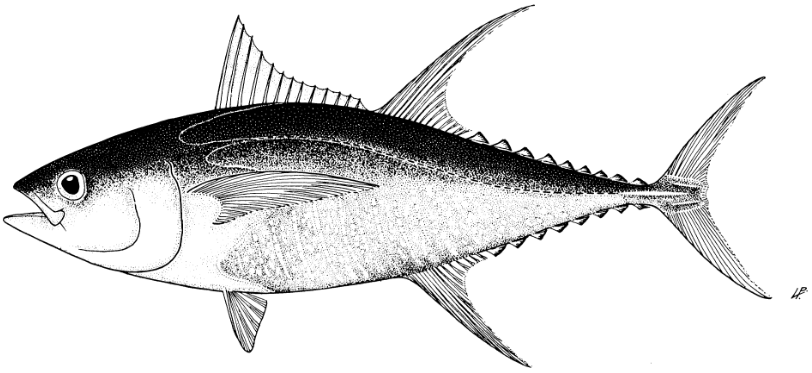
16th Meeting of the Standing Committee on Tuna and Billfish

SCTB 16
Mooloolaba, Qld, Australia
9-16 July 2003

SCTB16 Working Paper

SWG–8

Observer coverage in the Hawaii-based longline fishery: A Case Study



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Observer Coverage in the Hawaii-based Longline Fishery: A Case Study[1]

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Observer Coverage in the Hawaii-based Longline Fishery: A Case Study[2]

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Abstract

An observer program was established in the Hawaii longline fishery in 1994 to monitor interactions with sea turtles. During the first 6 years of the program, observers were placed on about 3-5% of fishing trips by the fleet. Data collected by observers indicated that bycatches ("takes") of turtles were particularly likely to occur on fishing operations using shallow-set gear to target swordfish in the subtropical frontal zone north of the main Hawaiian islands. In mid-2000, in response to a Federal court order, NMFS implemented new fishing rules designed to reduce turtle takes, including restrictions on the time and area of fishing. NMFS also expanded observer coverage to 20% to increase the precision of turtle take estimates. In 2001, additional regulations were introduced, including a prohibition on the use of shallow-set gear and the intentional targeting of swordfish. As expected, these measures have reduced the frequency of interactions with turtles per trip and the total turtle take by the fleet. However, interactions with turtles are now so infrequent that take estimates are actually less precise than before – despite higher observer coverage. Given the continuing scrutiny of the fishery and the high cost of fielding observers, it is important that an appropriate level of coverage be determined under the current conditions. Thus, in planning and budgeting for observer coverage, managers of the fishery need to decide on a primary monitoring objective (e.g., estimate of annual take of a particular turtle species) and the level of precision required (e.g., a specified coefficient of variation in the take estimate).

Introduction

In many commercial fisheries, scientific observers are deployed to help monitor the magnitude and composition of the catch and collect other data important to fishery science and management. One of the issues fishery managers face is to decide how many fishing trips to observe in each fleet consistent with monitoring objectives and annual budgets. The number of observed trips, together with the expected total number of trips by the fleet, will determine the level of *coverage*, defined as the proportion of total trips carrying observers. For a fixed total number of trips, higher observer coverage will mean better monitoring, e.g., more precise estimates of bycatch by the fleet, but also higher management costs. Conditions affecting

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coverage decisions include the total number of trips by the fleet, monitoring objectives, variability among sampling units in the factors being monitored (e.g., variation in turtle bycatch, or “takes”, per trip), and costs of deploying observers in the fishery. These conditions will vary by fishery. Planning of observer programs for fisheries not now monitored can be aided by case studies of similar fisheries where observers have been deployed in regional or national programs.

This paper is a case study of observer coverage in the Hawaii-based longline fishery. It reviews early events leading to deployment of observers, including development of a pilot program, and describes changes in observer coverage during the recent history of the fishery. Fishery logbook statistics and observer data for 2002 are used to calculate simple ratio estimates of catch for a several species of fishes, sea turtles, and albatrosses, and associated coefficients of variation. These results indicate the approximate levels of precision to be expected under the current level of observer coverage for a range of possible monitoring objectives.

