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COMPARISONS OF FISH CATCHES REPORTED BY FISHERY OBSERVERS AND IN LOGBOOKS OF HAWAII-BASED COMMERCIAL LONGLINE VESSELS

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ABSTRACT

Catch records for 15 fish taxa taken by Hawaii-based commercial longline vessels from March 1994 through December 1998 ($N = 2{,}684$ longline sets, from 230 trips), reported by National Marine Fisheries Service (NMFS) observers, were compared to the corresponding commercial logbook records to determine rates of concurrence (i.e., exact numerical agreement) and discrepancies. The underlying concept was that the rates of exact concurrence between observer and logbook data should represent an estimate of the maximum accuracy attainable in the logbooks, which in turn should provide an estimate of the acceptable margin of error for logbook reporting. The rates of concurrence for14 taxa were 66.4-96.0%; blue shark, *Prionace glauca*, by far the most numerous, had a much lower rate of concurrence (35.6%) than all others. Discrepancies were then evaluated, data judged questionable or erroneous were deleted, and a series of analyses were conducted to provide best-case estimates of the relationships between observer and logbook data. Data evaluations revealed that blue shark, albacore, *Thunnus alalunga*, and mahimahi, *Coryphaena hippurus,* were sometimes underreported in logbooks despite the presence of an observer. In addition, discrepancies in counts of finned or released blue shark and mahimahi were sometimes associated with the appearance of overreporting in the logbooks, but the data did not reveal whether this resulted from underreporting by observers, double-reporting in logbooks (i.e., listing a shark that had been finned and its carcass discarded as both finned and released), or both. Finally, taxonomic problems with billfishes (Istiophoridae) in both observer and logbook data distorted catch numbers for blue marlin, *Makaira nigricans*; striped marlin, *Tetrapturus audax*; and spearfish, *Tetrapturus angustirostris*. Regression analyses revealed close agreement between the observer and logbook data for bigeye tuna, *Thunnus obesus*; yellowfin tuna, *Thunnus albacares*; swordfish, *Xiphias gladius*; and albacore (when reported properly), which indicated that under normal circumstances, full or nearly full logbook reporting is attainable for these commercially important species. Regressions for blue shark and mahimahi suggested that these species could also be reported accurately if systematic recording errors could be eliminated. Protected species interactions were not associated with meaningful increases in fish count errors. Comparison of observer and logbook data to sales records from public fish auctions revealed additional evidence of underreporting and taxonomic errors, which indicated that the latter data source represents a useful resource for checking logbook and observer data. The results presented herein are expected to prove useful in establishing guidelines for logbook reporting under normal circumstances and in providing correction factors for stock assessments.

INTRODUCTION

A matter of considerable interest to the Honolulu Laboratory (HL) of the National Marine Fisheries Service (NMFS) is the accuracy of the logbook reports of commercial vessels that are submitted upon landing fish for sale in Hawaii. The most important resource for assessing their accuracy is the data gathered by the NMFS Hawaii Longline Observer Program. Although this program is designed to monitor interactions between the longline fishery and protected species, particularly marine turtles (DiNardo, 1993), the observers also record species-specific tallies of the catch from each longline set (Fisheries Observer Management, 1998). These counts and identifications are expected to be accurate because observers receive taxonomic instruction at the outset of employment and are not involved in the deployment or retrieval of the longline gear (see Summary of Duties in Fisheries Observer Management, 1998). As such, the correspondence between catches reported by observers and in logbooks should be directly related to the accuracy of the latter.

This report summarizes patterns of concurrence (i.e., exact numerical agreement) and discrepancies in catches of fishes as reported by NMFS fishery observers and in logbooks from March 1994, the start of the observer program, through December 1998. The entire set of fish catch data gathered by observers was initially compared to the logbook records from the same longline deployments to determine overall rates of concurrence. Questionable data (see Data Evaluations, below) were then deleted, and relationships between observer and logbook data were computed to provide best-case estimates of the maximum accuracy likely to be attained in the logbooks. This characterization is proposed because the presence of an observer represents a form of unofficial oversight on the vessel, which would presumably discourage underreporting, and because captains and observers may confer during logbook report preparation, which would presumably tend to increase rates of agreement. The significance of an estimate of maximum logbook accuracy is that it should in turn provide an estimate of the margin of error for logbook reporting.

Three types of factors were examined to elucidate their effects, if any, on the concurrence between data from observers and logbooks. First, evaluations by species and trip types were intended to identify associations between particular sectors of the fishery and specific patterns of concurrence or discrepancies. These analyses were expected to document close correspondence between observer and logbook data for species of major commercial importance; e.g., swordfish, *Xiphias gladius*; bigeye tuna, *Thunnus obesus*; and yellowfin tuna, *Thunnus albacares*. Conversely, it was expected that logbook and observer data for species of lesser commercial importance (e.g., spearfish, *Tetrapturus angustirostris* and skipjack tuna, *Katsuwonus pelamis*) and those that are sometimes very numerous in the catch (e.g., blue shark, *Prionace glauca* and mahimahi, *Coryphaena hippurus*) would agree less well, due either to differing priorities between observers and vessel personnel or simply to the inherent difficulty of counting large numbers of fish. Second, longline sets with protected species interactions were examined because these represent the highest priority for the observers, and it was considered appropriate to determine whether they are associated with increased frequencies of discrepancies between observers and logbooks. Finally, a third, smaller set of data gathered by HL and Hawaii Division of Aquatic Resources (HDAR) personnel at public fish auctions conducted by the United Fishing Agency (UFA), Honolulu, Hawaii, comprised of sales records for the landings from a subset of the trips that carried observers, was compared to the corresponding observer and logbook reports. The expectation in this case was that data from the observers and the auction would tend to agree, particularly in regard to taxonomic identifications.

It is expected that these results will be of threefold value. First, definition of optimal logbook reporting should be useful in establishing guidelines for logbook reporting practices under normal circumstances. Second, determination of the relationships between observer and logbook data may provide correction factors applicable in stock assessments that are founded upon either or both data source(s). Finally, this study represents the initial attempt to cross-check and evaluate the quality of data derived from the three major monitoring resources concerned with the Hawaii-based commercial longline fishery.

METHODS

Overall Patterns of Concurrence

Catch statistics (catch per longline set) were compiled for 15 fish taxa taken in the Hawaii-based longline fishery from data reported by NMFS observers and in commercial logbooks ($N = 2{,}684$ longline sets, deployed on 230 trips). Tabulations present descriptive statistics, percentages of concurrence between observer and logbook data, and chi-square tests that evaluated whether positive and negative discrepancies were independent of test conditions.

Data Evaluations

Detailed evaluations were conducted on a species-specific basis to detect and delete questionable and erroneous data. This entailed establishing arbitrary criteria regarding sizes of discrepancies (e.g., a difference of 10 fish of a certain species between the observer and logbook on a particular longline set) and examining the original logbook forms when such criteria were met. Data for the species in question were deleted if the logbook forms appeared to provide indications of either systematic or unintentional error(s). A species-specific approach was considered appropriate because prior experience with original logbook forms had indicated that many errors consist of individual entries (e.g., an entry for a single species on an incorrect line of the logbook form for one longline set) with no apparent influence on the overall accuracy of data for other taxa.

The evaluation criteria were predicated upon typical catch sizes and concerns relevant to particular species. For the major commercial species (i.e., tunas and swordfish), the original logbook forms were examined for any trip that included two or more longline sets with observer counts that exceeded the corresponding logbook counts by 5-9 fish, or any set(s) with an observer count that exceeded the logbook by 10 or more fish. These criteria reflected concern regarding possible occurrences of underreporting with these valuable species. Similar criteria were employed with blue shark and mahimahi except that logbook examinations were based on the absolute values of discrepancies. This difference reflected the fact that both of these species are occasionally very numerous in the catch (He et al., 1997), and relatively large positive or negative counting errors were believed possible under such circumstances. A discrepancy of three or more fish was used as the examination criterion for all other species because five was considered insufficiently rigorous relative to their typically lower abundance in the catch. An absolute value of three was used as the criterion with istiophorids because of an expectation that discrepancies could arise from taxonomic errors in either logbook or observer data.

The deletions involved either data from individual longline sets or all data for a species from an entire trip. An individual set (i.e., observer and logbook counts for one species from one set) was deleted if it was the only identifiable count error (e.g., a transposition) for a trip. Any trip with two or more count errors for the species in question or any systematic error(s) was deleted in its entirety from subsequent analyses. The consequence of this approach was that the best-case relationships between observer and logbook data for the various species were computed with different sample sizes, which ranged from 94.9% to >99.9% of the initial number of longline sets. Results from these evaluation procedures were summarized to describe aspects of both the observer and logbook data sets that affected their correspondence.

Species and Trip Types

Fish catches reported in logbooks were regressed on those from fishery observers for all species with a mean catch of 0.5 fish per set or more. The null hypotheses for each linear regression were that the intercept would be zero and the regression coefficient would be one (H_0: $b_0 = 0.0$; H_0: $b_1 = 1.0$). These hypotheses were tested by computing 95% confidence limits and *t*-statistic probabilities for the regression parameters.

Fish catches reported in logbooks were also regressed on those from fishery observers according to two categorizations of fishing trip types, which are similar but not identical. The first, presented by DiNardo (1993), is primarily based upon vessel characteristics. The second, which is employed by the HL Fishery Monitoring and Performance Investigation, utilizes logbook entries and interviews with vessel personnel regarding fishing practices and target species to define trip types. The categories of interest under both systems were swordfish-, tuna-, and mixed species-directed trips. These can be distinguished on the basis of several operational characteristics, including the type of gear, area fished, numbers of hooks and light sticks, and vessel history (He et al., 1997; Ito and Machado, 1997). Regression coefficients were compared within trip type categorizations by analyses of covariance.

Protected Species Interactions

Catch statistics were tabulated separately for sets with protected species interactions. The primary interest was to determine whether protected species interactions were associated with disproportionate numbers of discrepancies between observers and logbooks. This was believed possible for two reasons, which are not mutually exclusive. First, protected species interactions represent the highest priority for the observers, and the effort and attention demanded by such an occurrence might tend to increase difficulty in completing all of their other responsibilities. Second, the occurrence of an interaction might affect the working atmosphere aboard the vessel in such a way as to affect logbook accuracy. Therefore, patterns of concurrence and discrepancies between observer and logbook data were summarized in relation to protected species interactions for all fish taxa. Species that exhibited significant direct relationships between discrepancies and protected species interactions were then evaluated further, with results categorized as interactions with marine turtles, albatrosses, or both. These two groups were involved in 96% of all protected species interactions during the study.

Comparison with Auction Records

The final analysis involved the comparison of sales data recorded by HL and HDAR personnel at public fish auctions conducted by the UFA to the corresponding data from observers and logbooks. These data were available from 60 of the 230 trips during the study period (26.1%). Trip catch totals from the observers, the logbooks, and from the auction sales (numbers of fish) were tabulated for 12 species. This comparison was considered important because the auction data have heretofore been considered definitive regarding taxonomic identifications, particularly concerning the istiophorids (R.Y. Ito, personal communication). The auction data can also serve as rough checks on trip totals because a vessel should not be able to sell more fish than are listed in the logbook.

RESULTS

The preparation and use of fishery observer, commercial logbook, and fish auction data are summarized in Table 1. Fishery observers were present on a total of 2,812 longline sets during the study period, of which 128 sets had incomplete records. These were deleted, leaving 2,684 sets for the comparisons.

Overall Patterns of Concurrence

The pooled mean and median catch per set values (Table 2) reported by NMFS observers equaled or exceeded the corresponding logbook values for all 15 fish taxa studied except blue marlin and blue shark. The latter was by far the most numerous species. Albacore, bigeye tuna, swordfish, and mahimahi comprised the next group of species, with mean catch rates of 4.7-5.2 fish per set reported by observers. The least numerous fishes were opah, *Lampris guttatus*; wahoo, *Acanthocybium solandri*; mako sharks, *Isurus* spp.; and thresher sharks (Alopiidae), with pooled mean catch rates below 0.5 fish per set. All coefficients of variation exceeded 100%.

The initial comparison of observer and logbook data (Table 3) revealed 66.4-96.0% concurrence among 14 taxa; blue shark exhibited much lower concurrence than all others (35.6%). When counts differed, however, discrepancies were usually not uniformly distributed. All species except blue marlin exhibited significant departure from uniformity in the signs of discrepancies (14 chi-square tests: all $P < 0.01$). This reflected a consistent tendency toward greater observer than logbook values when the two differed. For example, the observer value exceeded the logbook in 71.1% of all discrepancies with albacore (20.2/28.4 = 0.711). Most count discrepancies were small (Table 4); 51.4 - 82.5% of the discrepancies with all taxa except mahimahi and blue shark consisted of differences of ±1 fish. Albacore, mahimahi, and blue shark were the only species in which large discrepancies (≥10 fish) exceeded 1.0% of the sets.

