.1133	0.2489	2.1970
POP	85	109.32	7.58	0.0648	0.2133	3.2923
Widow	186	979.45	39.26	0.0385	0.1081	2.8088
Yellowtail	193	396.34	100.87	0.2029	0.3467	1.7086
Fully observed trips						
All Fish	205	4091.86	2568.50	0.3856	0.1841	0.4775
Dover	190	740.85	77.16	0.0943	0.2131	2.2593
Sablefish	192	283.28	203.25	0.4178	0.3183	0.7619
Longspine	139	333.09	47.07	0.1238	0.1535	1.2393
Shortspine	180	98.60	43.40	0.3056	0.3327	1.0886
English	152	69.64	6.50	0.0853	0.1240	1.4530
Petrale	167	182.81	3.09	0.0166	0.0568	3.4163
Sanddab	68	22.25	21.06	0.4863	0.4483	0.9219
Lingcod	154	162.32	21.34	0.1162	0.2640	2.2716
Pac. Hake	185	0.00	399.13	1.0000	0.0000	0.0000
Sebastes	193	871.80	325.22	0.2717	0.2621	0.9645
Canary	111	95.68	14.33	0.1303	0.2787	2.1392
POP	93	112.41	12.03	0.0967	0.2030	2.0998
Widow	111	416.16	9.68	0.0227	0.1389	6.1097
Yellowtail	120	447.39	126.29	0.2201	0.3428	1.5570

* Thousands of pounds.

Table 6. Influential variables for the observer discard rates.

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
All Fish								
overall	11.39	204						
Qtow	10.62	203	0.77	1	14.72	0.000	6.3%	5
Ufsh	10.94	203	0.45	1	8.35	0.004	3.5%	7
Boat	7.76	181	3.63	23	3.69	0.000	23.2%	1
Port	10.79	196	0.60	8	1.36	0.216	1.4%	8
Gear	8.86	201	2.53	3	19.11	0.000	21.0%	2
Area	9.44	196	1.95	8	5.06	0.000	13.7%	3
Year	9.78	200	1.60	4	8.19	0.000	12.4%	4
Qtr	10.58	200	0.81	4	3.82	0.005	5.2%	6
Lbs	11.27	203	0.12	1	2.11	0.148	0.5%	9
Hrs	11.38	203	0.01	1	0.19	0.662	-0.4%	10
Deepwater complex								
overall	174.39	697						
Qtow	174.01	693	0.38	4	0.38	0.823	-0.4%	10
Ufsh	169.45	693	4.95	4	5.06	0.001	2.3%	9
Boat	126.41	606	47.98	91	2.53	0.000	16.6%	1
Port	156.70	666	17.70	31	2.43	0.000	6.0%	2
Gear	167.79	687	6.61	10	2.70	0.003	2.4%	8
Area	157.99	666	16.40	31	2.23	0.000	5.2%	3
Year	161.77	681	12.62	16	3.32	0.000	5.1%	4
Qtr	164.03	681	10.37	16	2.69	0.000	3.7%	5
Lbs	169.93	696	4.46	1	18.29	0.000	2.4%	7
Hrs	169.16	696	5.23	1	21.52	0.000	2.9%	6

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Boat	7.76	181	3.63	23	3.69	0.000	23.2%	
.Port	7.48	177	0.28	4	1.63	0.168	24.3%	4
.Gear	5.35	173	2.41	8	9.75	0.000	44.7%	1
.Area	6.01	167	1.75	14	3.47	0.000	35.5%	2
.Year	7.36	171	0.40	10	0.92	0.513	22.9%	6
.Qtr	6.34	153	1.42	28	1.22	0.220	25.8%	3
+Lbs	7.64	180	0.12	1	2.76	0.099	24.0%	5
+Hrs	7.76	180	0.00	1	0.01	0.925	22.8%	7
Boat	126.41	606	47.98	91	2.53	0.000	16.6%	
.Port	122.35	592	4.06	14	1.40	0.147	17.4%	7
.Gear	115.84	583	10.57	23	2.31	0.001	20.6%	3
.Area	109.29	555	17.12	51	1.70	0.002	21.3%	2
.Year	116.84	568	9.57	38	1.22	0.171	17.8%	6
.Qtr	96.69	501	29.72	105	1.47	0.004	22.9%	1
+Lbs	121.08	605	5.33	1	26.64	0.000	20.0%	4
+Hrs	121.98	605	4.43	1	21.99	0.000	19.4%	5

Table 6. Influential variables for the observer discard rates. (continued)

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Rockfish								
overall	115.21	623						
Qtow	112.96	618	2.25	5	2.46	0.032	1.2%	7
Ufsh	104.04	618	11.17	5	13.27	0.000	9.0%	4
Boat	71.15	515	44.06	108	2.95	0.000	25.3%	1
Port	89.21	586	26.01	37	4.62	0.000	17.7%	3
Gear	113.19	613	2.03	10	1.10	0.362	0.2%	8
Area	87.43	585	27.78	38	4.89	0.000	19.2%	2
Year	106.98	603	8.23	20	2.32	0.001	4.1%	5
Qtr	109.60	603	5.61	20	1.54	0.061	1.7%	6
Lbs	114.87	622	0.34	1	1.85	0.175	0.1%	9
Hrs	114.99	622	0.23	1	1.23	0.268	0.0%	10
Flatfish								
overall	52.26	384						
Qtow	51.91	381	0.35	3	0.87	0.459	-0.1%	9
Ufsh	49.51	381	2.75	3	7.04	0.000	4.5%	4
Boat	31.80	324	20.46	60	3.47	0.000	27.9%	1
Port	39.35	360	12.91	24	4.92	0.000	19.7%	2
Gear	49.96	376	2.30	8	2.16	0.030	2.4%	8
Area	41.78	360	10.48	24	3.76	0.000	14.7%	3
Year	48.95	373	3.31	11	2.29	0.010	3.6%	6
Qtr	49.18	372	3.08	12	1.94	0.028	2.9%	7
Lbs	50.22	383	2.04	1	15.59	0.000	3.7%	5
Hrs	52.26	383	0.00	1	0.00	0.952	-0.3%	10