Background

Historically, Hawaii’s longline fleet fished for tunas around the main Hawaiian islands and was a relatively minor contributor to the state’s total fish catch. Between 1989 and 1991 the fleet grew from 37 to 141 vessels and longlining became the most important Hawaii-based fishery (Ito and Machado 2001). The new longline vessels came primarily from U.S. fisheries in the Atlantic and Gulf of Mexico and introduced the monofilament gear and fishing methods developed there. In November 1990, as the fleet grew and catches increased, NOAA Fisheries (National Marine Fisheries Service, NMFS) established a logbook program to monitor the fishery. Longline vessel captains were required to record their daily catch and fishing effort and submit the data to NMFS after each trip. In the early days of the expanded fishery a few vessels also volunteered to carry NMFS observers to record more details of the catch and bycatch.

Many of the new vessels targeted swordfish in the subtropical frontal zone north of the main Hawaiian islands. Logbook data showed that catch rates of swordfish were much higher in this frontal region than in the tuna longline grounds farther south. The observer data, although sparse, showed that vessels fishing in the frontal zone were also much more likely to take sea turtles.

The incidental mortality of sea turtles soon became the central issue in management of the longline fishery. Under the U.S. Endangered Species Act, NMFS established annual turtle take and mortality limits and, in 1994, launched a pilot observer program to collect detailed data on fishing operations and catch by species for selected longline trips. NMFS combined the observer data and logbook data to estimate the total take of sea turtles by the fleet and ensure compliance with the take limits.

Coverage in the Pilot Observer Program

Statistical guidelines for the pilot observer program were developed by DiNardo (1993). The few observer data available in 1993 revealed that the frequency of turtle interactions (e.g., takes per longline set) varied according to the species of fish targeted on the fishing trip: higher turtle take rates were observed on swordfish trips; lower turtle take rates on tuna trips; and intermediate turtle take rates on trips where the aim was to maximize the catch of a mixture of species. Accordingly, the pilot observer program was designed around a a stratified sampling plan with fishing trips as the primary sampling unit. Strata were defined on the basis of trip type (swordfish, tuna, mixed) and time (quarter of year).

In developing the statistical guidelines, DiNardo computed a range of nominal sample sizes (in terms of the number of observed sets) that would achieve a specified statistical precision in a simple ratio estimator of total annual turtle take given assumed levels of take variability and the current magnitude of the fishery (total annual sets by the fleet). Precision was stated in terms of the coefficient of variation in the estimate of total turtle take, equivalent to achieving a specified “tolerable error” in the estimate of total turtle take with specified statistical confidence. DiNardo did not establish or recommend an appropriate level of precision; that decision was left to NMFS managers. The pilot observer program was implemented with 55 observed trips in 1994 and 42 trips in 1995, providing a trip coverage of 5.3% and 4.5%, respectively (Table 1). This coverage level was expected to yield an estimate of total turtle take (all turtle species combined) with a coefficient of variation (CV) of about 0.20, i.e., in theory estimates would be within 40% of the true take with about 95% confidence.

A Reassessment of Observer Coverage

In 1996, NMFS recommended that the pilot sampling design be replaced by a modified design in which strata were defined by vessel length, rather than target species, and suggested that coverage be increased to about 20% (Skillman et al. 1996). These recommendations followed an analysis of data from the 97 trips monitored during 1994 and 1995. A vessel’s overall length was found to be closely associated with key predictors of turtle take, e.g., target species and latitude of fishing. Large vessels were better able to undertake the longer trips to the distant swordfish grounds, whereas smaller boats often were confined to tuna grounds closer to Honolulu. Accordingly, large vessels tended to have more encounters with sea turtles than smaller vessels. Although several stratification schemes based on vessel length and other variables produced similar CVs of the take rate estimate, a design based on vessel length alone was deemed most practical, because it was easy to set up and maintain the necessary lists of vessels within the strata. A simple 2-stratum vessel length design was selected with a division at 70 ft (21.3 m). NMFS was advised to allocate sampled observer trips among the strata in proportion to the expected turtle take rates in the strata. This meant placing more observers on the larger boats, which had been accounting for 87% of the total turtle take. Skillman et al. (1996) included a table showing expected statistical precision and total observer fielding cost as a function of coverage in each stratum. The recommended 20% coverage in both strata was expected to double the precision of turtle take estimates, resulting in CVs of about 10-15%, assuming an average fleet effort of about 1,100 trips per year. In April 1997, NMFS accepted the recommendations but was unable to implement them for various reasons, including budget limitations and the need to deploy observers in the Hawaii lobster fishery; observer coverage of longline trips during 1997-1999 averaged only 3.5%.

