

**CONFIDENCE LIMITS OF CATCH PER UNIT EFFORT ESTIMATES AS A FUNCTION OF  
SAMPLING EFFORT FOR THE LARGE PELAGIC RECREATIONAL FISHERY IN VIRGINIA**

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**SUMMARY**

The precision of monthly estimates for the mean catch per unit effort of private and charter vessels fishing for large pelagic species off Virginia is examined as a function of the number of interviews. A bootstrap approach, wherein data from 1989 and 1990 are sampled as though they were the actual population, is used to generate the upper and lower confidence intervals associated with a given sampling intensity. The width of the 90 percent confidence interval, which is about equal to the magnitude of the mean at ten intervals per month, decreases asymptotically with the number of interviews. The gain in precision is rapid initially, but levels off to about one-third of the mean after 100 interviews. The number of interviews necessary to achieve a given level of precision was consistently higher for charter vessels than for private vessels. The precision of weekday estimates was greater than that of weekend estimates.

**RESUME**

La précision des estimations mensuelles de la prise par unité d'effort moyenne des bateaux privés et en location qui pêchent de grands pélagiques en Virginie est examinée en fonction du nombre d'interviews. Une méthode itérative, dans laquelle les données de 1989 et 1990 sont échantillonnées comme si elles représentaient la population actuelle, est utilisée pour calculer des intervalles de confiance supérieures et inférieures, associées à une intensité d'échantillonnage donnée. La couverture de 90% d'intervalle de confiance, qui est presque égale à l'ampleur de la moyenne de dix interviews par mois, baisse de façon asymptotique avec le nombre d'interviews. Au départ, le gain de précision est rapide, mais s'atténue à environ un tiers de la moyenne après 100 interviews. Le nombre d'interviews nécessaires pour atteindre un niveau donné de précision était conséquemment plus élevé pour les bateaux en location que pour les bateaux privés. La précision des estimations des jours ouvrables de la semaine était plus élevée que celle des estimations de fins de semaine.

**RESUMEN**

La precisión de las estimaciones mensuales para la captura media por unidad de esfuerzo de los barcos de propiedad privada o barcos alquilados que capturan grandes pelágicos en Virginia, se examina como una función del número de entrevistas. Se aplica un planteamiento de ensayos iterativos de reajuste a partir de submuestras ("bootstrap"), en el que se muestrean los datos de 1989 y 1990 como si fuesen la población real, para generar los intervalos de confianza superiores e inferiores asociados con una intensidad de muestreo dada. La amplitud del intervalo de confianza del 90%, que es aproximadamente igual a la magnitud de la media en diez entrevistas por mes, decrece de forma asintótica con el número de entrevistas. El aumento de la precisión es inicialmente rápido, pero se estabiliza aproximadamente a un tercio de la media tras 100 entrevistas. El número necesario de entrevistas para alcanzar un nivel dado de precisión era continuamente más alto para los barcos alquilados que para los barcos de propiedad privada. La precisión de las estimaciones de los días laborables era superior a las estimaciones de fin de semana.

Introduction

One of the principal concerns during the design of a survey program is the amount of sampling effort necessary to estimate the value of a given quantity (such as catch per unit effort) with reasonable precision. In many cases the data can be divided naturally into strata with different levels of magnitude or variation in the variable under consideration. In such a case one might then wish to determine how much effort to allocate to each of the separate strata. Clearly the optimal allocation scheme will depend not only on the variability within each strata, but also on the importance of each strata to the whole.

The purpose of this study was to determine the precision of estimates of the mean daily catch per vessel in Virginia as a function of the number of interviews conducted during the month.

Methods

The precision of the current estimators of the average catch per trip by vessel type ( $v$ ),

$$CPUE_v = \frac{\sum_{i=1}^{N_v} CPUE_{i,v}}{N_v}$$

was measured by computing the width of the 90 percent confidence interval from the standard deviation of 500 independent bootstrap estimates. Each individual bootstrap estimate was obtained by randomly drawing  $N_v$  observations (interviews) with replacement from actual catch data and then computing the mean. The value of  $N_v$  was varied from 15 to 255 in increments of 15 so that the confidence interval could be expressed empirically as a function of the number of interviews.