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Boat	71.15	515	44.06	108	2.95	0.000	25.3%	
.Port	69.10	502	2.06	13	1.15	0.315	25.6%	3
.Gear	69.20	491	1.95	24	0.58	0.948	23.8%	7
.Area	58.72	463	12.43	52	1.89	0.000	31.4%	1
.Year	62.80	471	8.35	44	1.42	0.042	27.9%	2
.Qtr	54.82	397	16.33	118	1.00	0.483	25.3%	4
+Lbs	71.15	514	0.00	1	0.02	0.895	25.2%	6
+Hrs	71.11	514	0.05	1	0.33	0.567	25.2%	5
Boat	31.80	324	20.46	60	3.47	0.000	27.9%	
.Port	31.64	314	0.16	10	0.16	0.999	26.0%	7
.Gear	27.95	311	3.85	13	3.29	0.000	34.0%	2
.Area	27.45	291	4.35	33	1.40	0.079	30.7%	3
.Year	28.49	302	3.31	22	1.59	0.046	30.7%	4
.Qtr	20.85	265	10.95	59	2.36	0.000	42.2%	1
+Lbs	30.69	323	1.11	1	11.68	0.001	30.2%	5
+Hrs	31.73	323	0.07	1	0.71	0.401	27.8%	6

Table 6. Influential variables for the observer discard rates. (continued)

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Other fish								
overall	36.19	337						
Qtow	36.19	335	0.01	2	0.05	0.956	-0.6%	9
Ufsh	35.62	335	0.57	2	2.68	0.070	1.0%	6
Boat	22.69	292	13.51	45	3.86	0.000	27.7%	1
Port	28.01	321	8.19	16	5.87	0.000	18.8%	2
Gear	36.05	332	0.14	5	0.26	0.933	-1.1%	10
Area	28.77	321	7.42	16	5.17	0.000	16.5%	3
Year	29.54	329	6.65	8	9.26	0.000	16.4%	4
Qtr	34.51	329	1.69	8	2.01	0.045	2.3%	5
Lbs	36.10	336	0.10	1	0.93	0.336	0.0%	8
Hrs	35.85	336	0.35	1	3.27	0.072	0.7%	7

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Boat	22.69	292	13.51	45	3.86	0.000	27.7%	
.Port	22.21	285	0.48	7	0.88	0.525	27.4%	6
.Gear	22.10	281	0.58	11	0.68	0.762	26.8%	7
.Area	19.62	267	3.06	25	1.67	0.027	31.6%	2
.Year	20.02	273	2.66	19	1.91	0.013	31.7%	1
.Qtr	17.84	237	4.85	55	1.17	0.210	29.9%	3
+Lbs	22.63	291	0.06	1	0.79	0.374	27.6%	5
+Hrs	22.13	291	0.56	1	7.31	0.007	29.2%	4

Table 7. Influential variables for the logbook discard rates.

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
All Fish								
overall	29.16	415						
Boat	24.24	390	4.92	25	3.17	0.000	11.5%	1
Year	28.31	411	0.85	4	3.07	0.016	2.0%	2
Qtr	28.32	411	0.84	4	3.04	0.017	1.9%	3
Lbs	29.16	414	0.00	1	0.06	0.809	-0.2%	5
Obs	29.15	414	0.01	1	0.21	0.647	-0.2%	4
Deepwater complex								
overall	240.93	1375						
Boat	179.42	1278	61.51	97	4.52	0.000	19.9%	1
Year	218.12	1361	22.81	14	10.17	0.000	8.5%	2
Qtr	234.11	1359	6.83	16	2.48	0.001	1.7%	3
Lbs	240.34	1374	0.59	1	3.40	0.065	0.2%	5
Obs	239.13	1371	1.80	4	2.58	0.036	0.5%	4
Rockfish								
overall	135.41	1029						
Boat	113.43	936	21.98	93	1.95	0.000	7.9%	1
Year	131.94	1010	3.46	19	1.40	0.120	0.7%	4
Qtr	129.00	1009	6.40	20	2.50	0.000	2.8%	2
Lbs	132.42	1028	2.98	1	23.15	0.000	2.1%	3
Obs	135.20	1024	0.21	5	0.31	0.905	-0.3%	5

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Boat	24.24	390	4.92	25	3.17	0.000	11.5%	
.Year	17.46	369	6.78	21	6.82	0.000	32.6%	1
.Qtr	20.53	343	3.70	47	1.32	0.089	14.8%	3
.Lbs	24.18	389	0.06	1	1.01	0.315	11.6%	4
.Obs	22.30	381	1.94	9	3.68	0.000	16.7%	2
Boat	179.42	1278	61.51	97	4.52	0.000	19.9%	
.Year	148.91	1203	30.51	75	3.29	0.000	29.4%	1
.Qtr	153.10	1115	26.32	163	1.18	0.077	21.6%	2
.Lbs	178.35	1277	1.07	1	7.69	0.006	20.3%	4
.Obs	172.94	1242	6.48	36	1.29	0.117	20.5%	3
Boat	113.43	936	21.98	93	1.95	0.000	7.9%	
.Year	96.56	860	16.86	76	1.98	0.000	14.7%	2
.Qtr	82.40	778	31.03	158	1.85	0.000	19.5%	1
.Lbs	113.00	935	0.43	1	3.53	0.060	8.2%	4
.Obs	103.19	904	10.24	32	2.80	0.000	13.3%	3

Table 7. Influential variables for the logbook discard rates. (continued)

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Flatfish								
overall	22.68	662						
Boat	11.49	606	11.19	56	10.54	0.000	44.7%	1
Year	21.98	651	0.69	11	1.87	0.040	1.4%	3
Qtr	22.23	650	0.45	12	1.10	0.360	0.2%	5
Lbs	22.34	661	0.33	1	9.84	0.002	1.3%	4
Obs	22.21	659	0.47	3	4.61	0.003	1.6%	2
Other fish								
overall	55.67	575						
Boat	43.76	530	11.91	45	3.21	0.000	14.7%	2
Year	40.70	567	14.97	8	26.07	0.000	25.9%	1
Qtr	54.89	567	0.78	8	1.01	0.427	0.0%	4
Lbs	55.67	574	0.00	1	0.03	0.871	-0.2%	5
Obs	54.84	573	0.83	2	4.36	0.013	1.2%	3

Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Boat	11.49	606	11.19	56	10.54	0.000	44.7%	
.Year	9.36	558	2.12	48	2.63	0.000	51.0%	1
.Qtr	9.92	509	1.57	97	0.83	0.869	43.1%	4
.Lbs	11.45	605	0.03	1	1.74	0.187	44.7%	3
.Obs	10.57	585	0.91	21	2.40	0.000	47.2%	2
Boat	43.76	530	11.91	45	3.21	0.000	14.7%	
.Year	32.03	491	11.73	39	4.61	0.000	32.6%	1
.Qtr	35.25	447	8.50	83	1.30	0.051	18.5%	2
.Lbs	43.73	529	0.03	1	0.38	0.538	14.6%	3
.Obs	42.50	514	1.26	16	0.95	0.512	14.6%	4

Table 8. Halibut bycatch reported in the enhanced logbooks and by the observers. These tabulations exclude trips with unobserved tows or for which logbook discards were missing.