Data Evaluations

Species-specific evaluations (Table 5) revealed four factors that systematically affected the concurrence of observer and logbook data. Substantial underreporting in logbooks, taxonomic errors by both observers and logbooks, the difficulty of counting the most numerous species, and incorrect use of the logbooks contributed to discrepancies between observer and logbook reports. Data entry or transcription errors were the other major source of count discrepancies.

Underreporting in logbooks was detected with four taxa. Eight trips (four swordfish, four mixed species) by six vessels were deleted for underreporting albacore. The observers reported zero albacore catches for three sets on these trips, whereas the logbooks listed 54 zeroes, including 13 sets when the observers listed 20 or more albacore. Five trips were deleted from blue shark computations. The logbooks listed zero blue sharks for the total on three of these, and a trip totaled 100 less than that of the observer on a fourth. Logbook entries for the fifth trip listed zeroes for five of the nine sets when the observer listed 3-10 blue shark per set. Five trips were deleted from computations with mahimahi; logbook entries were zeroes when observers reported catches as high as 182 per set. A single trip was deleted for underreporting with wahoo.

Taxonomic discrepancies were the second major reason for deletions of data. For example, all *Thunnus* spp. from one trip were listed as yellowfin tuna by a novice observer, when the logbook listed three different species in plausible proportions. This was the only systematic error detected with the major commercial species. In contrast, there were problems with istiophorid taxonomy or reporting on at least five trips. The first deletion consisted of a trip with logbook reports of 38 blue and zero striped marlin when the observer listed 39 striped and zero blue marlin. A second trip was deleted because a substitute observer reported a total of 56 blue marlin when the logbook reported zero. Data from an additional three trips by a single vessel were deleted because comparison of the observer and logbook reports suggested that some spearfish were listed in the logbook reports as marlins, including black marlin, *Makaira indica*. The remaining taxonomic problem involved thresher shark from one trip. The logbook listed 44 sharks as 'Other' along with one thresher shark, whereas the observer listed 16 thresher sharks.

Examinations of the data for blue shark and mahimahi, the most numerous species, revealed other types of systematic errors that were apparently related to their uses or to the magnitude of the catch. Blue shark data from five trips were deleted because the logbook reports of shark catches were considerably greater than those reported by the observer. The total shark catch is computed as the sum of entries for finned, released, and kept sharks. For these trips, however, the logbook reports provided entries for both finned and released sharks, whereas the observers reported totals that apparently corresponded to the logbook report of the finned sharks without the releases. This may have reflected an inability on the part of the observer to enumerate both the finned and released sharks, which created the appearance of overreporting in the logbook. One of these trips was the first for the observer, and three others involved a single observer. Another deleted trip exhibited an apparent correspondence between the observer total and the logbook releases. It is also possible that logbook entries may have been inflated by reporting the discarded carcasses of finned sharks as releases (i.e., double-reporting). The two alternatives are not mutually exclusive, and the data do not reveal which, if either, is correct. Two additional trips were deleted because the logbooks listed zero blue shark fins when the observer reported averages of 4.2 and 26.8 finned blue sharks per set, even as the logbook release totals exceeded those from the observers by 125% and 349%, respectively. Mahimahi data from one trip were deleted because the logbook release totals did not appear credible; 14 of 16 release entries were multiples of 5 or 10, and the logbook mean exceeded that from the observer by 14.5 released mahimahi per set.

Inappropriate use of the logbook forms, the final source of systematic errors, refers to catches that were logged but done so incorrectly. For example, pomfret catches from four trips were deleted because handwritten entries that included the species identification were incorrectly positioned on the logbook form and apparently not detected during data transcription. Similarly, mahimahi catches from one trip were deleted because the entries were misplaced and the errors were not detected.

Species and Trip Types

The relationships between observer and logbook data for the most important commercial species (i.e., albacore, bigeye tuna, yellowfin tuna, and swordfish), a lesser commercial species (mahimahi), an incidentally taken species (blue shark), and an important game fish (blue marlin) are presented in Figure 1 a-g. The scaling of these plots reflects three general levels of abundance in the catch: blue shark with axes of 0-400 fish per set; albacore, bigeye tuna, yellowfin tuna, swordfish, and mahimahi with axes of 0-100 fish per set; and blue marlin with axes of 0-25 fish per set. It was necessary to delete five observations from these plots (albacore: one set; mahimahi: three sets; blue marlin: one set) to standardize axes and attain a common multiple between levels, but these observations were included in the subsequent regression analyses (Table 6) and their deletion did not noticeably alter plot trajectories.

The regression analyses revealed the following major points concerning the relationships between observer and logbook data. All regression coefficients were significantly less than 1.0, which was consistent with the general pattern of lower logbook than observer catch rates. Five intercepts were nonsignificant ($P > 0.05$), which led to acceptance of the null hypothesis of passage through the origin. Bigeye tuna, yellowfin tuna, and swordfish were characterized by regression coefficients greater than 0.90 and coefficients of determination (0.932-0.956) that represented strong linear relationships between observer and logbook data. Albacore, mahimahi, and blue shark also had high regression coefficients (0.859-0.963), but these reflected prior deletions of greater quantities of data and for some different reasons than with all other taxa (e.g., discrepancies associated with finned or released fish). This indicated that these species can be reported accurately if gross underreporting were eliminated and greater effort were devoted to the counts of released fish. The 95% confidence limits about the regression (Fig. 2 a-d) did not increase greatly in breadth with increasing catches of albacore, bigeye tuna, mahimahi, and blue shark. Finally, the sums of blue and striped marlins were accurately reported, but the regression coefficients for blue and striped marlins were inflated and deflated, respectively. This reflected the tendency to misidentify and report striped marlin as blue marlin in logbooks. .

The within-trip type analyses (Table 7) detected significant differences in the regression coefficients that related logbook to observer data with each of the six most numerous species according to the NMFS Observer categorization system and in four species according to the NMFS Honolulu Laboratory system. There were no significant differences in regression coefficients with bigeye and yellowfin tuna according to the HL system. The coefficient for swordfish on tuna trips was significantly less than both other coefficients under both systems.

Protected Species Interactions

Protected species interactions (Table 8) occurred on 16.6% of the longline sets studied. There were greater than expected frequencies of discrepancies between observer and logbook counts with albacore, swordfish, and the mako sharks (three chi-square tests: all $P<0.001$). Discrepancies were independent of interactions with mahimahi and blue shark (two chi-square tests: both $P>0.05$) and occurred less frequently among sets with interactions than those without in all other species (10 chi-square tests: all $P<0.05$). These findings were apparently related to catch size. Specifically, there were higher mean catch rates for albacore, swordfish, and the mako sharks on sets with protected species interactions than on those without, whereas the other 10 species had lower mean catch rates on sets with protected species interactions. Examination of specific types of interactions (Table 9) indicated that either or both albatross and turtle interactions were associated with greater frequencies of discrepancies in counts of albacore, swordfish, and mako sharks than were observed in sets without interactions. Once again, however, these results were influenced by catch sizes. For example, 48.9% of all sets with protected species interactions had count discrepancies for swordfish, but the mean catch size among these sets was more than double that among all sets (11.4 swordfish per set vs. 5.2 swordfish per set). When count discrepancies were compared for catch sizes of 6-16 swordfish per set, which was the interquartile range of catch sizes for sets without interactions, there was a higher percentage of count discrepancies on sets without (59.0%) than with interactions (49.6%). This type of catch size-specific comparison was not conducted with albacore because the ranges were not comparable.

Comparison with Auction Records

Fishery observer and logbook catch totals from 60 trips are presented along with auction sales totals in Table 10. The predominant pattern, observed in all species except striped marlin, was auction<logbooks, logbooks<observers. Departure from this pattern by striped marlin probably reflected taxonomic problems. For example, both the observer and logbook reported over 80 blue marlin and 20 striped marlin on one trip, whereas the auction listed sales of 99 striped marlin and 2 blue marlin. In addition, both observer and auction data from a second trip listed approximately 20 striped marlin but the logbook report listed these as blue marlin.

Comparisons of the observer and logbook trip totals to auction sales (Table 11) revealed complete agreement on 45 trips with opah, which corresponded to 25.1% of the total auction sales for this species. In eight other species, there were 11-26 trips with complete concurrence. However, such agreement was generally associated with small catches; the trips with exact concurrence accounted for 4.2%, 0.1%, and 10.1% of the auction sales totals for albacore, bigeye tuna, and yellowfin tuna, respectively. A common pattern, involving the largest individual fraction of the sales total for 7 of the 12 species, was observer totals greater than those from the logbooks, which in turn were greater than those from the auction (i.e., observer>logbook, logbook>auction) . In four other species, the observer totals were greater than those from the logbooks, but the latter were less than those from the auction. The pattern observer<logbook, logbook<auction was observed in only 3 of 12 species. One such trip had a blue marlin total from the observer equal to the striped marlin total from the auction and other discrepancies among the three data sources that involved blue marlin, striped marlin, and spearfish. The trip of this type with bigeye tuna involved a difference of 55 fish between the observer and auction totals, whereas the difference from two trips with yellowfin tuna involved four fish.

DISCUSSION

The results presented herein summarize patterns of concurrence in fish catch data provided separately by fishery observers and in logbooks under conditions favoring concurrence before and after deletion of outliers. As such, the results can be regarded as indicators of the actual and potential levels of agreement between these two data sources. Because the primary concern underlying this study is the accuracy of the logbook reports, the observer data must first be critically assessed in order to justify the premise that concurrence can be equated to accuracy.

Observer Data

The species-specific data evaluations revealed a maximum of eight (3.5%) trips that may have been characterized by observer errors, and among these, six could be grouped comprehensibly. Two trips that were apparently characterized by misidentifications of *Thunnus* spp. and blue marlin involved new and substitute observers, respectively. One of the five trips that exhibited correspondence between the observer total for blue shark and the logbook fins value involved a new observer, and three of the remaining four involved a single observer. Thus, most discrepancies that apparently resulted from observer errors seemed attributable to inexperience in either the job or this fishery or to the ongoing performance of a single individual.

The substantive issues regarding observer data quality were the enumeration of finned blue shark, enumeration of releases of this and the other numerous species, and identification of marlins. The latter in particular clearly posed difficulties for both observers and logbooks, as evidenced by contradictory identifications provided by the fish auction. Otherwise, the results provided little evidence of inaccuracy in the observer data, at least among the taxa other than blue marlin with low to moderate catch sizes. Moreover, the small number of errors by observers did not preclude detailed investigation of logbook data characteristics.

Overall Patterns of Concurrence

The principal characteristic of the pattern of concurrence between logbook and observer data was the tendency toward lower logbook values even in the presence of an observer, as demonstrated by significant chi-square test results with 14 taxa. There were at least two distinct aspects to this pattern. The first was that logbook reports, particularly with large catches, were sometimes expressed in round numbers, such as the observation of mahimahi releases reported as multiples of 5 or 10, which might be termed underestimation. The second aspect was underreporting, which required more deletions than any other type of systematic error. The implication of the overall pattern, not unexpectedly, is that the principal task confronting those charged with enforcement responsibilities would appear to be definition of an acceptable level of shortfall in the logbook reports rather than attempting to reduce occurrences of random inaccuracies.

One possibility for acceptable shortfall levels might entail the use of an arbitrary margin of error, such as ±2 fish, although in practice this would presumably consist of a logbook value two less than the actual number of fish landed. This would offer the advantages of simplicity and ease of understanding but would fail to consider the catch sizes typical of the various taxa. For example, a margin of two fish would be an order of magnitude greater than the mean catch of mako sharks, but less than one-fifth that of blue shark. The likely results would be very lenient standards applied to the uncommon species but excessively or even impossibly stringent standards for the more numerous and important species. An obvious alternative might involve use of lower confidence limits obtained from the best-case regressions, so as to allow definition of acceptable error in terms of some fraction of the catch.