Litigation and Recent Increases in Observer Coverage

For the past several years, turtle conservation groups have engaged NMFS in litigation seeking to reduce the incidental mortality of turtles caused by Hawaii longline fishing. In November, 1999, the U.S. District Court in Honolulu ordered the temporary closure of a large area of the swordfish grounds to Hawaii vessels and directed NMFS to study the fishery's interactions with turtles in relation to season and ocean area. In August 2000, the court issued new orders included new time-area restrictions, based on results of the NMFS study, and an immediate increase in observer coverage — up to 100% coverage on trips to the main swordfish grounds and at least 20% in other areas. As a result, the overall coverage in 2000 was 10.4%. In March 2001, the court issued a revised order which tightened restrictions on the longline fleet, including a prohibition on targeting of swordfish. These measures were consistent with recommendations in a NMFS Environmental Impact Statement. Concurrently, NMFS issued a Biological Opinion requiring continuation of observer coverage of 20% or higher, as had been recommended in the 1996 study and required by the court order. Under the expanded observer program, overall coverage increased to 22.5% in 2001 and 24.6% in 2002.

The 20% minimum coverage requirement remains in effect. In May 2002, observer program managers at the NMFS Pacific Islands Region Office (PIRO) installed a new protocol for placing observers based on a systematic sampling scheme, with trips stratified by quarter. The new protocol allows for the estimation of turtle takes using probability sampling methods. NMFS aims to achieve fairly even coverage in all quarters. The observer program contractor, Saltwater, Inc., maintains a staff of observers sufficient to accomplish this goal.

Current Precision of Catch Estimates: Analysis of the 2002 Observer and Logbook Data

If the catches of all species caught were accurately reported in logbooks, catch and bycatch monitoring would not require observer data – we could simply tally the daily logbook entries. However, because interactions with protected species often are not recorded in the Hawaii logbooks or not recorded correctly, observer data are used to estimate annual takes of sea turtles, seabirds, and marine mammals. Likewise, logbook statistics often significantly understate the catch of fish species with little or no commercial value. In such cases, accurate assessments of total catch require that observer data be applied to estimate the catch on unobserved trips, as with the protected species (Walsh and Pooley 2002).

A simple analysis was done to illustrate the approximate level of precision that could be expected under current conditions if observer and logbook data were used jointly to estimate annual catch by species. For purposes of this exercise, the catch in 2002 was estimated for a list of selected species recorded in the logbooks and observer records: 7 species of fish, 2 species of albatrosses, and 4 species of sea turtles. The data consisted of daily logbook records covering 1,161 trips involving a total of 13,761 sets and 26.7 million hooks. Observer data were available for 287 trips sampled in 2002 covering 3,500 sets and 6.7 million hooks.

Total 2002 catch estimates were computed using a simple ratio estimator (Table 2). Specifically, total catch of a species was estimated as the total number of sets hauled by the fleet during 2002 multiplied by the ratio of the total observed catch of the species to the total number of observed sets. The ratio estimator was used because it was easy to apply to all the species in the data set and convenient for illustrating how the precision of catch estimates depends on the variability of catch rate. However, the ratio estimator is biased and bias was likely increased by violations of key assumptions underlying the estimator, namely that observed trips were sampled independently and with equal probability from all trips hauling gear during the year. These limitations of the ratio estimates should be kept in mind when considering the following results.

Other methods would provide better estimates of catch for each of the selected species. In particular, McCracken is using a Horvitz-Thompson estimator to compute the official 2002 takes of sea turtles, albatrosses, and marine mammals [Marti McCracken, pers. comm.; work in progress]. Her estimator, which is unbiased, explicitly takes into account changes in the protocols for deploying observers during 2002 and the time-specific inclusion probabilities for the sampled trips.