	Logbooks	Observers
Total Number of Trips <a>	395	205
Total Number of Tows <a>	2956	1859
Total Tow Duration (hr) <a>	15,010.6	8,160.9
Number of Tows with Halibut	690	733
Number of Halibut Caught <b>	5,079	11,221
Halibut Catch Weight (lb) <c>	123,956	188,066
Number of Halibut per Trawl Hour <d>	0.848	1.375
Halibut Weight per Trawl Hour <e>	14.53	23.05
Number of Halibut / Landed Fish Weight <d>	0.001776	0.002742
Halibut Weight / Landed Fish Weight <e>	0.03154	0.04596

<a> Excludes trips with incomplete data (missing discards, missing trawl hours).
<b> Many logbooks reported halibut bycatch only as weight.
<c> Many logbooks reported halibut bycatch only as numbers of fish.
<d> From logbooks that reported halibut bycatch as the numbers of halibut.
<e> From logbooks that reported halibut bycatch as the weight of halibut.

Table 9. Influential variables for halibut bycatch rates from the observer data.

Y-Variable	Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Proportions of tows that caught halibut									
logit	overall	740.37	204						
logit	Qtow	740.31	203	0.05	1	0.01	0.903	-0.5%	10
logit	Ufsh	719.23	203	21.14	1	5.97	0.015	2.4%	6
logit	Boat	480.12	181	260.25	23	4.27	0.000	26.9%	1
logit	Port	605.56	196	134.81	8	5.45	0.000	14.9%	3
logit	Gear	718.94	201	21.43	3	2.00	0.116	1.4%	7
logit	Area	562.27	196	178.10	8	7.76	0.000	21.0%	2
logit	Year	719.29	200	21.08	4	1.47	0.214	0.9%	8
logit	Qtr	682.46	200	57.91	4	4.24	0.003	6.0%	5
logit	Lbs	684.96	203	55.41	1	16.42	0.000	7.0%	4
logit	Hrs	740.27	203	0.10	1	0.03	0.868	-0.5%	9
Halibut bycatch rate$_1$ (numbers of halibut per hour of trawling)									
ln(No/Hr)	overall	412.89	161						
ln(No/Hr)	Qtow	402.09	160	10.80	1	4.30	0.040	2.0%	8
ln(No/Hr)	Ufsh	393.69	160	19.19	1	7.80	0.006	4.1%	6
ln(No/Hr)	Boat	213.77	138	199.12	23	5.59	0.000	39.6%	1
ln(No/Hr)	Port	258.38	154	154.51	7	13.16	0.000	34.6%	2
ln(No/Hr)	Gear	404.32	159	8.56	2	1.68	0.189	0.8%	9
ln(No/Hr)	Area	296.47	153	116.42	8	7.51	0.000	24.4%	3
ln(No/Hr)	Year	392.01	157	20.87	4	2.09	0.085	2.6%	7
ln(No/Hr)	Qtr	370.69	157	42.20	4	4.47	0.002	7.9%	5
ln(No/Hr)	Lbs	346.05	160	66.83	1	30.90	0.000	15.7%	4
ln(No/Hr)	Hrs	408.28	160	4.60	1	1.80	0.181	0.5%	10
Halibut bycatch rate$_1$ (weight of halibut [lb] per hour of trawling)									
ln(Lb/Hr)	overall	406.63	161						
ln(Lb/Hr)	Qtow	394.10	160	12.53	1	5.09	0.025	2.5%	7
ln(Lb/Hr)	Ufsh	386.85	160	19.78	1	8.18	0.005	4.3%	6
ln(Lb/Hr)	Boat	232.00	138	174.63	23	4.52	0.000	33.4%	1
ln(Lb/Hr)	Port	274.16	154	132.47	7	10.63	0.000	29.5%	2
ln(Lb/Hr)	Gear	401.23	159	5.40	2	1.07	0.345	0.1%	9
ln(Lb/Hr)	Area	299.97	153	106.66	8	6.80	0.000	22.4%	3
ln(Lb/Hr)	Year	396.60	157	10.03	4	0.99	0.413	0.0%	10
ln(Lb/Hr)	Qtr	369.39	157	37.24	4	3.96	0.004	6.8%	5
ln(Lb/Hr)	Lbs	352.41	160	54.23	1	24.62	0.000	12.8%	4
ln(Lb/Hr)	Hrs	399.47	160	7.17	1	2.87	0.092	1.1%	8

Table 9. Influential variables for halibut bycatch rates from the observer data. (continued)

Y-Variable	Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Halibut bycatch rate$_2$ (numbers of halibut per gross landings of fish [lb])									
ln(No/Gr)	overall	350.55	161						
ln(No/Gr)	Qtow	344.56	160	5.99	1	2.78	0.097	1.1%	7
ln(No/Gr)	Ufsh	335.48	160	15.07	1	7.19	0.008	3.7%	6
ln(No/Gr)	Boat	203.86	138	146.69	23	4.32	0.000	32.2%	2
ln(No/Gr)	Port	264.64	154	85.91	7	7.14	0.000	21.1%	3
ln(No/Gr)	Gear	299.20	159	51.35	2	13.64	0.000	13.6%	4
ln(No/Gr)	Area	220.67	153	129.87	8	11.26	0.000	33.8%	1
ln(No/Gr)	Year	339.64	157	10.91	4	1.26	0.288	0.6%	8
ln(No/Gr)	Qtr	312.39	157	38.15	4	4.79	0.001	8.6%	5
ln(No/Gr)	Lbs	348.70	160	1.85	1	0.85	0.359	-0.1%	9
ln(No/Gr)	Hrs	350.15	160	0.40	1	0.18	0.669	-0.5%	10
Halibut bycatch rate$_2$ (weight of halibut [lb] per gross landings of fish [lb])									
ln(Lb/Gr)	overall	358.62	161						
ln(Lb/Gr)	Qtow	351.33	160	7.29	1	3.32	0.070	1.4%	7
ln(Lb/Gr)	Ufsh	343.03	160	15.59	1	7.27	0.008	3.7%	6
ln(Lb/Gr)	Boat	223.31	138	135.31	23	3.64	0.000	27.4%	2
ln(Lb/Gr)	Port	289.71	154	68.91	7	5.23	0.000	15.5%	3
ln(Lb/Gr)	Gear	300.13	159	58.49	2	15.49	0.000	15.3%	4
ln(Lb/Gr)	Area	228.49	153	130.13	8	10.89	0.000	33.0%	1
ln(Lb/Gr)	Year	354.38	157	4.24	4	0.47	0.758	-1.3%	10
ln(Lb/Gr)	Qtr	324.37	157	34.25	4	4.14	0.003	7.2%	5
ln(Lb/Gr)	Lbs	358.32	160	0.30	1	0.13	0.715	-0.5%	9
ln(Lb/Gr)	Hrs	357.26	160	1.36	1	0.61	0.437	-0.2%	8

Table 10. Influential variables for halibut bycatch rates from the logbook data.