Species and Trip Types

The regression analyses proved useful by delineating groupings of taxa within the fishery in which logbook reporting habits apparently reflected catch sizes and value. This finding was consistent with a priori expectations. The regressions for the most valuable commercial species were particularly important because their coefficients of determination and regression coefficients approaching 1.0 suggested that full or nearly full reporting was either attainable or already achieved. In contrast to the major commercial species, results with certain lesser commercial species (e.g., pomfrets, skipjack) were less definitive. Lower coefficients of determination and regression coefficients may have been somewhat artefactual because the applicable evaluation criterion (i.e., a discrepancy of three or more fish between observer and logbook counts) was large relative to the typical catch rates for these taxa. It is therefore possible and indeed likely that systematic errors went undetected and were used in computing the best-case relationships with these taxa.

The within-trip type regression analyses documented the strength of the linear relationships between logbook and observer data for the major commercial species in relation to the trip target (e.g., swordfish on swordfish trips, and bigeye tuna on tuna trips). However, these analyses also revealed that the relationships between logbook and observer data were not necessarily uniform for all sectors of the fishery. The most obvious example was swordfish, which had much lower regression coefficients for catch rates on tuna- than swordfish- and mixed species-directed trips. Because swordfish catch rates on tuna trips tend to be quite low (Ito and Machado, 1999), this represented another example of the influence of catch sizes on the relationships between observer and logbook data. In addition, the patterns of variation within trip types were not consistent in the two categorization systems. There was no significant variation in the regression coefficients for bigeye tuna and yellowfin tuna according to the HL classification system, whereas every species exhibited significant variation under the observer classification system. The finding with the HL system was welcome because it appears to represent uniformity in reporting practices with these two valuable species. If so, and regression analyses were to be incorporated into enforcement efforts, it would not seem necessary to utilize trip type-specific limits with these species. Differences between the two systems were also revealed by patterns in the regression coefficients, most notably with albacore. This species was reported most fully on mixed species trips according to the observer system, whereas its mixed species regression coefficient under the HL system was significantly less than the others. These species- or sector-specific findings are important because they suggest that the effectiveness of educational, enforcement, or other ameliorative measures might be maximized by carefully targeting such efforts.

Protected Species Interactions

The analyses of longline sets with protected species interactions revealed no indications that the latter were associated with disproportionate occurrences of count discrepancies. Although 13 of 15 chi-square tests for the independence of discrepancies from interactions were significant, 10 of these reflected lower, rather than higher, frequencies of discrepancies than would be expected. The nonsignificant test results with mahimahi and blue shark suggest that protected species interactions are considerably less influential than the inherent difficulty of enumerating these abundant species. The results with swordfish provided further evidence that catch size influences concurrence between observer and logbook data, but protected species interactions exert little if any effect.

Comparison of the Three Data Sources

The comparison of the fish auction records with the observer and logbook data represents the first detailed attempt to employ these independent sources of information in an integrated manner so as to improve monitoring efforts in this fishery. The value of this approach was most clearly demonstrated by detection of marlin taxonomy problems with auction data that were not detected by the previously used evaluation criteria. The reason is that the latter were defined according to differences between the observers and logbooks, so sets with similar but erroneous observer and logbook values would not be detected.

The second and potentially more important benefit derived from use of the three data sources was that this provided an additional and independent means to verify logbook accuracy. Catch totals from trips with exact agreement between observers and logbooks that also tallied exactly with the auction sales total were presumably accurate. However, differences in catch totals from the observer or logbooks and the auction did not necessarily reflect inaccuracies. For example, concurrence between the observer and the logbook with a lower auction total could simply reflect personal consumption. Moreover, the relative importance of the possible types of inaccuracies differs considerably. A pattern observer>logbook, logbook=auction could reflect a tendency to concentrate on logging the fish that will be sold, whereas observer<logbook, logbook=auction could represent a problem in observer data quality. It was noteworthy that observer<logbook, logbook<auction, the ‘worst-case’ data quality scenario, was observed in only three species.

CONCLUSIONS

The low number and comprehensibility of detectable errors demonstrated that the fishery observer data employed in this study, particularly for *Thunnus* spp. and swordfish, were of generally high quality. Five recognizable sources of discrepancies occurred between observer and logbook data, the most serious of which was underreporting, but these affected small fractions of the data sets. Most discrepancies between observer and logbook data were small, so it is reasonable to infer that accurate reporting is attainable under normal circumstances and that margins of error for enforcement purposes need not be large (e.g., two fish or 10% of the catch of some species). Fish auction data can usefully complement observer reports in assessments of the accuracy of logbook data. It is suggested that these three data sources be used in conjunction for ongoing monitoring of the Hawaii-based longline fishery.

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TABLES

Table 1.--Summary of data preparation and use in a study of fish catches by Hawaii-based commercial longline vessels from March 1994 through December 1998. All sample sizes are numbers of longline sets except the sample size for the fish auction records, which is expressed as the number of trips.

Stage of the Study	Data Source(s)	Sample Size	Number of Taxa	Data Presentation
Data Preparation	Logbook	56,116	-----	-----
	Logbook without Observer	53,304	-----	-----
	Observer (All sets)	2,812*	-----	-----
Overall Concurrence	Observer with Logbook	2,684	15	Figure 1, Tables 2 - 4
Species-specific Aspects	Observer with Logbook	2,523-2,682**	12	Figure 2, Tables 5 - 7
Protected Species Interactions	Observer with Logbook	446***	15	Table 8
	Observer with Logbook	446	3	Table 9
Fish Auction Records	Auction with Logbook and Observer	60	12	Tables 10 - 11

*The observer total from March 1994 through December 1998 included 128 sets (4.6%) with incomplete records.
**The range of sample sizes reflects deletions performed after species-specific data evaluations.
***These were all sets with complete records and observers present when protected species interactions occurred.

Table 2.--Summary of catches per longline set of 15 fish taxa (see footnotes) by the Hawaii-based commercial longline fishery from March 1994 through December 1998 (N = 2,684 longline sets). Entries are the mean, median, maximum, coefficient of variation (%), and rank for each taxon relative to the data source (i.e., NMFS fishery observer or commercial logbook reports).

Species	Data Source	Mean	Median	Maximum	CV	Rank
Albacore (*Thunnus alalunga*)	Observers	4.7	1	117	208.5	5
	Logbooks	4.0	1	117	222.5	5
Bigeye Tuna (*Thunnus obesus*)	Observers	5.1	2	88	149.0	3
	Logbooks	4.9	2	88	151.0	2
Yellowfin Tuna (*Thunnus albacares*)	Observers	1.9	1	60	205.3	6
	Logbooks	1.7	0	60	211.8	6
Skipjack Tuna (*Katsuwonus pelamis*)	Observers	0.9	0	57	355.6	8
	Logbooks	0.7	0	51	385.7	8
Swordfish (*Xiphias gladius*)	Observers	5.2	2	73	134.6	2
	Logbooks	4.8	1	81	143.8	3
Spearfish (*Tetrapturus angustirostris*)	Observers	0.7	0	20	214.3	10
	Logbooks	0.6	0	18	250.0	9
Striped Marlin (*Tetrapturus audax*)	Observers	1.4	0	29	178.6	7
	Logbooks	1.2	0	21	191.7	7
Blue Marlin (*Makaira nigricans*)	Observers	0.5	0	27	260.0	11
	Logbooks	0.6	0	36	283.3	10
Mahimahi (*Coryphaena hippurus*)	Observers	5.1	1	193	215.7	4
	Logbooks	4.4	1	193	236.4	4
Opah (*Lampris guttatus*)	Observers	0.4	0	17	300.0	13
	Logbooks	0.4	0	16	300.0	12
Wahoo (*Acanthocybium solandri*)	Observers	0.4	0	9	250.0	12
	Logbooks	0.4	0	20	250.0	13
Pomfrets (Bramidae) *	Observers	0.8	0	28	237.5	9
	Logbooks	0.6	0	21	283.3	11
Blue Shark (*Prionace glauca*)	Observers	11.3	6	359	163.7	1
	Logbooks	11.5	6	358	176.5	1
Mako Sharks (*Isurus spp.*) **	Observers	0.2	0	4	200.0	15
	Logbooks	0.1	0	17	600.0	15

Table 2.--Continued.

Species	Data Source	Mean	Median	Maximum	CV	Rank
Thresher Sharks (Alopiidae) ***	Observers	0.3	0	23	433.3	14
	Logbooks	0.3	0	63	566.7	14

*Pacific pomfret, *Brama japonica*, bigscale pomfret, *Tarachtichthys steindachneri*, and dagger pomfret, *Taractes rubescens*.
**Shortfin mako, *Isurus oxyrinchus*, longfin mako, *Isurus paucus*, and unidentified mako sharks, *Isurus sp.*
***Bigeye thresher, *Alopias superciliosus*, common thresher, *Alopias vulpinus*, pelagic thresher, *Alopias pelagicus*, and unidentified thresher sharks, Alopiidae sp.

Table 3.--Summary of comparisons of fish catches (N = 2,684 longline sets) reported by NMFS fishery observers ('Obs') and in commercial logbooks ('Log'). The percent concurrence, the percentages of discrepancies in which the observer value is greater and less than the corresponding logbook value, respectively, and a chi-square test (df = 1) for uniformity of occurrence of positive and negative discrepancies are presented for 15 fish taxa taken in the Hawaii-based longline fishery.

Species	Obs = Log	Obs > Log	Obs < Log	χ^2
Albacore	71.6	20.2	8.1	138.798, $P = 0$
Bigeye Tuna	68.8	21.6	9.6	123.108, $P = 0$
Yellowfin Tuna	83.8	13.0	3.2	161.437, $P = 0$
Skipjack Tuna	85.9	11.8	2.2	176.095, $P = 0$
Swordfish	67.8	26.6	5.6	368.167, $P = 0$
Spearfish	84.8	10.6	4.5	65.280, $P = 6.7*10^{-16}$
Striped Marlin	76.3	16.1	7.6	80.893, $P = 0$
Blue Marlin	84.3	7.3	8.3	1.732, $P = 0.188$
Wahoo	91.3	6.7	2.0	65.709, $P = 5.6*10^{-16}$
Mahimahi	66.4	23.6	10.0	148.510, $P = 0$
Opah	96.0	2.6	1.4	8.981, $P = 0.003$
Pomfrets	85.5	12.2	2.3	84.319, $P = 0$
Blue Shark	35.6	35.1	29.2	14.447, $P = 1.4*10^{-4}$
Mako Sharks	93.7	4.5	1.8	32.212, $P = 1.4*10^{-8}$
Thresher Sharks	87.0	9.4	3.6	69.931, $P = 1.1*10^{-16}$

Table 4.--Summary of discrepancies in fish catches (N = 2,684 longline sets) reported by NMFS fishery observers ('Obs') and in commercial logbooks ('Log'). The percentage of total discrepancies (see Table 3 for comparison) and the percentages of positive and negative discrepancies of specific magnitudes are presented for 15 fish taxa taken in the Hawaii-based longline fishery. The left and right entries for each taxon are the positive (i.e., 'Obs' > 'Log') and negative (i.e., 'Obs' < 'Log') discrepancies, respectively.

Species	Obs ≠ Log	Obs = Log ±1	Obs = Log ± 2	Obs = Log ± 3 ... 4	Obs = Log ± 5 ... 9	Obs ≥ Log + 10 Obs ≤ Log - 10
Albacore	28.4	9.7, 4.9	3.1, 1.4	2.6, 0.9	2.6, 0.6	2.3, 0.3
Bigeye Tuna	31.2	12.8, 5.7	4.3, 1.7	2.6, 1.0	1.5, 0.9	0.4, 0.4
Yellowfin Tuna	16.2	8.5, 2.2	2.2, 0.4	2.1, 0.6	1.1, 0.3	0.3, 0.1
Skipjack Tuna	14.1	7.2, 1.5	1.9, 0.5	1.3, 0.1	1.0, 0.2	0.4, 0.0
Swordfish	32.2	14.2, 3.5	6.6, 0.8	4.1, 0.7	1.6, 0.4	0.2, 0.1
Spearfish	15.2	7.7, 2.8	1.4, 0.9	1.2, 0.5	0.2, 0.3	0.1, 0.0
Striped Marlin	23.7	9.8, 5.4	3.2, 1.3	3.7, 0.7	1.2, 0.3	0.2, 0.0
Blue Marlin	15.7	5.3, 4.6	1.2, 1.3	0.5, 1.3	0.3, 1.1	0.1, 0.1
Wahoo	8.7	5.1, 1.6	1.1, 0.1	0.5, 0.2	0.0, 0.0	0.0, 0.1
Mahimahi	33.6	10.3, 4.8	4.4, 2.2	3.7, 1.3	2.8, 0.9	2.5, 0.8

Table 4.--Continued.