For each species, Table 2 also lists the reported logbook catch in 2002. The discrepancies between these statistics and the ratio estimates of catch vary by species, as expected. For most of the listed fish species, logbook catch totals are reasonably close to the ratio estimates of catch. But for turtles and albatrosses the logbook totals are much smaller than the ratio estimates – hence the need for the observer program.

Precision of the catch estimates is measured by the coefficient of variation (CV) of the estimate, also given in Table 2. Higher CVs indicate less precision. The CVs of the ratio estimates vary widely from 0.89 for green turtles to 0.03 for the target species, bigeye tuna. The CV of the catch estimate is directly related to the CV of catch per trip (1.0 for green turtles and 0.63 for bigeye tuna) and inversely related to the average catch frequency of the species, e.g., the mean catch per trip. In 2002, the observed mean catch per trip was 130.5 for bigeye tuna and 3.5×10^{-3} for the rarely encountered green turtle – only a single green turtle was recorded during the 287 observed trips. For all species of sea turtles combined, the observed catch per trip was 4.9×10^{-2} and the CV of estimated catch was 0.25. These results show clearly that the catch of species caught rarely, e.g., sea turtles, can be estimated only with low precision under the current level of observer coverage.

The ratio estimates of catch for commonly occurring species, e.g., tunas, are much more precise (Table 2). Such estimates show that catches of commercially important fish species are generally recorded with reasonable accuracy. However, logbooks often significantly under-report the catch of fish with low commercial value that are usually discarded. Observer data are needed to derive accurate catch estimates for these species. Statistical models based on observer data have been developed to predict catches on the unobserved trips (Walsh 2000; Walsh and Pooley 2002; Walsh et al. 2003). These models would be preferable to the simple ratio estimators used here.

The higher observer coverage in place since late 2000 would have been expected to approximately double the precision of turtle take estimates, assuming no change in other factors affecting precision. However, the ban on swordfish operations and the resulting change in geographical distribution of fishing effort (Figure 1) significantly altered another key factor, namely the distribution of turtle take frequency (e.g., the mean and CV of take per trip). Turtle take frequency varies with the depth of fishing. The regulations specifically prohibited use of shallow-set gear typically used to target swordfish and accelerated a trend towards use of deep-set gear, targeting bigeye tuna, that had begun in the late 1990s (Figure 2). Based on all observer data collected to date, the mean take per set of turtles (all species combined) on deep sets (defined here as those using 10 or more hooks per float) is only about 4% of the mean take rate on shallow sets (fewer than 10 hooks per float) (Figure 3). The CV of take per set on deep sets is about 4 times greater than on shallow sets (Figure 3). In 2002 all longline sets were classified as deep sets. Accordingly, despite the higher observer coverage in recent years precision in total take estimates has not increased. The CV for the ratio estimate of total turtle take in 2002 is about 25%, similar to the CV in 1996.

Although McCracken's official estimates of the 2002 turtle and albatross takes haven't been finalized, her preliminary results show that the Horvitz-Thompson estimates are fairly close to the simple ratio estimates. Judging by CVs, the precision of the ratio estimates and Horvitz-Thompson estimates of albatross takes also are very similar. For sea turtles, which occur less frequently in the catch, the preliminary Horvitz-Thompson estimates have CVs much larger than those of the ratio estimates. The differences are striking in the case of leatherbacks and green turtles, the two species with lowest frequency of occurrence. These comparisons must be tempered by the fact that the ratio estimates are biased to an unknown degree. Nevertheless, because the Horvitz-Thompson estimates are based on properly estimated inclusion probabilities, their CVs are likely to better reflect the real uncertainty in estimates of turtle take. The CVs of the ratio estimates given in Table 2 undoubtedly overstate the precision of those estimates.

The coefficient of variation of take estimates decreases predictably with observer coverage and depends systematically on variability in take per trip. The relationship of CV[estimated take] and coverage is shown in Figure 4 for a range of potential levels of variation in catch per trip. The plotted values were computed with the formula used to generate the results in Table 2. They assume a total fleet effort fixed at 1,161 trips, as in 2002.