Y-Variable	Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Proportions of tows that caught halibut									
logit	overall	1242.02	394						
logit	Boat	866.07	370	375.95	24	6.7	0.000	0.2575	1
logit	Port	1075.15	386	166.87	8	7.5	0.000	0.1164	2
logit	Gear	1241.95	393	0.07	1	0.0	0.880	-0.0025	7
logit	Year	1106.39	390	135.63	4	12.0	0.000	0.1001	3
logit	Qtr	1157.46	390	84.56	4	7.1	0.000	0.0585	4
logit	Lbs	1230.11	393	11.91	1	3.8	0.052	0.0071	5
logit	Hrs	1241.68	393	0.34	1	0.1	0.744	-0.0023	6
Halibut bycatch rate$_1$ (numbers of halibut per hour of trawling)									
No/Hr	overall	319.12	153						
No/Hr	Boat	222.63	136	96.49	17	3.5	0.000	0.2152	1
No/Hr	Port	254.83	147	64.29	6	6.2	0.000	0.1689	2
No/Hr	Gear	316.47	152	2.66	1	1.3	0.260	0.0018	7
No/Hr	Year	270.29	150	48.84	3	9.0	0.000	0.1361	3
No/Hr	Qtr	299.03	149	20.09	4	2.5	0.045	0.0378	5
No/Hr	Lbs	308.47	152	10.66	1	5.3	0.023	0.0270	6
No/Hr	Hrs	304.99	152	14.14	1	7.0	0.009	0.0380	4
Halibut bycatch rate$_1$ (weight of halibut [lb] per hour of trawling)									
Lb/Hr	overall	387.26	205						
Lb/Hr	Boat	285.77	184	101.49	21	3.1	0.000	0.1778	1
Lb/Hr	Port	316.16	199	71.10	6	7.5	0.000	0.1590	2
Lb/Hr	Gear	387.25	204	0.00	1	0.0	0.962	-0.0049	7
Lb/Hr	Year	358.10	201	29.16	4	4.1	0.003	0.0569	3
Lb/Hr	Qtr	368.59	201	18.66	4	2.5	0.041	0.0293	6
Lb/Hr	Lbs	367.19	204	20.07	1	11.2	0.001	0.0472	4
Lb/Hr	Hrs	371.25	204	16.01	1	8.8	0.003	0.0366	5

Table 10. Influential variables for halibut bycatch rates from the logbook data. (continued)

Y-Variable	Model	Dev	df	Δ Dev	Δ df	F ratio	P value	Adj. R^2	Rank
Halibut bycatch rate$_2$ (numbers of halibut per gross landings of fish [lb])									
No/Gr	overall	299.44	153						
No/Gr	Boat	172.99	136	126.45	17	5.8	0.000	0.3501	1
No/Gr	Port	243.93	147	55.51	6	5.6	0.000	0.1521	3
No/Gr	Gear	295.10	152	4.34	1	2.2	0.137	0.0080	6
No/Gr	Year	243.12	150	56.32	3	11.6	0.000	0.1718	2
No/Gr	Qtr	278.87	149	20.57	4	2.7	0.031	0.0437	4
No/Gr	Lbs	295.18	152	4.26	1	2.2	0.141	0.0077	7
No/Gr	Hrs	294.96	152	4.48	1	2.3	0.131	0.0085	5
Halibut bycatch rate$_2$ (weight of halibut [lb] per gross landings of fish [lb])									
Lb/Gr	overall	344.25	205						
Lb/Gr	Boat	239.80	184	104.45	21	3.8	0.000	0.2239	1
Lb/Gr	Port	299.25	199	44.99	6	5.0	0.000	0.1045	2
Lb/Gr	Gear	343.47	204	0.77	1	0.5	0.499	-0.0026	7
Lb/Gr	Year	321.43	201	22.81	4	3.6	0.008	0.0477	3
Lb/Gr	Qtr	333.45	201	10.80	4	1.6	0.169	0.0121	4
Lb/Gr	Lbs	342.06	204	2.19	1	1.3	0.254	0.0015	6
Lb/Gr	Hrs	338.47	204	5.78	1	3.5	0.063	0.0120	5

Table 11. Groundfish trawl landings in Oregon during the study period and landings by groundfish trawlers covered by enhanced logbooks or at-sea observers. "Hake" trips landed more than 10,000 pounds that were at least 50% Pacific hake. "Big" trips landed more than 10,000 pounds with less than 50% Pacific hake. "Small" trips landed less than 10,000 pounds.

		------- Logbooks? -------			------- Observers? -------		
Trip Type	Overall	No	Yes	%Yes	No	Yes	%Yes
Number of Trips (unique Boat & Date combinations)							
Hake	4,355	4,355	0	0%	4,355	0	0%
Big	6,307	5,835	472	7.48%	6,186	121	1.92%
Small	3,431	3,231	200	5.83%	3,382	49	1.43%
Overall	14,093	13,421	672	4.77%	13,923	170	1.21%
Landings (millions of pounds):			All Fish				
Hake	652.849	652.849	0	0%	652.849	0	0%
Big	156.699	145.540	11.159	7.12%	153.543	3.156	2.01%
Small	17.898	16.660	1.237	6.91%	17.589	0.309	1.72%
Overall	827.446	815.049	12.397	1.50%	823.981	3.465	0.42%
	All Groundfish						
Hake	646.586	646.586	0	0%	646.586	0	0%
Big	156.474	145.334	11.140	7.12%	153.319	3.155	2.02%
Small	17.843	16.612	1.231	6.90%	17.535	0.308	1.73%
Overall	820.903	808.532	12.371	1.51%	817.440	3.463	0.42%
	DTS (Dover sole, thornyheads, sablefish)						
Hake	0.219	0.219	0	0%	0.219	0	0%
Big	59.862	55.125	4.737	7.91%	58.677	1.185	1.98%
Small	8.692	8.039	0.653	7.52%	8.519	0.173	1.99%
Overall	68.773	63.384	5.390	7.84%	67.415	1.358	1.97%
	All Flatfish						
Hake	0.013	0.013	0	0%	0.013	0	0%
Big	58.326	54.329	3.997	6.85%	57.323	1.003	1.72%
Small	8.517	7.987	0.530	6.23%	8.418	0.099	1.16%
Overall	66.857	62.329	4.528	6.77%	65.755	1.102	1.65%
	All Rockfish						
Hake	5.450	5.450	0	0%	5.450	0	0%
Big	60.575	56.680	3.895	6.43%	59.348	1.227	2.03%
Small	3.445	3.239	0.206	5.98%	3.364	0.081	2.34%
Overall	69.469	65.369	4.101	5.90%	68.162	1.308	1.88%
	Pacific Hake						
Hake	636.800	636.800	0	0%	636.800	0	0%
Big	0.336	0.320	0.016	4.85%	0.336	0	0%
Small	0.089	0.089	0	0%	0.089	0	0%
Overall	637.225	637.209	0.016	0%	637.225	0	0%