The data employed for the bootstrap procedure were obtained by combining catch per trip data collected from dock-side and telephone interviews made in Virginia during June and July of 1989 and 1990. Two types of catch data were considered: the catch of school-sized bluefin tuna and the catch of all species combined. The catches of school bluefin were censored at the party limit (a bag limit of 2 multiplied by the number of anglers on the vessel plus captain and mate) to reflect the reduction in variance that would be expected to accompany the bag limit that the Commission implemented in 1992. The data were divided by vessel type (private versus charter) and day type (weekend versus weekday).

The key assumption germane to this bootstrap application is that the observed distribution of catch per trip is similar to the actual distribution of catch per trip in the real fishery. This assumption is reasonable for data collected during 1989 and 1990 because the observations in each strata were numerous (from 44 to 182) and taken without prior regard to catch rates (i.e., they are unbiased).

As mentioned earlier, the optimum distribution of sampling effort among vessel types and day types depends not only on the variance in catch rates within each strata, but also on the relative importance of those strata to the total catch. Moreover, the total number of interviews is constrained (here at 150 and 300 interviews per month) so that the interview effort available to one strata depends on the interview effort allocated to the remaining strata. Hence, the optimal allocation scheme cannot be derived from the strata-specific confidence intervals alone. In this study, the optimum allocation scheme was selected from the set of all possible allocation schemes by minimizing the variance of the estimate for the overall mean catch per trip (the strata-specific means weighted by the corresponding number of observations in each strata).

Finding this optimal allocation scheme via the bootstrap approach requires one additional assumption: that the number of observations in each data category be in the same proportion as the actual number of trips in the fishery (e.g., the number of observations of catches made by private anglers on weekends divided by the total number of observations should equal the number of private anglers that went fishing on weekends divided by the total number of anglers that went fishing). This assumption is probably not reasonable inasmuch as most of the catch data were obtained from dockside interviews, which were not conducted at random and therefore probably do not accurately reflect the relative numbers of anglers falling in any given category. The telephone survey interviews were collected at random, however there are too few observations from this portion of the survey to satisfy the first assumption (the distribution of the data is similar to the true distribution).

### Results

The width of the 90 percent confidence intervals associated with each vessel type, day type, and catch category (bluefin versus all species) are plotted against the number of interviews in figures 1-8. Typically, the width of the 90% confidence interval is slightly less than the magnitude of the mean when only 15 interviews are allocated to each strata per month. The gain in precision with additional interviews is rapid initially, but levels off to about one quarter of the mean after 100 interviews.

The number of interviews required to obtain a given level of precision was consistently higher for charter vessels than for private, with the exception of weekday catches of all species in 1989 where they are the same. Estimates corresponding to 1990 weekdays were more precise (for a given number of interviews) than those corresponding to 1990 weekends, however no such trend existed in 1989.

The optimum sampling schemes when 150 or 300 interviews are conducted each month are summarized in tables 1 and 2. The optimal

distribution of interviews heavily favored weekends in both years, however this is to some extent an artifact resulting from the use of dockside interview data, which is biased in favor of weekend trips. In general however, the "unbiased" telephone interview data indicates that the number of trips and total catch is greater on weekends than weekdays, therefore the true optimum allocation scheme probably would favor weekends, but not to the degree suggested by the tables.

The optimal distribution of interviews for 1990 heavily favored charter vessels. In 1989 charter vessels are favored when only 150 interviews were made, but private vessels are favored when 300 interviews are conducted. Inasmuch as the precision of charter estimates was only slightly lower than that of private estimates, this trend predominantly reflects the fact that the total catch of charter vessels exceeded that of private vessels in the data at hand. A future study could better resolve this issue by utilizing either data that are unbiased with respect to vessel type (and day type) or unbiased estimates of the total number of trips made by each vessel category.

TABLE 1. Optimum distribution of sampling effort among 1989 strata for various levels of sampling intensity and four clue types. Clue type 1 is for bluefin catches only and clue type 2 is for all species. Total int. refers to the total number of interviews across all strata.

	total int.	clue type	weekday private	weekday charter	weekend private	weekend charter	C.I. width
150	1	15	15	45	75		1.1
150	2	15	15	60	60		2.5
300	1	45	45	120	90		0.7
300	2	30	75	120	75		1.7

TABLE 2. Optimum distribution of sampling effort among 1990 strata for various levels of sampling intensity and four clue types. Clue type 1 is for bluefin catches only clue type 2 is for all species with the bluefin catch limited to 2 per angler plus 2. Total int. refers to the total number of interviews across all strata. Note that the 95% confidence limits for the estimators are the mean +/- 1.96 \* SQRT(variance).