In planning observer coverage, it is important to remember that the precision of take estimates depends not only on coverage, per se, but more directly on the number of trips observed (sample size) and hence the total number of trips from which the sample is drawn. For example, suppose the objective is to monitor takes of a species with a rarity similar to that of olive ridleys, i.e., a CV[take per trip] = 6. In a fishery with with 1,000 total trips, 25% coverage would involve 250 sampled trips and a CV[take estimate] of about 33% (Figure 5). Under the same conditions, but in a fishery with 500 total trips, the same coverage would mean a sample of only 125 observed trips and a higher CV[take estimate] of about 46% (Figure 5). On the other hand, if the observer budget allowed sampling of 250 trips in either case, the smaller fleet would be covered at 50% giving a smaller CV[take estimate] of about 27%. Clearly, all of the factors must be weighed in planning observer coverage.

Unresolved Issues in Observer Coverage

There are several issues needing resolution with respect to observer coverage in the Hawaii longline fishery. First, what is the principal monitoring objective? Since the inception of the observer program the list of key objectives has grown to include monitoring of albatross takes as well as turtle takes. If turtles are still the primary focus, is the goal to monitor the take of a particular species, e.g., leatherback turtles, rather than the total take of all turtles combined? If so, the coverage requirements may be much greater than heretofore considered.

Second, what level of precision is required? This depends on how the take estimate is used. If the primary focus is to monitor compliance with established annual take limits for turtles (e.g., limits specified in the Biological Opinion’s Incidental Take Statement), how will these limits be set in relation to the current statistical distribution of takes in the fishery? Given these limits, what are acceptable levels of Type I error (false positives) and Type II error (false negatives)? What level of observer coverage is needed to satisfy these requirements?

If take estimates are to be used as inputs to models of turtle populations, with a view to assessing impacts of the fishery, is the take by the fishery considered to be a substantial part of total human-caused mortality? If not, will a higher CV suffice?

Finally, are there other estimation methods that will increase precision of the take estimates? If so, the same monitoring objective may be achieved with lower observer coverage and cost.

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Acknowledgments

The draft of this paper was improved greatly by comments from several astute reviewers, including Joe Arceneaux, Ray Clarke, Charles Karnella, Marti McCracken, Bob Skillman, and William Walsh. Mahalo to them all.

Table 1. Observer coverage in the Hawaii longline fishery.
Source: NMFS/PIRO observer program reports.

Year	Trips Departing	Trips With Observers	Coverage
1994	1031	55	5.3%
1995	937	42	4.5%
1996	1062	52	4.9%
1997	1123	40	3.6%
1998	1180	48	4.1%
1999	1136	38	3.3%
2000	1134	118	10.4%
2001	1035	233	22.5%
2002	1128	278	24.6%

Table 2. Catch statistics for selected species from 2002 Hawaii longline observer data, estimates of the total 2002 catch for each species using a simple ratio estimator, and coefficients of variation (CV) of the catch estimates.

Selected Species	Mean Catch Per Trip	Mean Catch Per Set	Mean Catch Per 1,000 Hooks	CV[Catch/Trip]	Estimated Catch (*ratio method*)	CV[Est. Catch] (*ratio method*)	Reported Logbook Catch
Sea turtles							
Leatherback	0.0100	0.0006	0.0003	11.96	8	0.63	2
Loggerhead	0.0139	0.0011	0.0006	8.43	16	0.44	4
Olive ridley	0.0244	0.0020	0.0010	6.34	28	0.33	6
Green turtle	0.0035	0.0003	0.0002	16.94	4	0.89	0
Total ID'd turtles	0.0488	0.0040	0.0021	4.74	55	0.25	12
Seabirds							
Laysan albatross	0.0558	0.0046	0.0024	6.63	63	0.35	---
Black-footed albatross	0.0627	0.0051	0.0027	5.24	71	0.28	---
Total albatrosses	0.1185	0.0097	0.0051	4.17	134	0.22	29
Fishes							
Albacore	17.21	1.41	0.73	1.96	19,415	0.10	20,455
Bigeye tuna	130.51	10.70	5.56	0.63	147,262	0.03	138,720
Yellowfin tuna	27.09	2.22	1.15	2.93	30,573	0.15	20,164
Swordfish	5.20	0.43	0.22	1.99	5,870	0.10	3,659
Blue marlin	2.86	0.23	0.12	1.57	3,224	0.08	3,936
Blue shark	45.73	3.75	1.95	0.83	51,600	0.04	39,617
Opah	7.95	0.65	0.34	1.03	8,968	0.05	9,231