Figure 1. Box and whisker plot showing boat-to-boat variability in the %Agreement between the logbooks and observers that discarding occurred.

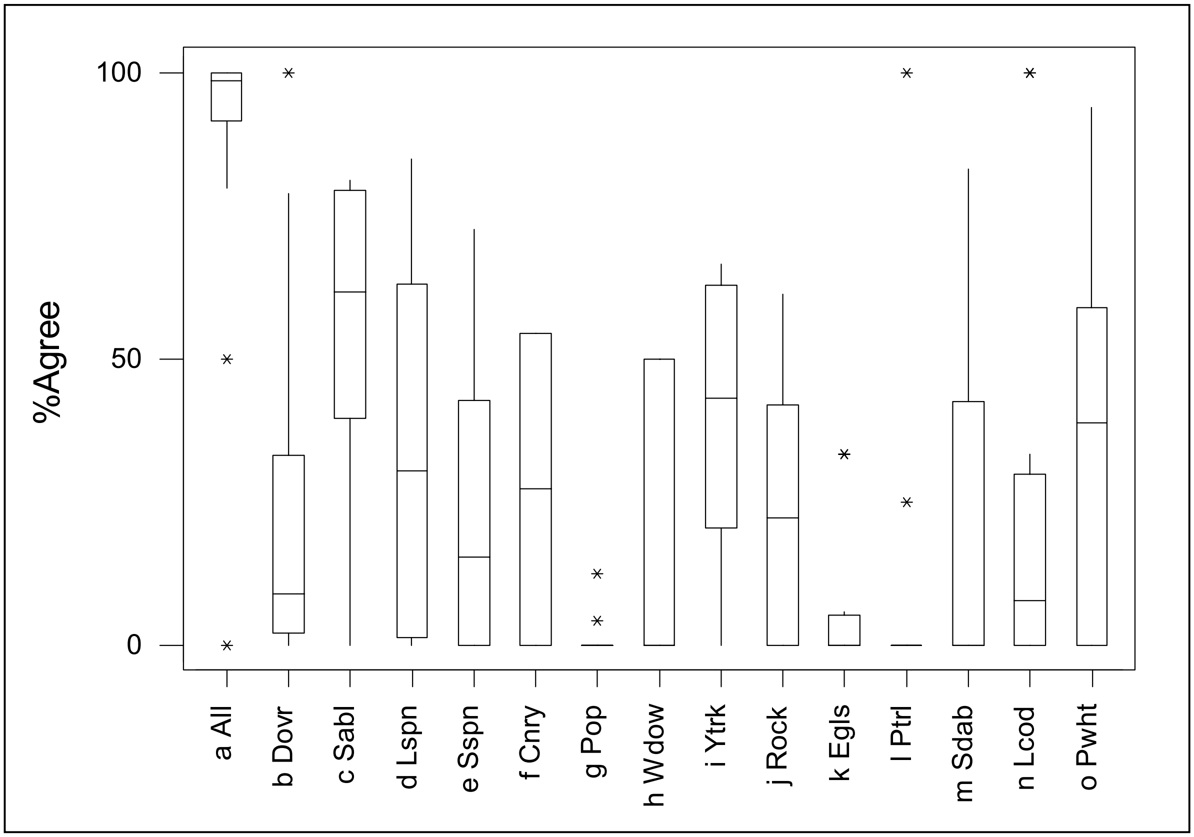


Figure 2. Box and whisker plot showing boat-to-boat variability in the $\log_{10}$ of the Log/Obs Ratio (logbook discards over observer discards) for tows where both reported discards. Here the ratios were based only on those tows where both logbooks and observers indicated non-zero discard amounts. The horizontal line indicates perfect agreement between the logbook discards and the observer discards.