Species	Obs ≠ Log	Obs = Log ±1	Obs = Log ± 2	Obs = Log ± 3 ... 4	Obs = Log ± 5 ... 9	Obs ≥ Log + 10 Obs ≤ Log - 10
Opah	4.0	2.1, 1.2	0.3, 0.2	0.1, 0.0	0.0, 0.0	0.0, 0.0
Pomfrets	14.5	7.9, 1.5	2.2, 0.5	1.2, 0.2	0.9, 0.0	0.1, 0.0
Blue Shark	64.4	13.1, 10.4	6.9, 5.7	7.0, 4.8	5.1, 4.4	3.0, 3.9
Mako Sharks	6.3	3.9, 1.2	0.6, 0.3	0.1, 0.1	0.0, 0.0	0.0, 0.0
Thresher Sharks	13.0	6.9, 2.3	1.6, 0.8	0.7, 0.4	0.1, 0.0	0.0, 0.1

Table 5.--Summary of the species-specific evaluations of the NMFS observer and logbook data sets ($N = 2,684$ longline sets).

Species	Data Deleted			Data Retained			Causes for Deletions				
	Sets	Trips	%	Sets	Trips	%	Substantial Under-Reporting	Taxonomy	Fins/Releases	Logbook Use	Data Entry
Albacore	104	9	3.9	2,580	221	96.1	8 trips, 88 sets	1 trip, 9 sets	0 sets	0 sets	2 sets
Bigeye Tuna	14	1	0.5	2,670	229	99.5	0 sets	1 trip, 9 sets	0 sets	0 sets	5 sets
Yellowfin Tuna	11	1	0.4	2,673	229	99.6	0 sets	1 trip, 9 sets	0 sets	0 sets	2 sets
Skipjack Tuna	2	0	0.1	2,682	230	99.9	0 sets	0 sets	0 sets	0 sets	2 sets
Swordfish	24	1	0.9	2,660	229	99.1	0 sets	0 sets	0 sets	0 sets	1 trip, 24 sets
Spearfish	56	5	2.1	2,628	225	97.9	0 sets	5 trips, 46 sets	0 sets	0 sets	10 sets
Marlins	45	4	1.7	2,639	226	98.3	0 sets	4 trips, 44 sets	0 sets	0 sets	10 sets
Mahimahi	127	7	4.7	2,557	223	95.3	5 trips, 89 sets	0 sets	1 trip, 15 sets	1 trip, 19 sets	0 sets
Wahoo	13	1	0.5	2,671	229	99.5	1 trip, 13 sets	0 sets	0 sets	0 sets	1 set
Opah	1	0	<0.1	2,683	230	>99.9	0 sets	0 sets	0 sets	0 sets	1 set
Pomfrets	50	5	1.9	2,634	225	98.1	0 sets	0 sets	0 sets	5 trips, 49 sets	1 set
Blue Shark	140	12	5.2	2,523	218	94.0	5 trips, 42 sets	0 sets	7 trips, 90 sets	0 sets	17 sets
Mako Sharks	13	1	0.5	2,671	229	99.5	0 sets	0 sets	0 sets	0 sets	1 trip, 13 sets
Thresher Sharks	13	1	0.5	2,671	229	99.5	0 sets	1 trip, 11 sets	0 sets	0 sets	3 sets

'Marlins' refers to blue and striped marlins.

Table 6.--Summary of the linear relationships between fish catches reported in logbooks and by NMFS fishery observers. The number

Table 6.--Summary of the linear relationships between fish catches reported in logbooks and by NMFS fishery observers. The number of longline sets, linear regression, 95% confidence limits for the regression parameters, *t*-test probabilities, and coefficient of determination are presented for each taxon.

Species	N	Regression	Intercept CL	Pr(>|t|)	Slope CL	Pr(>|t|)	r^2
Albacore	2580	Y = 0.963X - 0.104	-0.185, -0.022	0.012	0.955, 0.971	0	0.953
Bigeye Tuna	2670	Y = 0.941X + 0.070	-0.012, 0.152	0.096	0.932, 0.950	0	0.941
Yellowfin Tuna	2671	Y = 0.917X - 0.009	-0.049, 0.031	0.662	0.908, 0.927	0	0.932
Skipjack Tuna	2682	Y = 0.767X - 0.015	-0.055, 0.026	0.481	0.755, 0.779	0	0.850
Swordfish	2660	Y = 0.939X - 0.093	-0.160, -0.026	0.007	0.932, 0.947	0	0.956
Spearfish	2628	Y = 0.850X + 0.055	0.026, 0.085	$3.0*10^{-4}$	0.832, 0.869	0	0.762
Blue Marlin	2639	Y = 0.901X + 0.102	0.064, 0.140	$5.7*10^{-8}$	0.873, 0.928	$1.5*10^{-12}$	0.602
Striped Marlin	2639	Y = 0.793X + 0.102	0.060, 0.143	$7.8*10^{-7}$	0.778, 0.808	0	0.804
Marlins	2639	Y = 0.926X + 0.014	-0.019, 0.047	0.407	0.916, 0.936	0	0.929
Mahimahi	2557	Y = 0.937X - 0.125	-0.236, -0.014	0.027	0.926, 0.947	0	0.923
Pomfrets	2634	Y = 0.791X + 0.004	-0.026, 0.034	0.798	0.776, 0.806	0	0.806
Blue Shark	2523	Y = 0.859X + 1.182	0.807, 1.557	$7.9*10^{-8}$	0.841, 0.876	0	0.778

'Marlins' refers to the sum of blue and striped marlins.

Table 7.--Summary of linear relationships between catches of six species reported in logbooks and by NMFS fishery observers in relation to trip types in the Hawaii-based longline fishery. The number of longline sets, linear regression, 95% confidence limits for the regression parameters, and coefficient of determination are presented by species and trip types, as classified by NMFS observers ('Obs') and the HL Fishery Monitoring and Economic Performance Investigation ('HL'). Letters denote significant differences ($P < 0.05$) in regression coefficients among trip types within classifications.

Species	Trip Type	*N*	Regression	Intercept CL	Slope CL	r^2	Slopes Comparison
Albacore	Swordfish/Obs	262	Y = 0.970X - 0.210	-0.435, 0.016	0.943, 0.996	0.952	AB
	Tuna/Obs	505	Y = 0.955X - 0.011	-0.125, 0.104	0.943, 0.967	0.980	B
	Mixed Species/Obs	411	Y = 0.992X - 0.053	-0.181, 0.076	0.979, 1.005	0.982	A
	Swordfish/HL	434	Y = 1.004X - 0.094	-0.372, 0.184	0.984, 1.024	0.956	a
	Tuna/HL	1239	Y = 0.966X - 0.084	-0.155, -0.013	0.960, 0.972	0.985	b
	Mixed Species/HL	907	Y = 0.826X + 0.108	-0.181, 0.076	0.801, 0.851	0.811	c
Bigeye Tuna	Swordfish/Obs	262	Y = 0.904X + 0.010	-0.178, 0.199	0.880, 0.927	0.956	B
	Tuna/Obs	505	Y = 0.973X - 0.135	-0.439, 0.170	0.945, 0.999	0.907	A
	Mixed Species/Obs	432	Y = 0.958X + 0.111	-0.013, 0.234	0.941, 0.974	0.967	A
	Swordfish/HL	487	Y = 0.918X + 0.031	-0.032, 0.094	0.896, 0.940	0.935	a
	Tuna/HL	505	Y = 0.938X + 0.170	-0.006, 0.346	0.924, 0.952	0.934	a
	Mixed Species/HL	945	Y = 0.929X + 0.042	-0.060, 0.144	0.905, 0.953	0.874	a

Table 7.--Continued.

Species	Trip Type	*N*	Regression	Intercept CL	Slope CL	r^2	Slopes Comparison
Yellowfin Tuna	Swordfish/Obs	262	Y = 0.805X + 0.091	0.017, 0.164	0.780, 0.829	0.941	C
	Tuna/Obs	505	Y = 0.894X - 0.013	-0.096, 0.071	0.874, 0.913	0.942	B
	Mixed Species/Obs	432	Y = 0.989X - 0.037	-0.144, 0.070	0.963, 1.015	0.926	A
	Swordfish/HL	487	Y = 0.933X + 0.014	-0.011, 0.039	0.913, 0.953	0.945	a
	Tuna/HL	1239	Y = 0.916X - 0.039	-0.119, 0.041	0.902, 0.930	0.930	a
	Mixed Species/HL	945	Y = 0.934X - 0.007	-0.056, 0.042	0.916, 0.952	0.920	a
Swordfish	Swordfish/Obs	262	Y = 0.951X - 0.127	-0.331, 0.077	0.925, 0.976	0.953	A
	Tuna/Obs	505	Y = 0.640X - 0.003	-0.048, 0.042	0.591, 0.688	0.572	B
	Mixed Species/Obs	432	Y = 0.955X - 0.069	-0.298, 0.160	0.930, 0.980	0.927	A
	Swordfish/HL	487	Y = 0.929X + 0.182	-0.130, 0.494	0.907, 0.951	0.938	a
	Tuna/HL	1250	Y = 0.653X + 0.014	-0.027, 0.055	0.622, 0.684	0.576	b
	Mixed Species/HL	923	Y = 0.946X - 0.195	-0.369, -0.021	0.928, 0.964	0.925	a

Table 7.--Continued.

Species	Trip Type	*N*	Regression	Intercept CL	Slope CL	r2	Slopes Comparison
Mahimahi	Swordfish/Obs	243	Y = 0.861X - 0.265	-0.854, 0.323	0.810, 0.911	0.823	B
	Tuna/Obs	505	Y = 0.887X - 0.014	-0.149, 0.120	0.858, 0.916	0.879	B
	Mixed Species/Obs	418	Y = 0.993X - 0.110	-0.289, 0.070	0.969, 1.016	0.942	A
	Swordfish/HL	474	Y = 0.926X - 0.157	-0.506, 0.192	0.901, 0.951	0.917	b
	Tuna/HL	1248	Y = 0.870X - 0.043	-0.088, 0.174	0.848, 0.892	0.828	c
	Mixed Species/HL	835	Y = 0.961X - 0.127	-0.329, 0.075	0.945, 0.977	0.948	a
Blue Shark	Swordfish/Obs	262	Y = 0.873X + 0.779	-1.049, 2.606	0.827, 0.918	0.846	A
	Tuna/Obs	505	Y = 0.815X + 0.370	0.157, 0.582	0.782, 0.847	0.824	B
	Mixed Species/Obs	380	Y = 0.892X + 0.985	0.486, 1.485	0.859,0.924	0.886	A
	Swordfish/HL	486	Y = 0.917X + 2.504	0.897, 4.111	0.872, 0.962	0.774	a
	Tuna/HL	1217	Y = 0.813X + 0.437	0.251, 0.623	0.789, 0.837	0.793	b
	Mixed Species/HL	841	Y = 0.781X + 2.992	2.132, 3.852	0.744, 0.818	0.659	b

Table 8.--Summary of the effects of protected species interactions ($N = 446$ longline sets) on fish catches reported by NMFS fishery observers and in commercial logbooks. The percentages of exact concurrence on longline sets with and without interactions, a chi-square test for the independence of discrepancies from protected species interactions, the percentages of protected species interaction sets with an observer value greater and less than the corresponding logbook value, and a chi-square test for the uniformity of occurrence of positive and negative discrepancies.

Species	No Interaction Obs = Log	Interaction Obs = Log	χ^2	Interaction Obs > Log	Interaction Obs < Log	χ^2
Albacore	76.2	60.1	25.171, $P = 5.2*10^{-7}$	30.5	9.4	49.640, $P = 1.8*10^{-12}$
Bigeye Tuna	66.8	78.9	17.543, $P = 2.8*10^{-5}$	15.5	5.6	20.596, $P = 5.7*10^{-6}$
Yellowfin Tuna	82.6	89.7	11.472, $P = 7.1*10^{-4}$	8.1	2.2	14.696, $P = 1.3*10^{-4}$
Skipjack Tuna	84.6	92.6	16.980, $P = 3.8*10^{-5}$	6.1	1.3	13.364, $P = 2.6*10^{-4}$
Swordfish	71.1	51.1	46.235, $P = 1.0*10^{-11}$	40.1	8.7	89.908, $P = 0$
Spearfish	83.1	93.5	26.476, $P = 2.7*10^{-7}$	4.7	1.8	5.828, $P = 0.015$
Striped Marlin	74.0	87.4	28.173, $P = 1.1*10^{-7}$	9.6	2.9	16.071, $P = 6.1*10^{-5}$
Blue Marlin	82.8	91.9	19.780, $P = 8.7*10^{-6}$	3.6	4.5	0.444, $P = 0.505$
Mahimahi	66.1	67.6	0.288, $P = 0.592$	23.5	8.7	30.250, $P = 3.8*10^{-8}$
Opah	95.6	98.2	6.455, $P = 0.011$	0.4	1.3	-----
Wahoo	90.5	95.1	8.798, $P = 0.003$	2.9	2.0	0.727, $P = 0.394$
Pomfrets	83.8	93.9	26.299, $P = 2.9*10^{-7}$	5.8	0.2	-----

Table 8.--Continued.