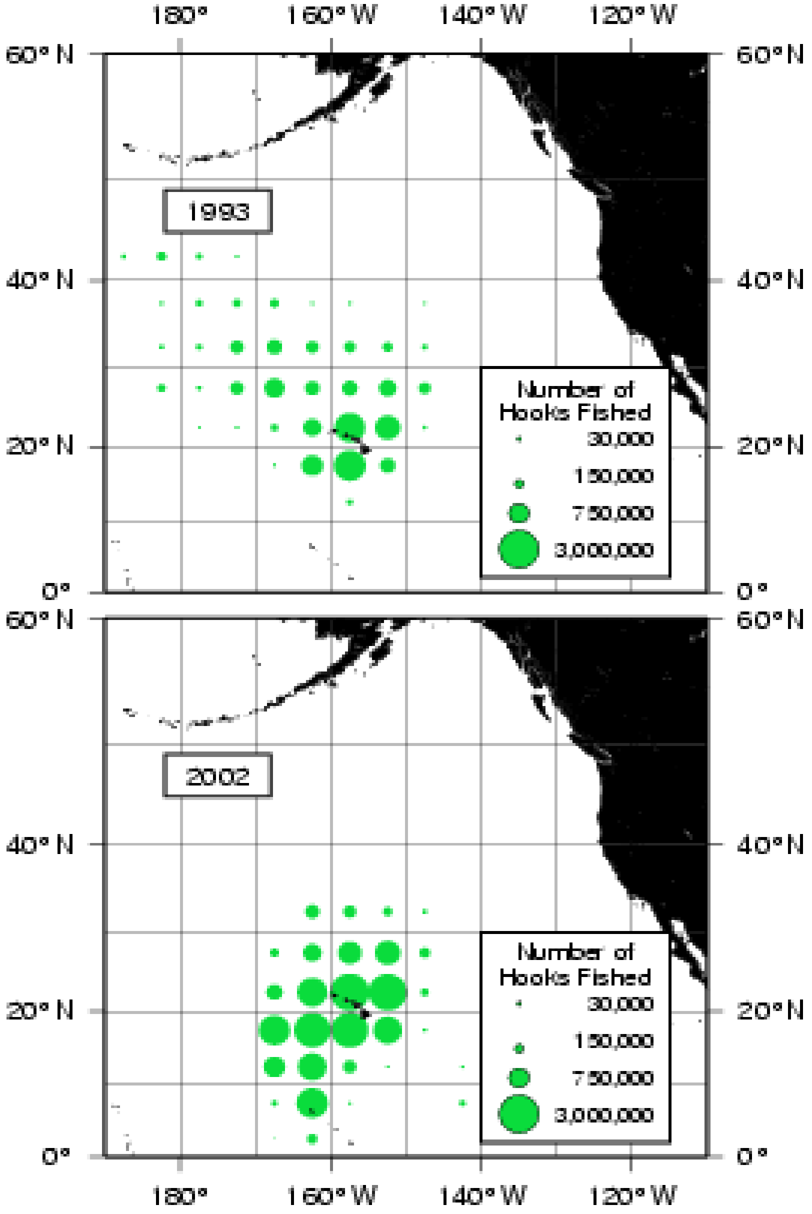

Figure 1. Geographical distribution of fishing effort in the Hawaii longline fishery in 1993, when fishing was unrestricted, and in 2002, after targeting of swordfish was prohibited. Based on NMFS logbook data.