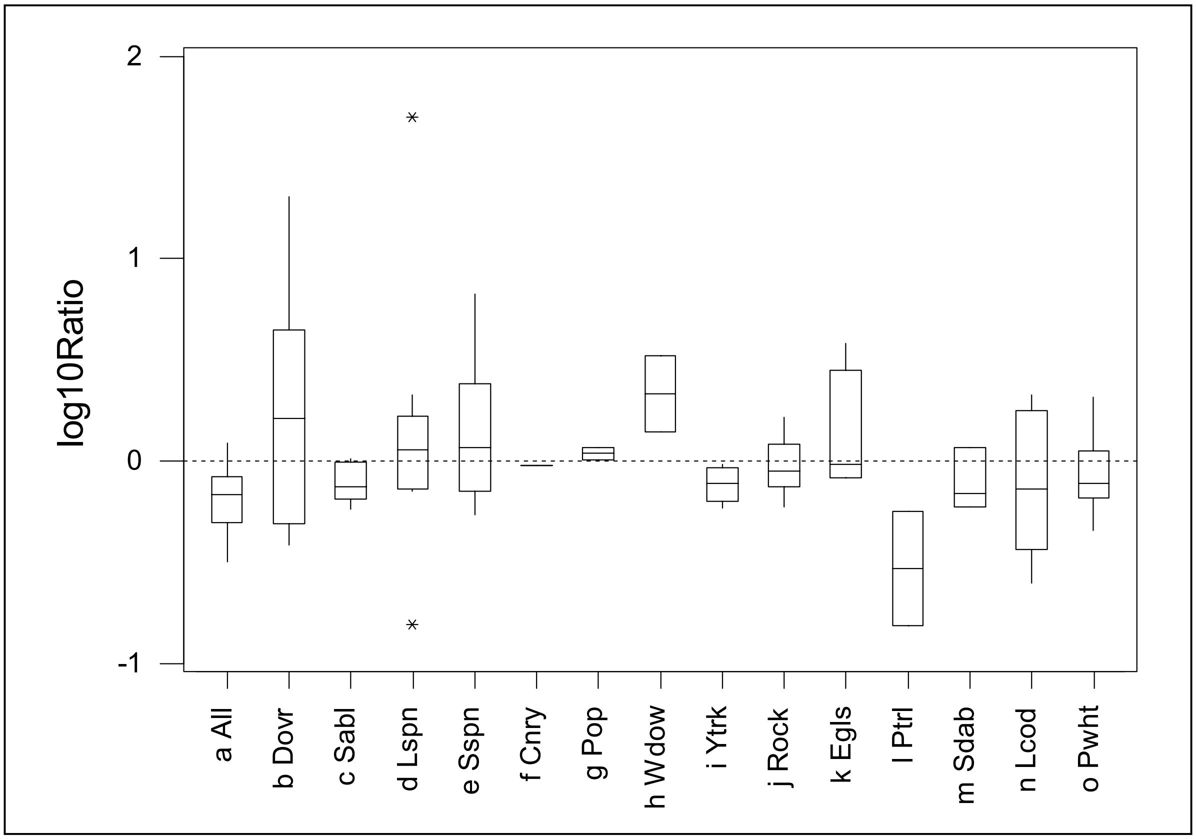


Figure 3. Comparison of overall logbook discard rates with observer discards. The diagonal line indicates exact equality between the two rates.

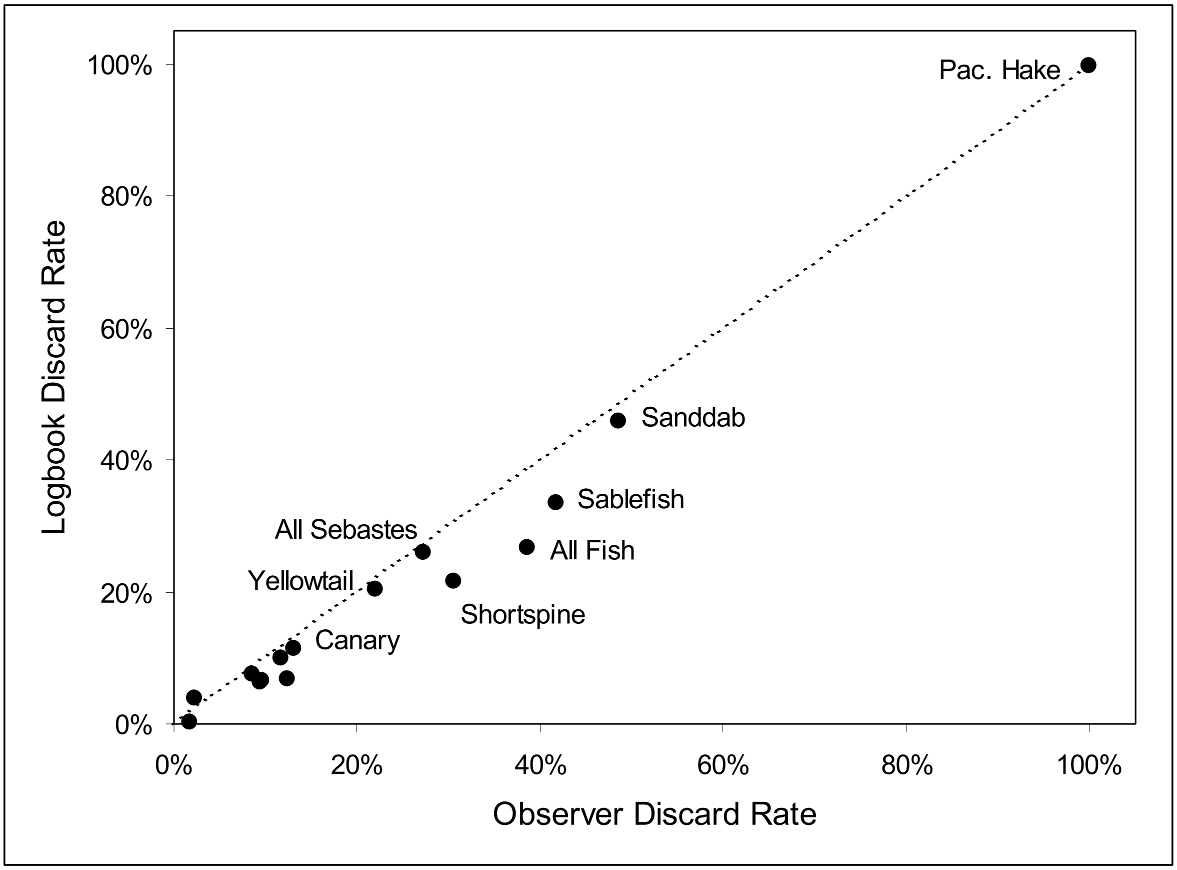


Figure 4. Individual weights and lengths of halibut measured by the observers and the fitted weight-length relationship used to estimate halibut weights from their lengths.