Species	No Interaction Obs = Log	Interaction Obs = Log	χ^2	Interaction Obs > Log	Interaction Obs < Log	χ^2
Blue Shark	36.3	32.3	0.915, $P = 0.339$	32.7	35.0	0.331, $P = 0.565$
Mako Sharks	94.6	89.0	18.270, $P = 1.9*10^{-5}$	8.3	2.7	-----
Thresher Sharks	85.0	97.1	41.688, $P = 1.1*10^{-10}$	2.2	0.7	-----

Table 9.--Summary of the patterns of exact concurrence in fish catches reported by NMFS fishery observers and in commercial logbooks relative to specific types of protected species interactions for four taxa taken in the Hawaii-based longline fishery. Entries for each taxon are the percentage of exact concurrence on longline sets without interactions, on sets with interactions with albatrosses, turtles, and both albatrosses and turtles, and chi-square tests for the independence of discrepancies from protected species interactions. See footnotes for scientific names and sample sizes.

Species	No Interaction	Albatross	Turtles	Both Types	χ^2 (Albatross)	χ^2 (Turtle)	χ^2 (Both Types)
Albacore	73.9	60.6	59.5	55.6	22.831, $P = 1.8*10^{-6}$	12.941, $P = 3.2*10^{-4}$	7.57, $P = 0.005$
Swordfish	71.1	53.9	49.6	42.2	23.110, $P = 1.5*10^{-6}$	2.997, $P = 0.083$	12.490, $P = 4.10^{-4}$
Mako Sharks	94.6	90.0	92.6	73.3	9.479, $P = 0.002$	-----	35.553, $P = 2.5*10^{-9}$
Blue Shark	36.3	33.8	29.8	28.9	0.553, $P = 0.457$	5.351, $P = 0.021$	22.057, $P = 2.6*10^{-6}$

'Turtles' include: Green turtle, *Chelonia mydas*, Leatherback turtle, *Dermochelys coriacea*, Loggerhead turtle, *Caretta caretta*, Olive ridley turtle, *Lepidochelys olivacea*, and unidentified turtles.
'Albatrosses' include: Laysan albatross, *Diomedea immutabilis*, and Black-footed albatross, *Diomedea nigripes*.
No interactions: $N = 2{,}168$ longline sets (Albacore); $N = 2{,}229$ longline sets (Swordfish); $N = 2{,}242$ longline sets (Mako sharks); $N = 2{,}144$ longline sets (Blue shark) .
Albatross interactions: $N = 269$ longline sets; Turtle interactions: $N = 121$ longline sets; Albatross and turtle interactions: $N = 45$ longline sets.

Table 10.--Numbers of fish sold at the United Fishing Agency, Honolulu, Hawaii, are presented with fish catch totals ($N = 60$ trips) reported by NMFS fishery observers and in commercial logbooks for 12 fish species taken in the Hawaii-based longline fishery.

Species	Auction Total	Logbook Total	Observer Total
Albacore	1311	1625	1842
Bigeye Tuna	2953	3265	3330
Yellowfin Tuna	1195	1201	1334
Skipjack Tuna	121	273	349
Swordfish	2473	3036	3309
Spearfish	481	486	541
Striped Marlin	1063	985	1048
Blue Marlin	329	458	513
Wahoo	267	298	341
Mahimahi	1122	1933	2315
Opah	370	374	380
Pomfrets	411	439	604

Table 11.--Summary of NMFS fishery observer ('O') and commercial logbook reports ('L') in relation to United Fishing Agency auction sales totals ('A'). The number of trips (left entry) and the number of fish sold in each condition (parenthetical entry) are presented for 12 fish species taken in the Hawaii-based longline fishery ($N = 60$ trips).

Species	O=L, L=A	O=L, L>A	O=L, L<A	O>L, L=A	O>L, L>A	O>L, L<A	O<L, L=A	O<L, L>A	O<L, L<A
Albacore	16(55)	7(23)	2(192)	3(24)	15(390)	7(275)	1(6)	9(346)	0(0)
Bigeye Tuna	1(3)	12(271)	0(0)	3(29)	19(1411)	7(293)	2(121)	15(673)	1(152)
Yellowfin Tuna	17(121)	5(35)	1(3)	8(249)	9(222)	14(438)	1(22)	3(24)	2 (81)
Skipjack Tuna	26(2)	9(2)	0(0)	3(0)	12(39)	6(37)	0(0)	4(41)	0(0)
Swordfish	11(12)	6(45)	0(0)	8(21)	29(1986)	4(199)	0(0)	2(210)	0(0)
Spearfish	16(21)	5(73)	2(27)	8(35)	6(47)	16(214)	1(17)	6(47)	0(0)
Striped Marlin	8(47)	10(72)	4(121)	5(47)	11(286)	9(132)	2(152)	11(206)	0(0)
Blue Marlin	19(20)	5(16)	1(3)	7(83)	4(19)	12(112)	1(8)	10(56)	1(12)
Wahoo	15(15)	12(9)	2(6)	8(28)	9(62)	10(98)	0(0)	4(49)	0(0)
Mahimahi	5(9)	10(151)	1(24)	3(29)	28(690)	3(24)	0(0)	10(195)	0(0)
Opah	45(93)	3(19)	1(18)	1(9)	2(150)	4(35)	1(24)	3(22)	0(0)
Pomfrets	24(15)	7(29)	0(0)	7(8)	11(271)	10(82)	0(0)	1(6)	0(0)

FIGURES

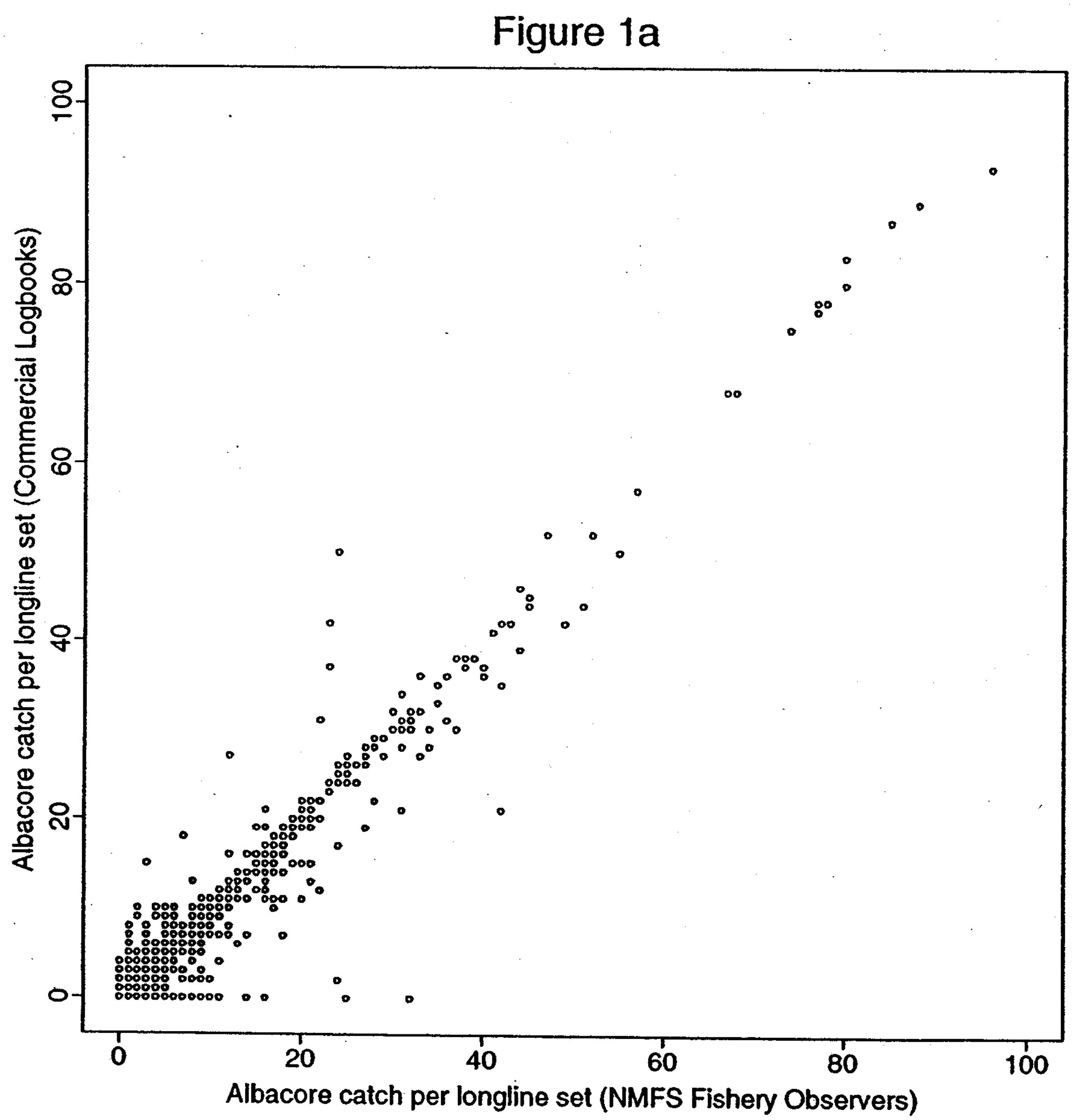

Figure 1a.--Catches of albacore reported in the logbooks of Hawaii-based commercial longline vessels in relation to catches reported by NMFS fishery observers from March 1994 through December 1998.

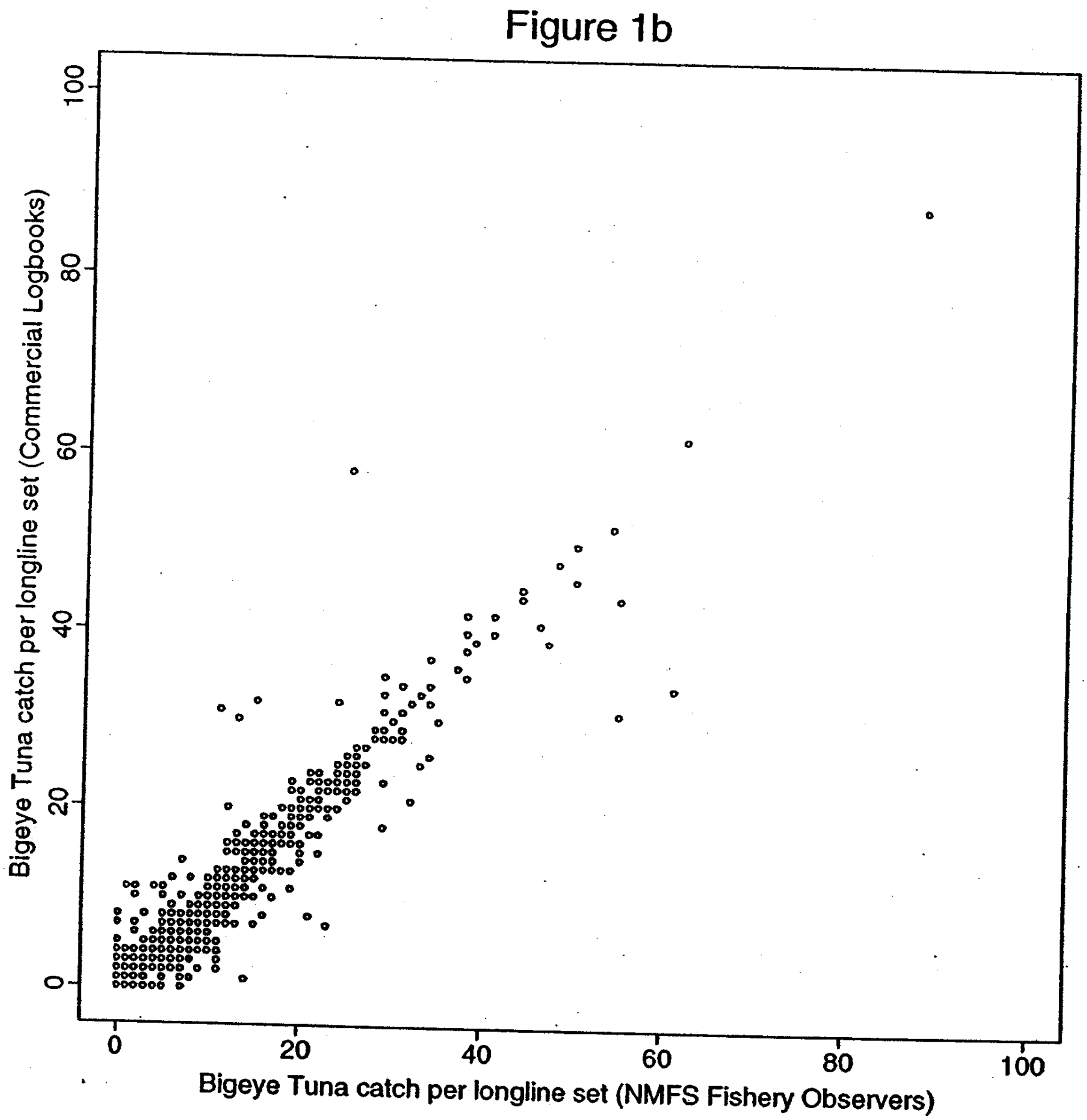

Figure 1b.--Catches of bigeye tuna reported in the logbooks of Hawaii-based commercial longline vessels in relation to catches reported by NMFS fishery observers from March 1994 through December 1998.