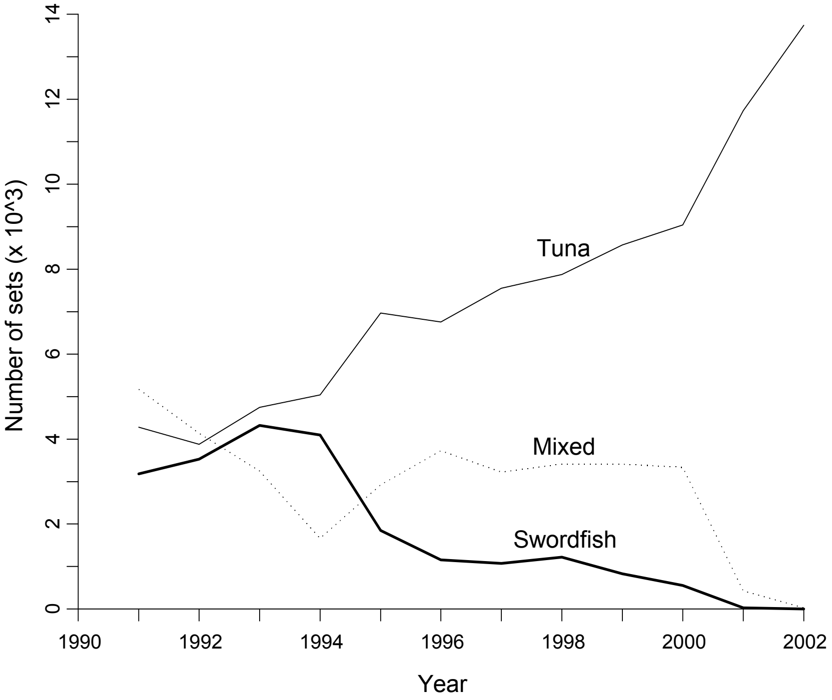

Figure 2. Number of sets (in thousands) completed by Hawaii longline vessels, by year and trip type, based on logbook data.

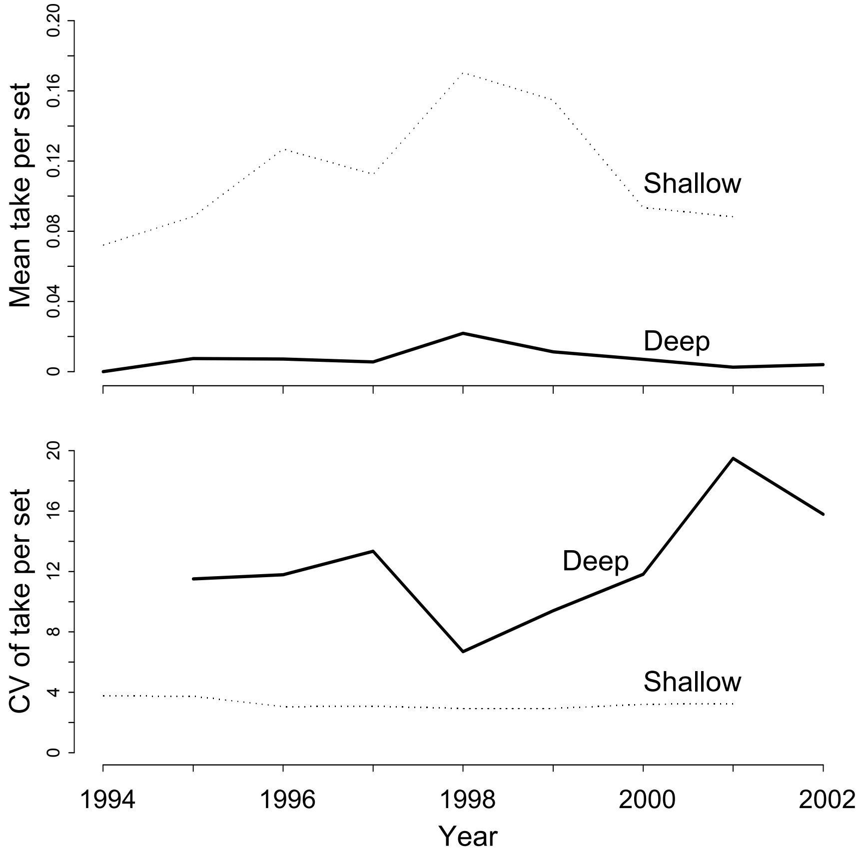

Figure 3. Mean turtle take per set (all species combined) and the coefficient of variation of take per set, by year and depth of set, based on NMFS observer data.