	total int.	clue type	weekday private	weekday charter	weekend private	weekend charter	C.I. width
150	1	15	45	30	60		0.8
150	2	15	30	30	75		2.8
300	1	45	45	90	120		0.5
300	2	30	75	75	120		1.9

1989 Bluefin CPUE (private vs. charter, weekdays)

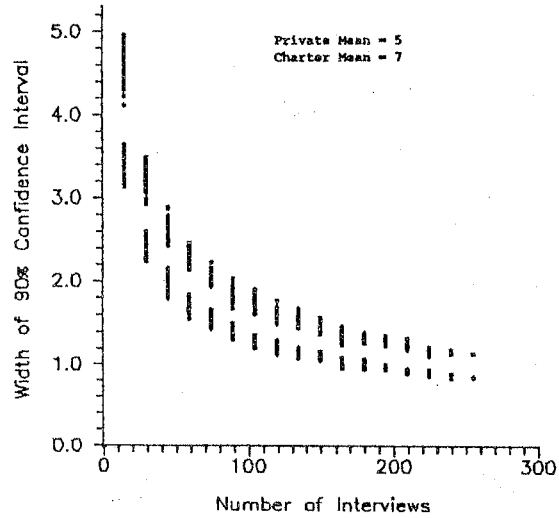


Figure 1. Confidence interval width of estimates for the mean CLUE of bluefin tuna plotted against the number of bootstrap draws (interviews) taken from 1989 weekday data. The upper curve represents charter vessels.

1989 All species CPUE (private vs. charter, weekdays)

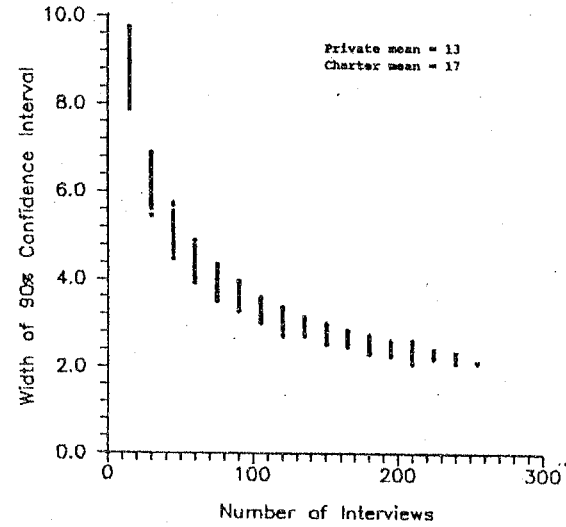


Figure 3. Confidence interval width of estimates for the mean CLUE of all species plotted against the number of bootstrap draws (interviews) taken from 1989 weekday data. The upper curve represents charter vessels.

1989 Bluefin CPUE (private vs. charter, weekends)

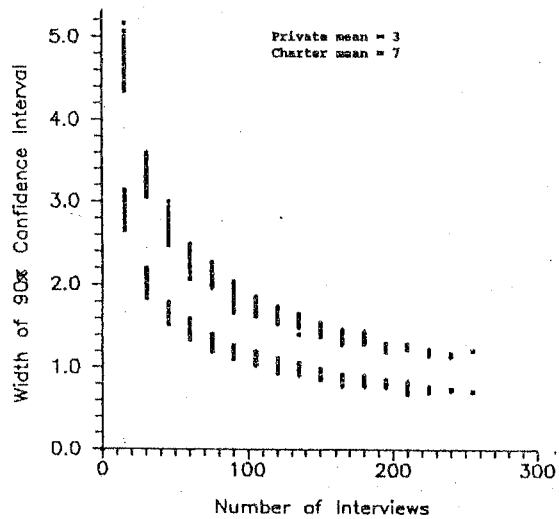


Figure 2. Confidence interval width of estimates for the mean CLUE of bluefin tuna plotted against the number of bootstrap draws (interviews) taken from 1989 weekend data. The upper curve represents charter vessels.