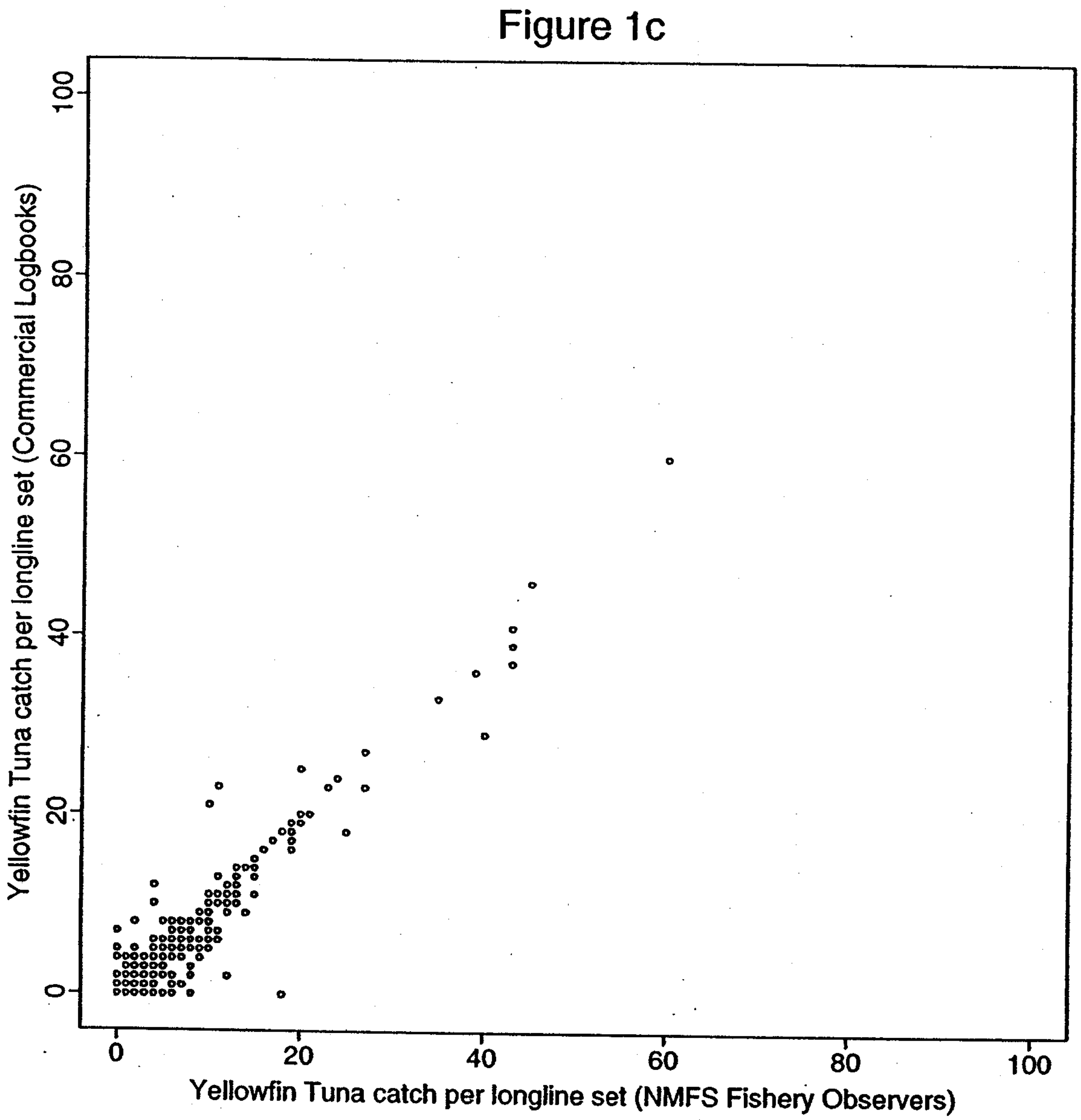

Figure 1c.--Catches of yellowfin tuna reported in the logbooks of Hawaii-based commercial longline vessels in relation to catches reported by NMFS fishery observers from March 1994 through December 1998.

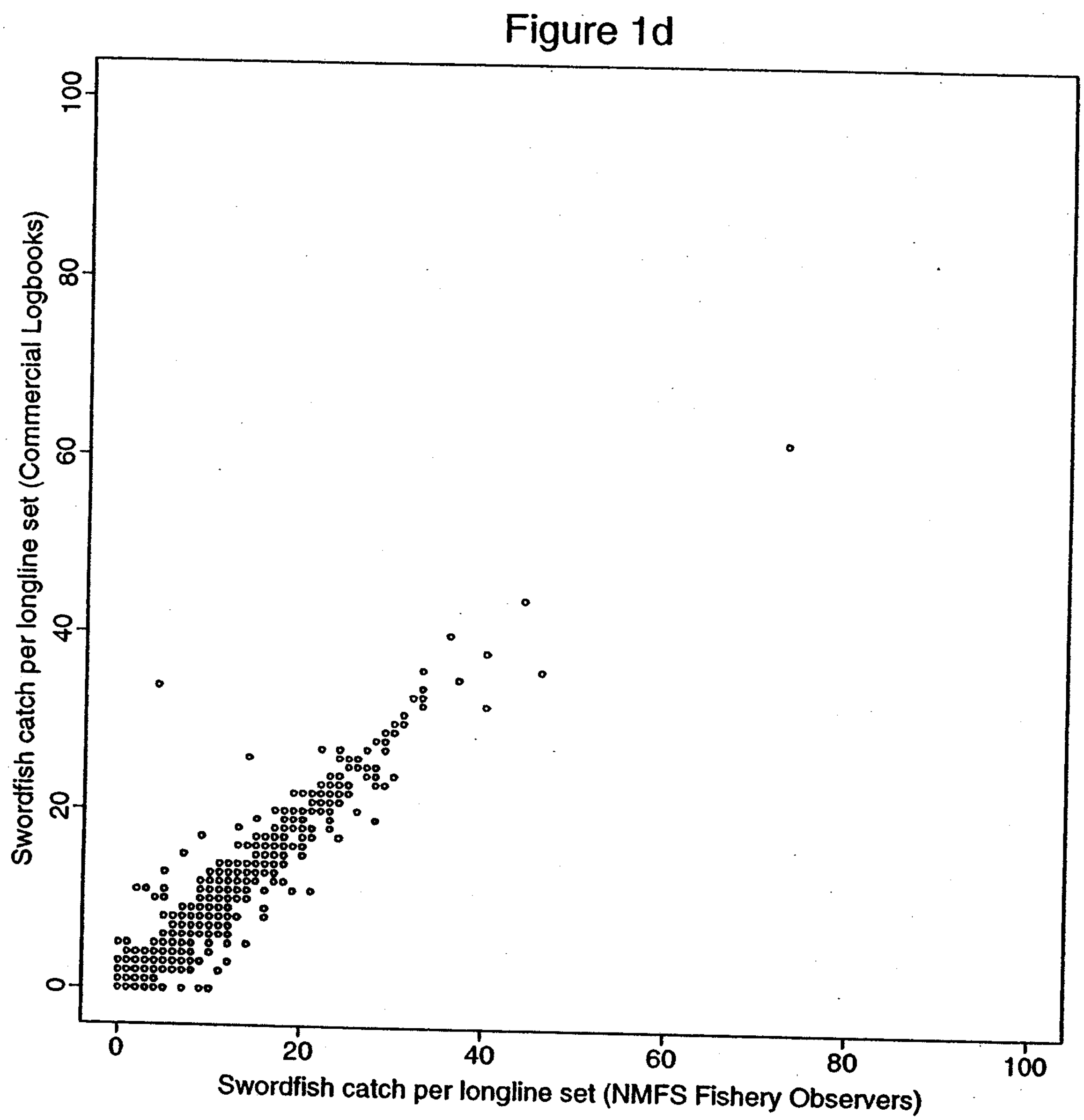

Figure 1d.--Catches of swordfish reported in the logbooks of Hawaii-based commercial longline vessels in relation to catches reported by NMFS fishery observers from March 1994 through December 1998.

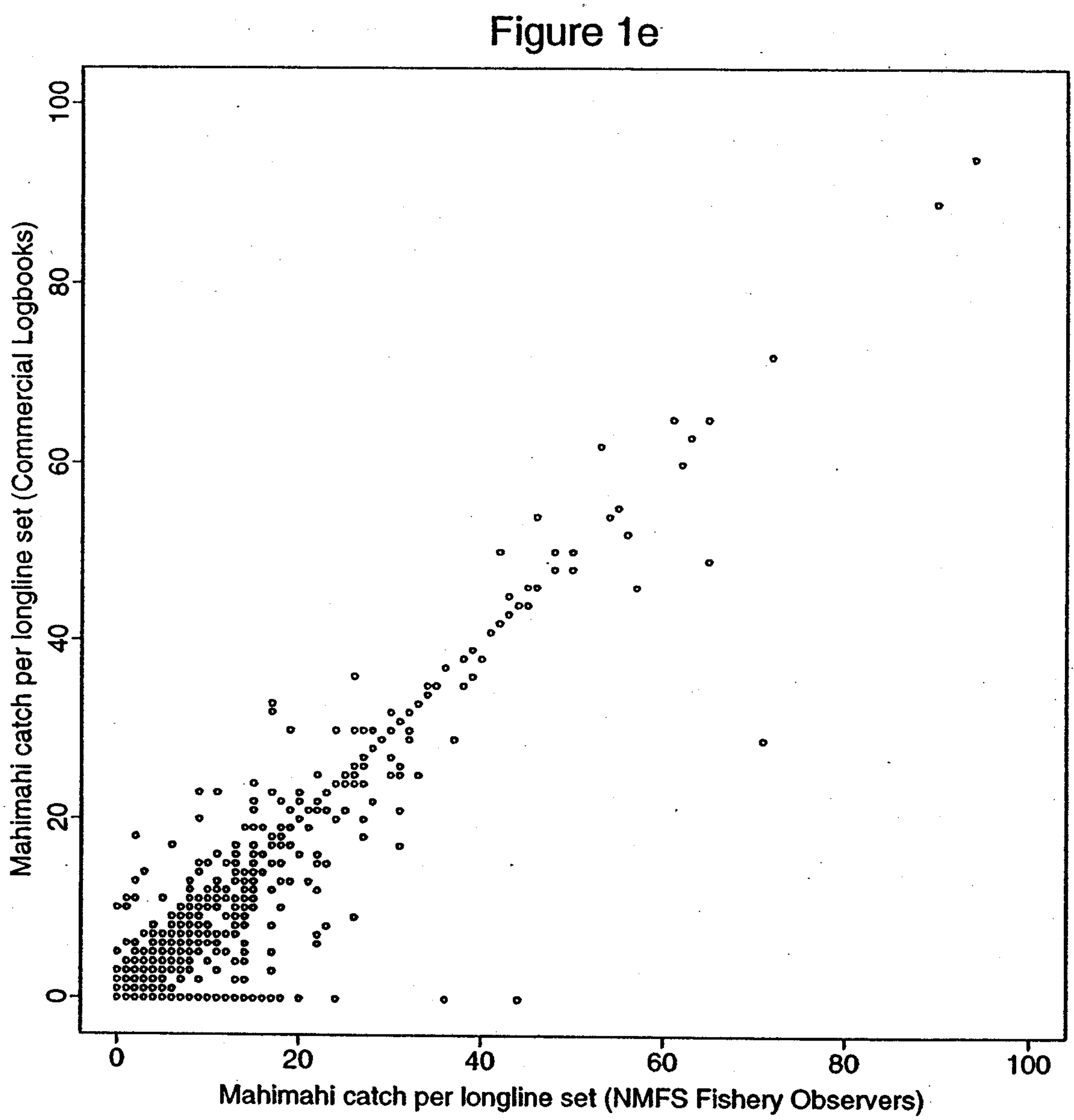

Figure 1e.--Catches of mahimahi reported in the logbooks of Hawaii-based commercial longline vessels in relation to catches reported by NMFS fishery observers from March 1994 through December 1998.