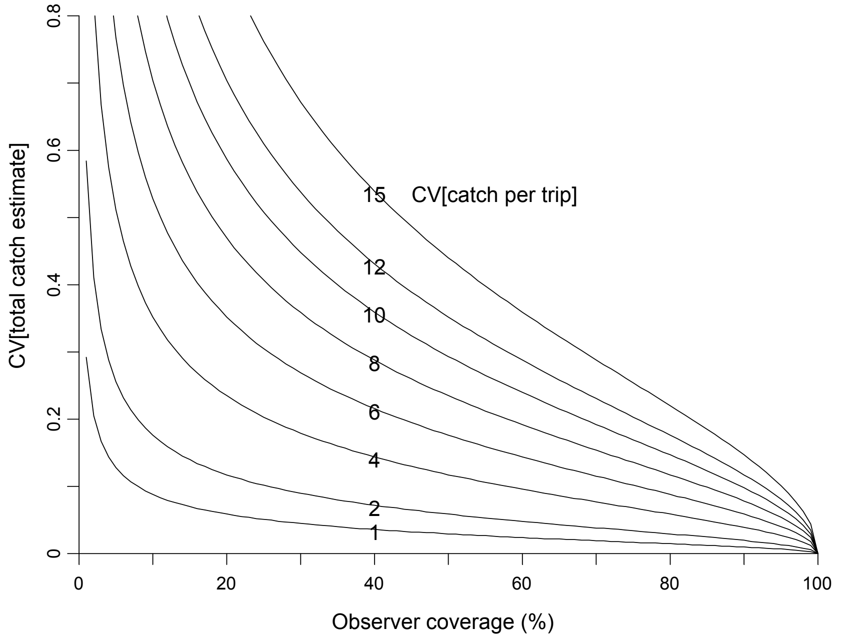

Figure 4. Coefficient of variation of total catch estimate as a function of observer coverage and CV[catch per trip], assuming a total fleet effort of 1,161 trips (as in 2002).

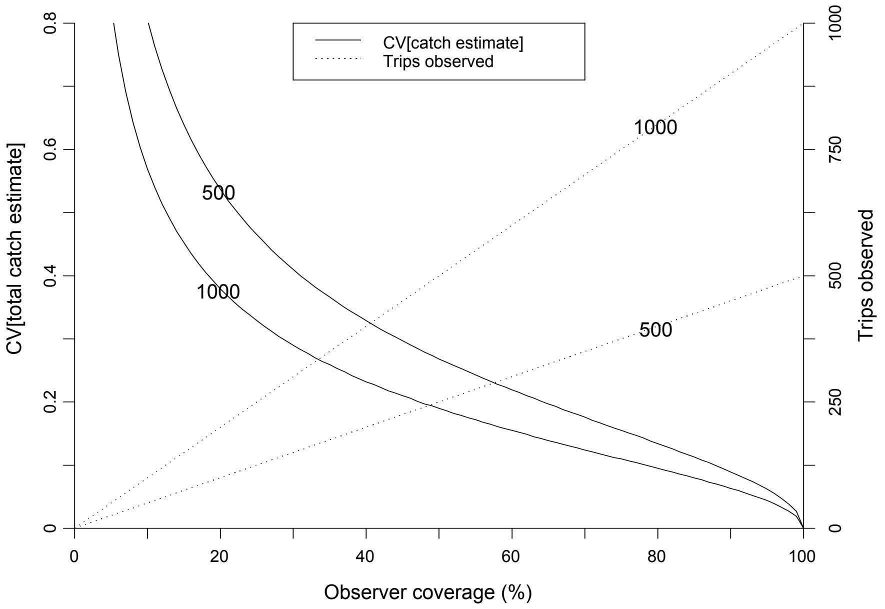

Figure 5. Coefficient of variation of total catch estimate and number of trips observed as functions of observer coverage for total fleet effort levels of 500 and 1,000 trips, assuming CV[catch per trip] = 6.