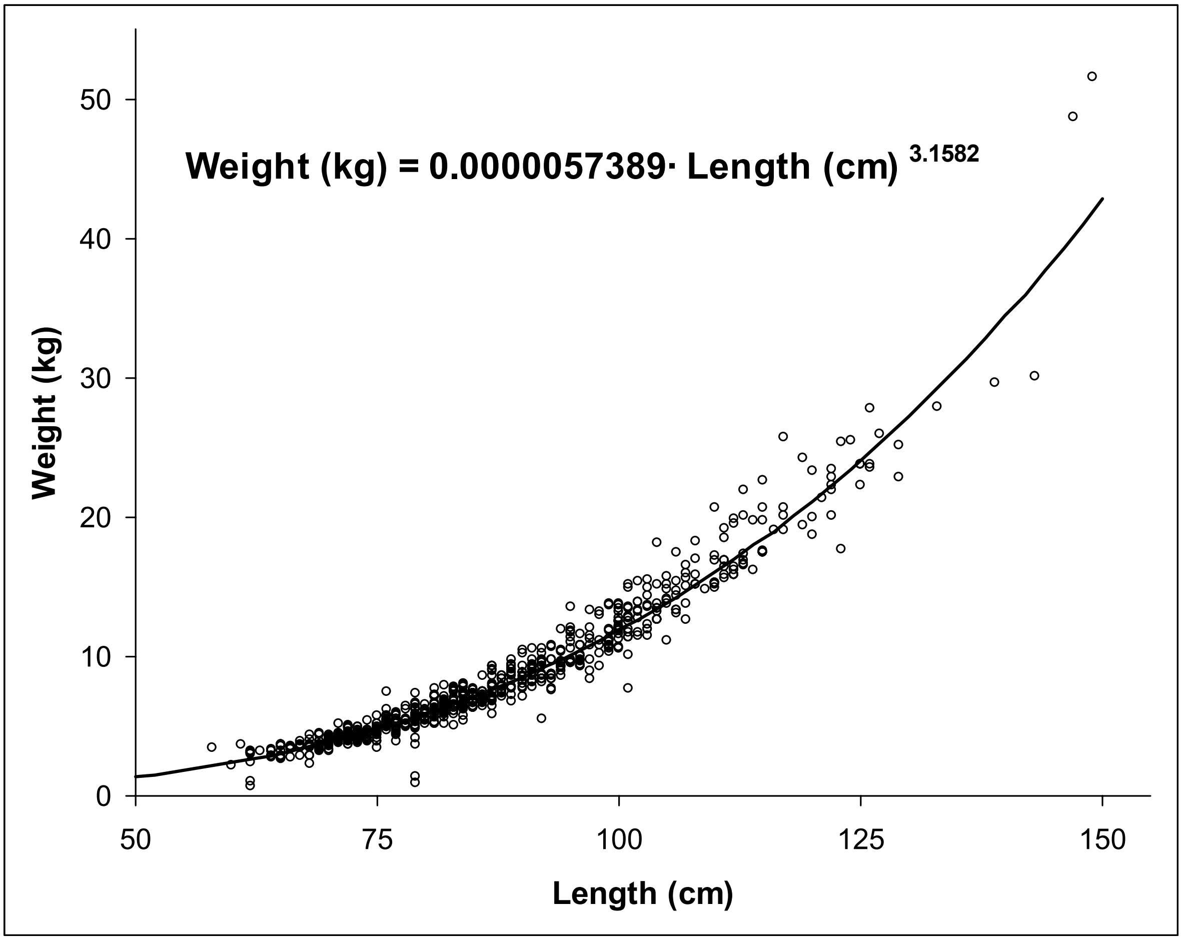
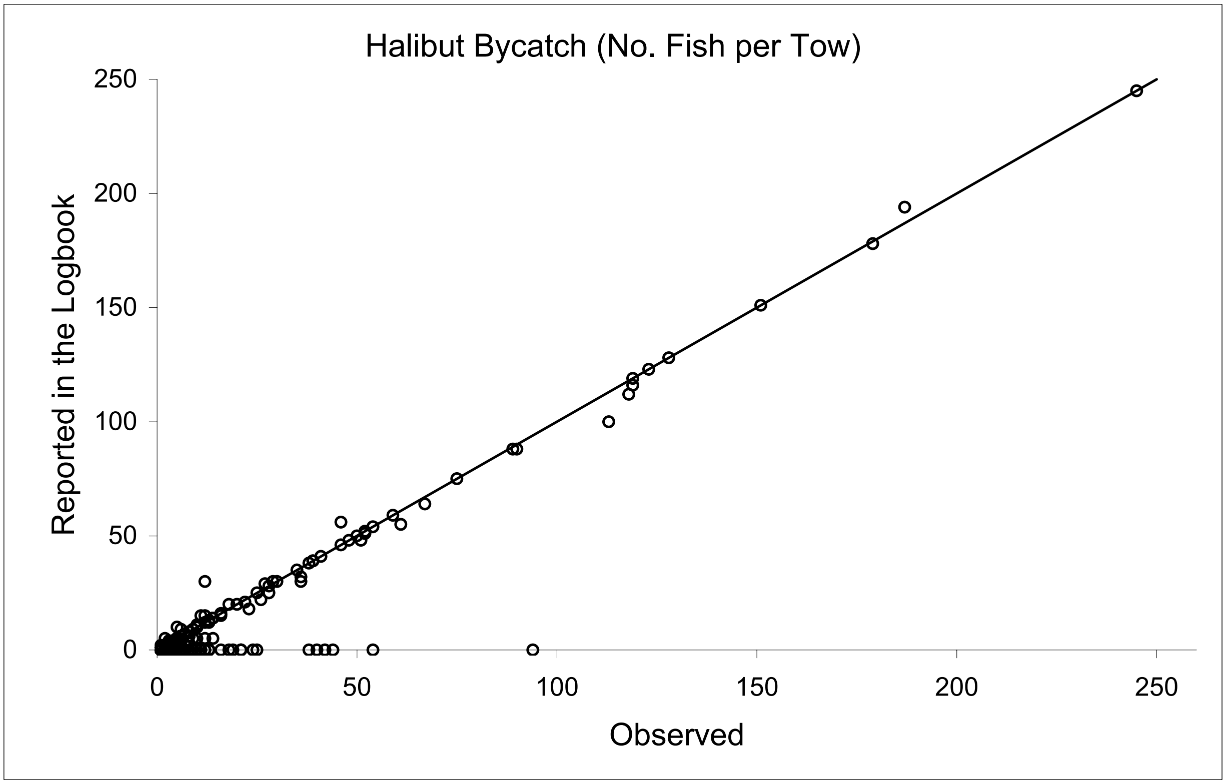


Figure 5. Halibut bycatch from enhanced logbooks paired with corresponding observer data.