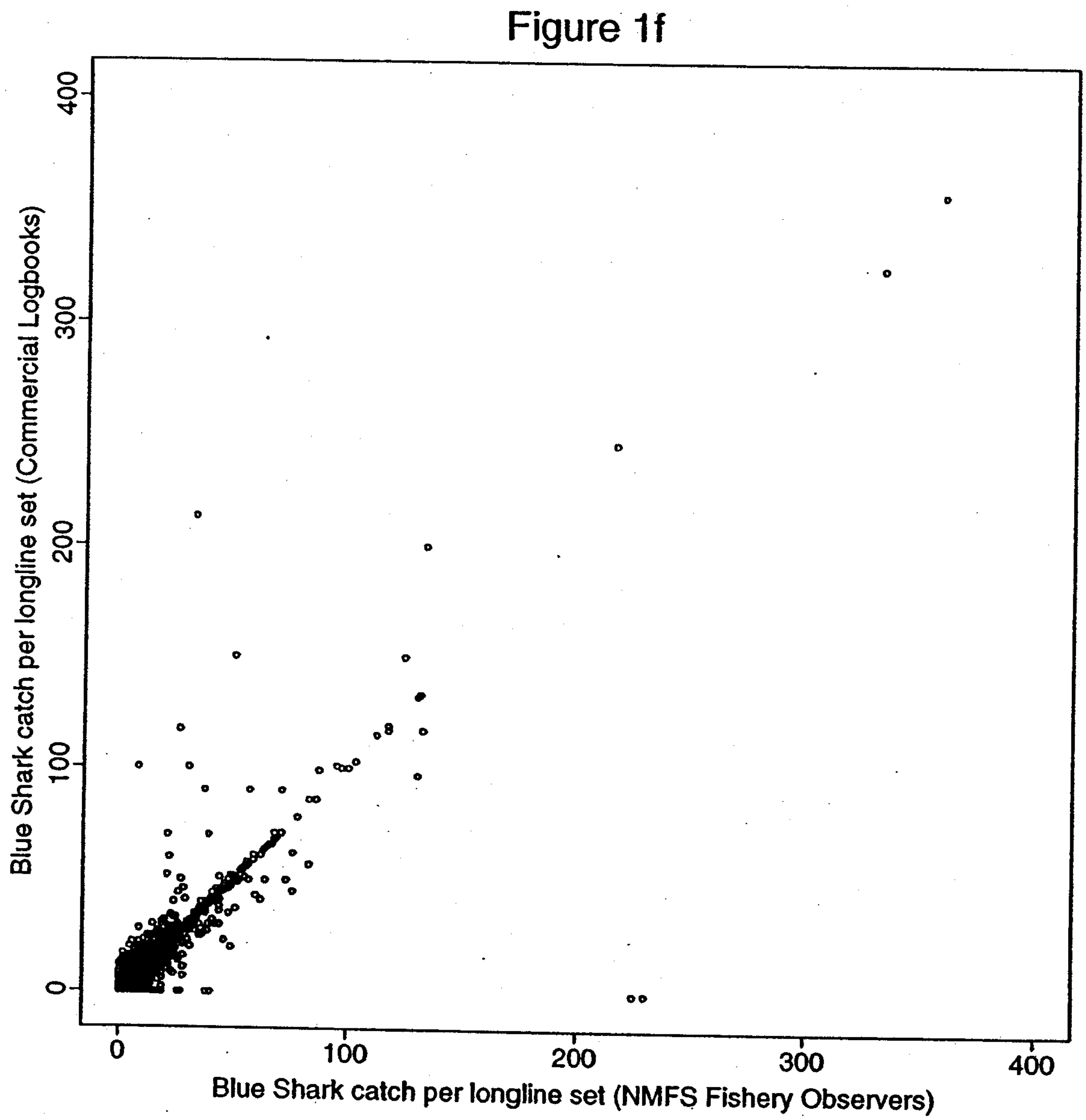

Figure 1f.--Catches of blue shark reported in the logbooks of Hawaii-based commercial longline vessels in relation to catches reported by NMFS fishery observers from March 1994 through December 1998.

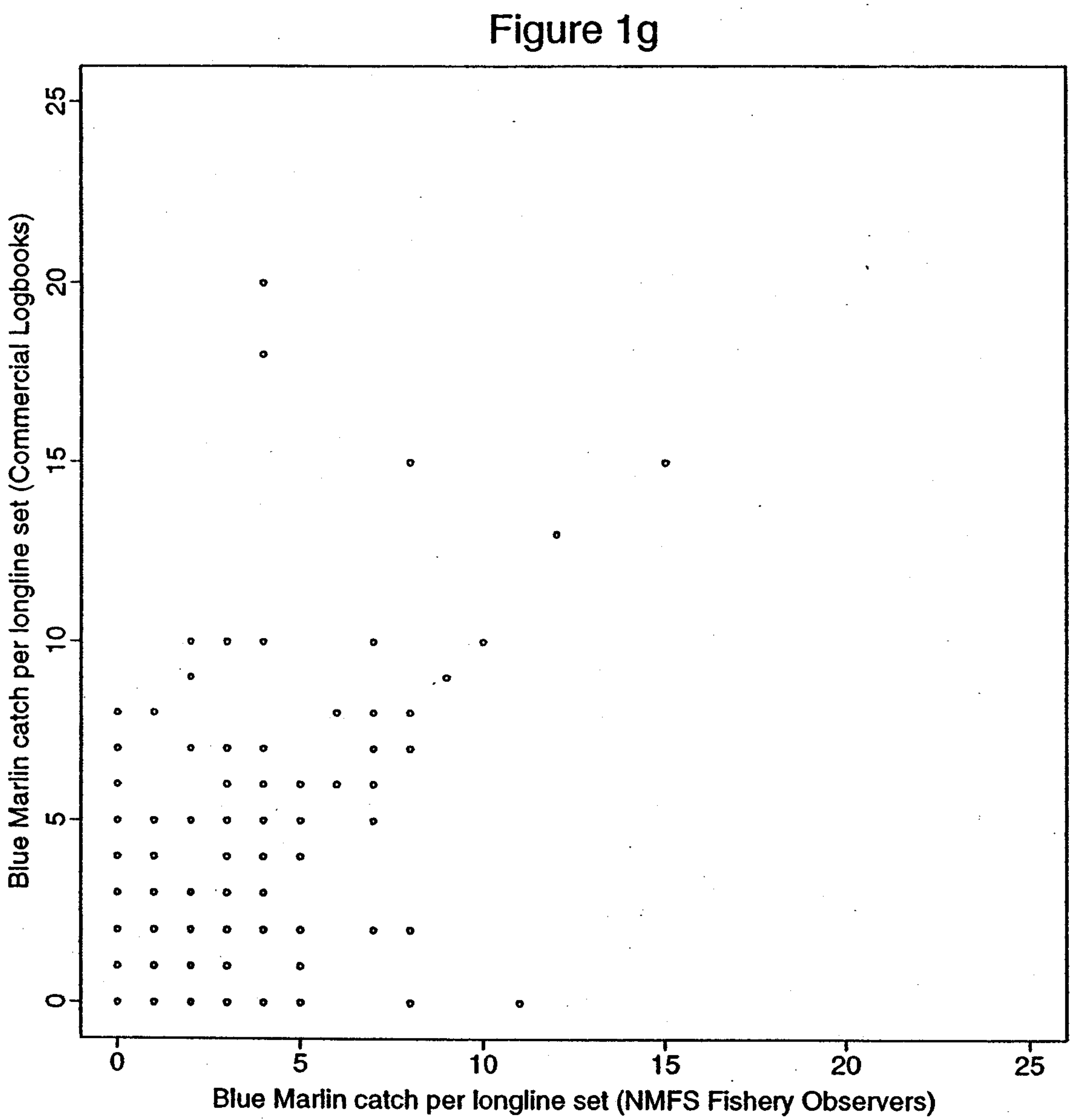

Figure 1g.--Catches of blue marlin reported in the logbooks of Hawaii-based commercial longline vessels in relation to catches reported by NMFS fishery observers from March 1994 through December 1998.

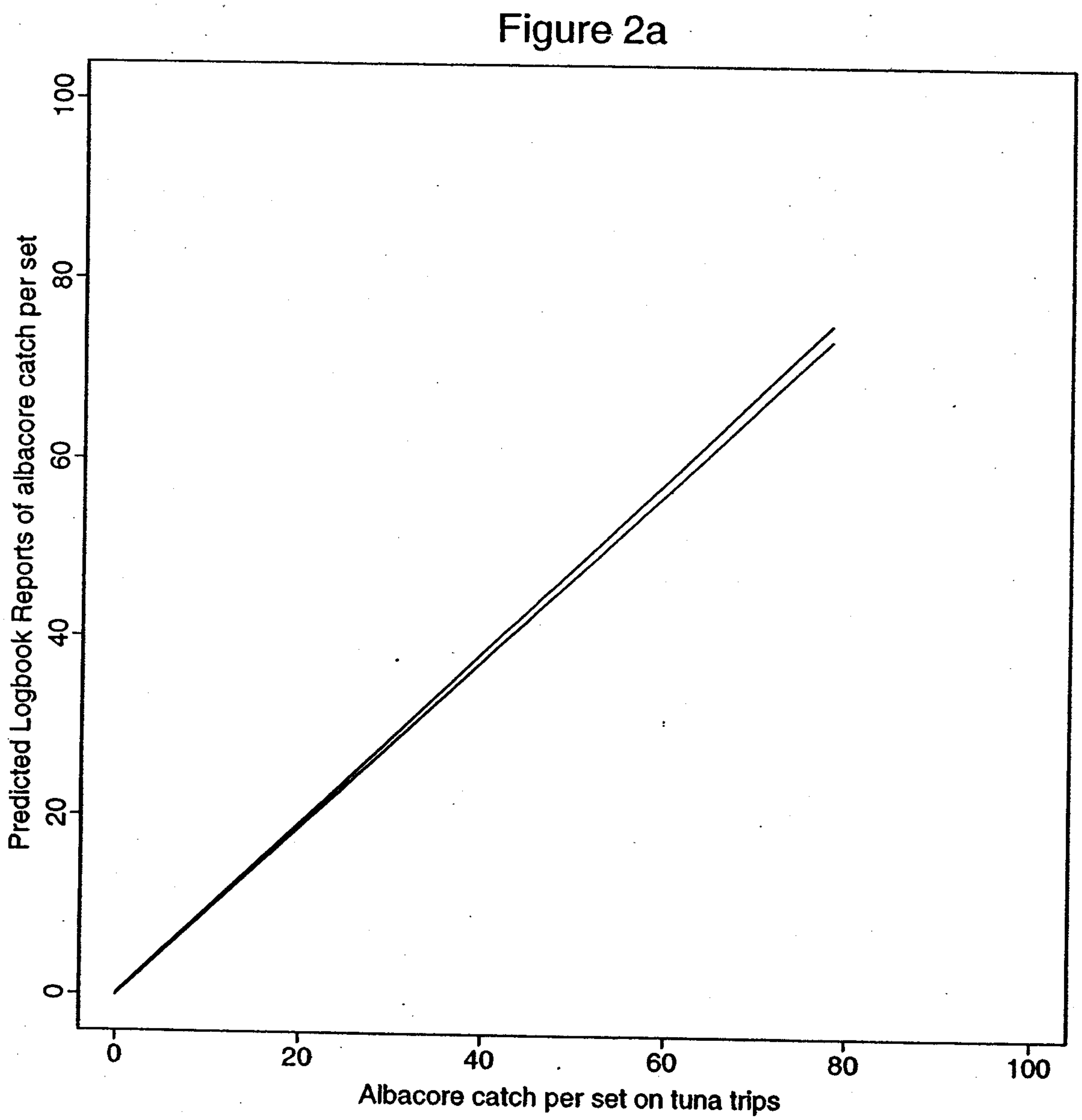

Figure 2a.--95% confidence belts about predicted logbook catch reports for albacore in relation to catch sizes obtained from linear regression analyses.