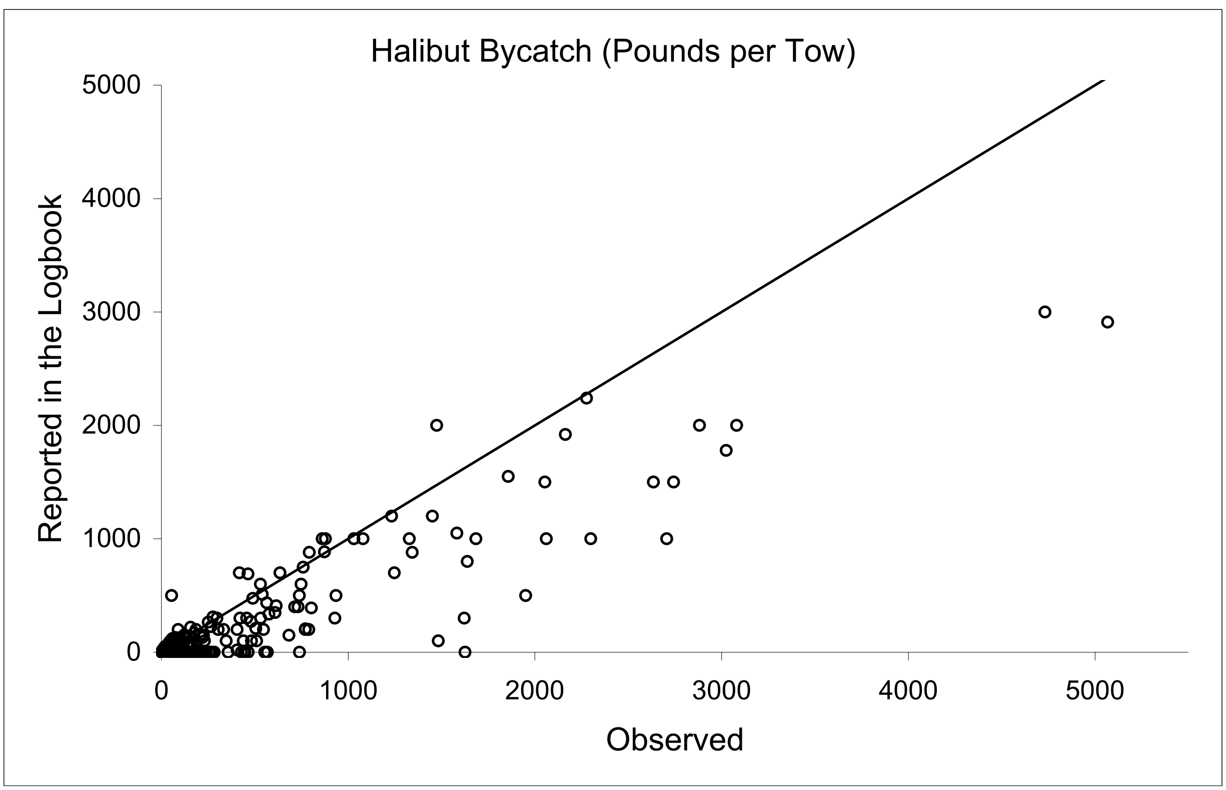


Figure 6a. Principal components analysis (PCA) scores (X=PCA1, Y=PCA2) based on fish landings and species composition data from *big* groundfish trips in Oregon (>10,000 lb, <50% Pacific hake). Each point in the upper panel represents one fishing trip. The closed circles are the trips for which there were enhanced logbooks. The crosses in the lower panel indicate the relative species composition characteristics corresponding to the trips in the upper panel.

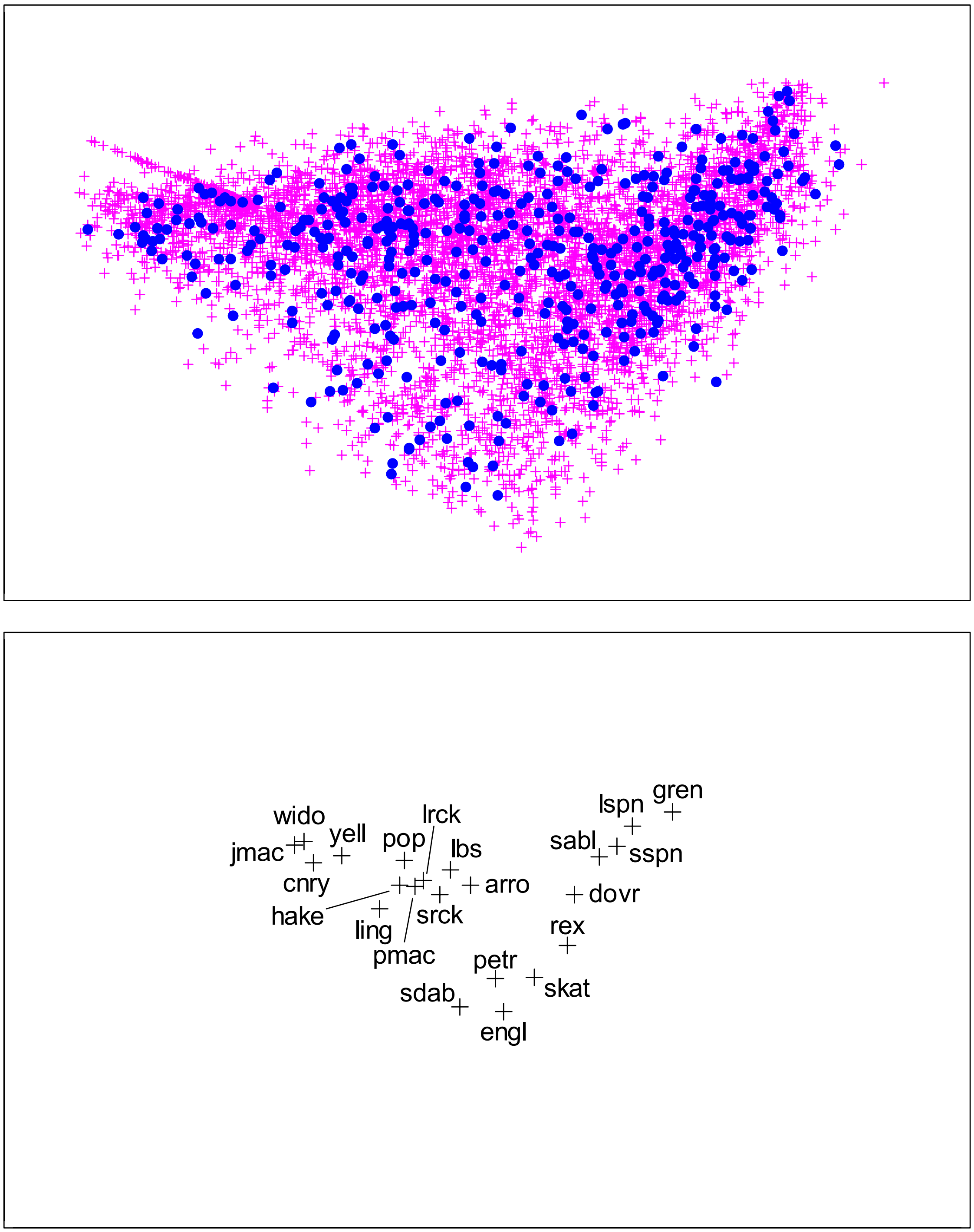


Figure 6b. PCA scores (X=PCA1, Y=PCA2) based on fish landings and species composition data from *small* groundfish trips in Oregon (<10,000 lb).