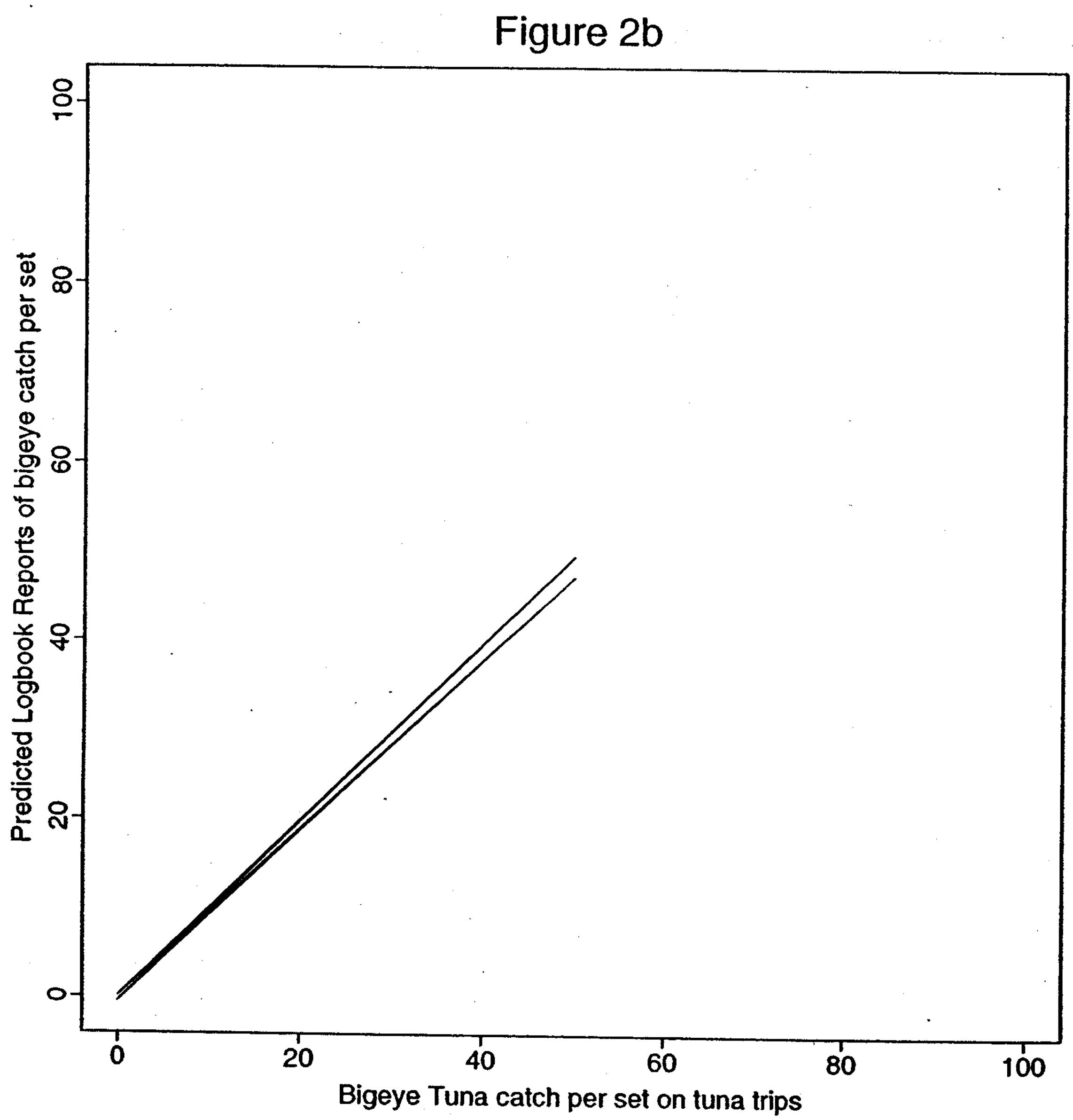

Figure 2b.--95% confidence belts about predicted logbook catch reports for bigeye tuna in relation to catch sizes obtained from linear regression analyses.

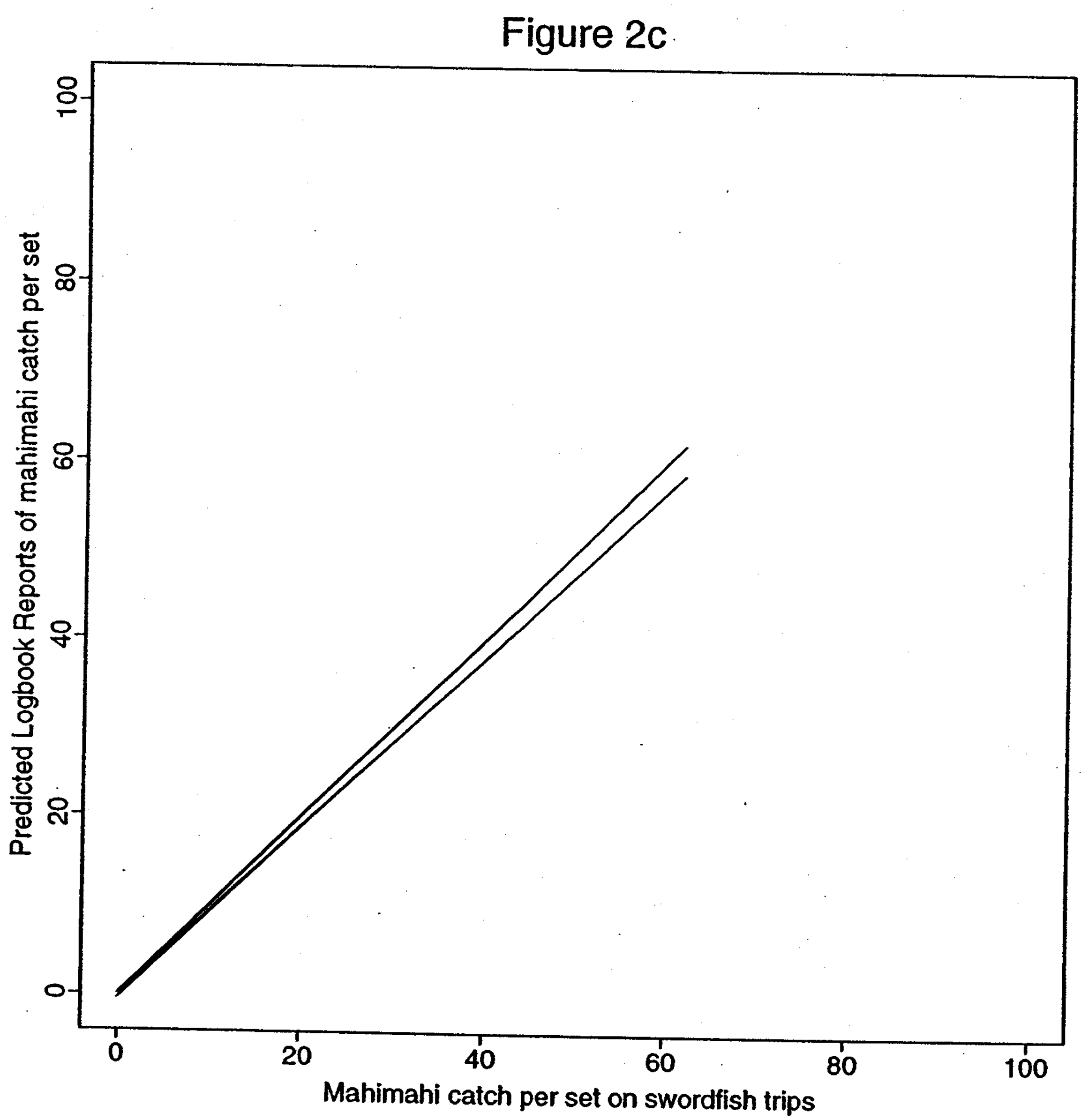

Figure 2c.--95% confidence belts about predicted logbook catch reports for mahimahi in relation to catch sizes obtained from linear regression analyses.

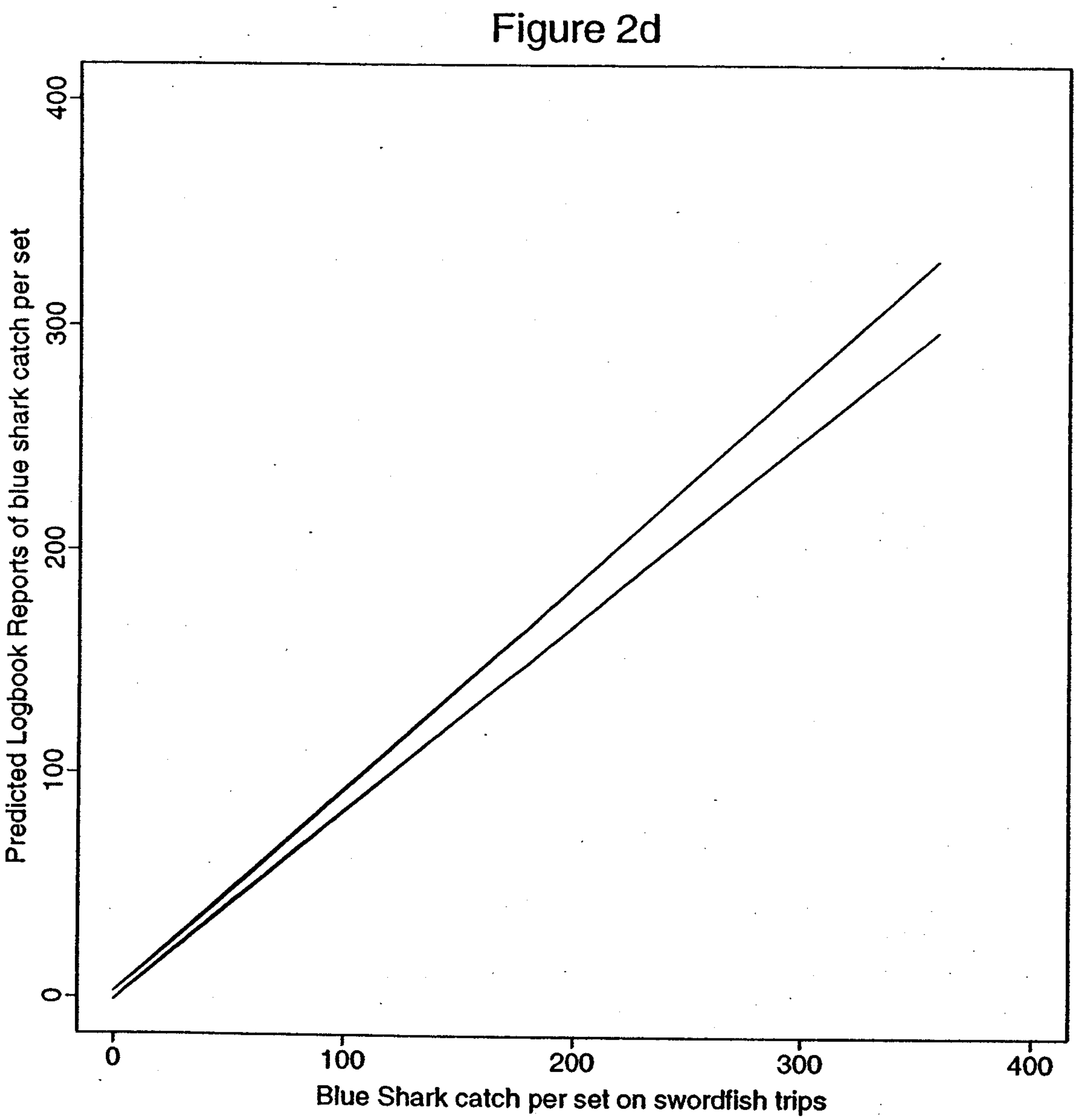

Figure 2d.--95% confidence belts about predicted logbook catch reports for blue shark in relation to catch sizes obtained from linear regression analyses.