1989 All species CPUE (private vs. charter, weekends)

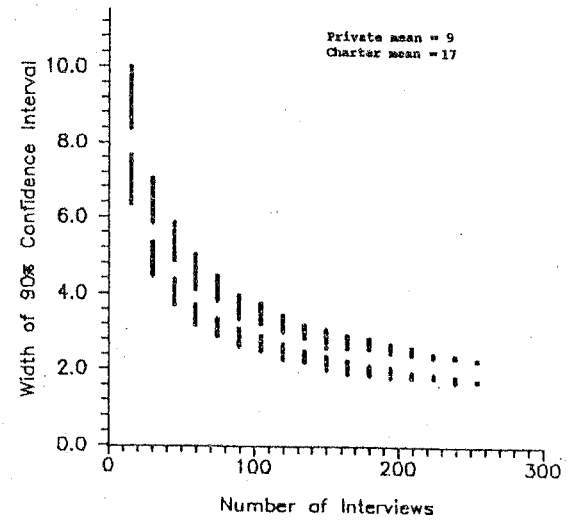


Figure 4. Confidence interval width of estimates for the mean CLUE of all species plotted against the number of bootstrap draws (interviews) taken from 1989 weekend data. The upper curve represents charter vessels.

1990 Bluefin CPUE (private vs. charter, weekends)

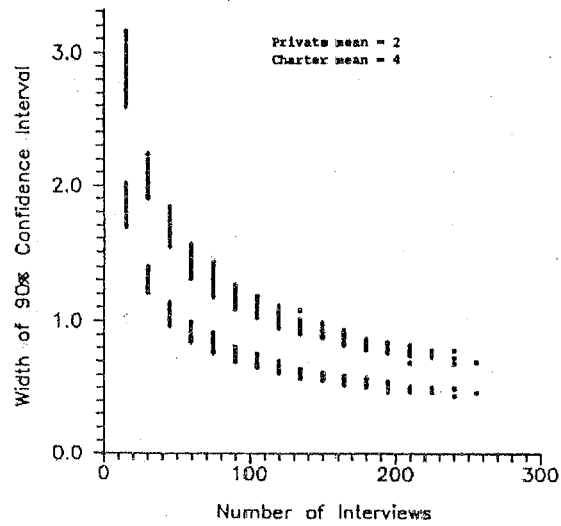


Figure 6. Confidence interval width of estimates for the mean CLUE of bluefin tuna plotted against the number of bootstrap draws (interviews) taken from 1990 weekend data. The

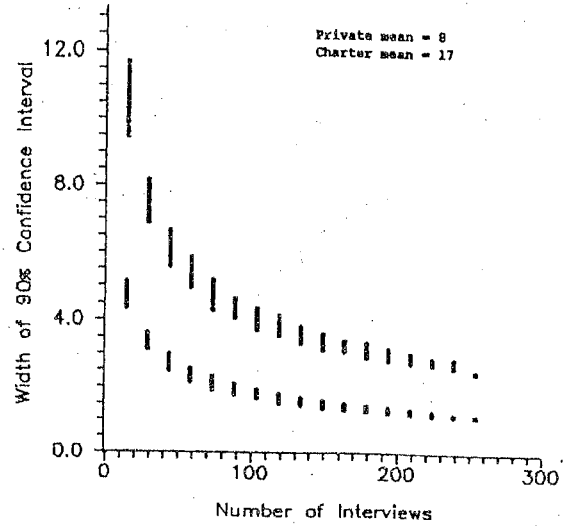


Figure 7. Confidence interval width of estimates for the mean CLUE of all species plotted against the number of bootstrap draws (interviews) taken from 1990 weekday data. The upper curve represents charter vessels.

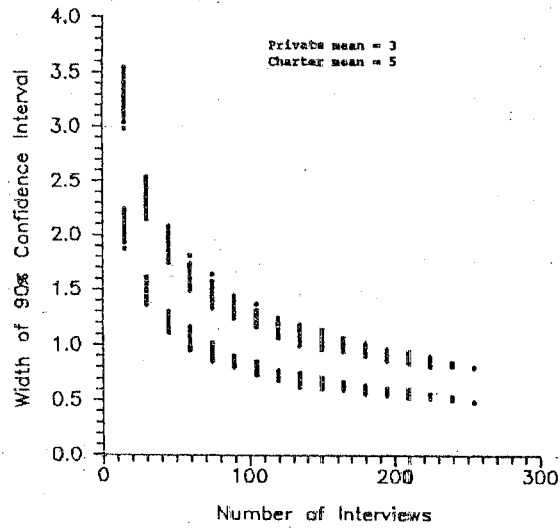


Figure 5. Confidence interval width of estimates for the mean CLUE of bluefin tuna plotted against the number of bootstrap draws (interviews) taken from 1990 weekday data. The upper curve represents charter vessels.

1990 All species CPUE (private vs. charter, weekends)

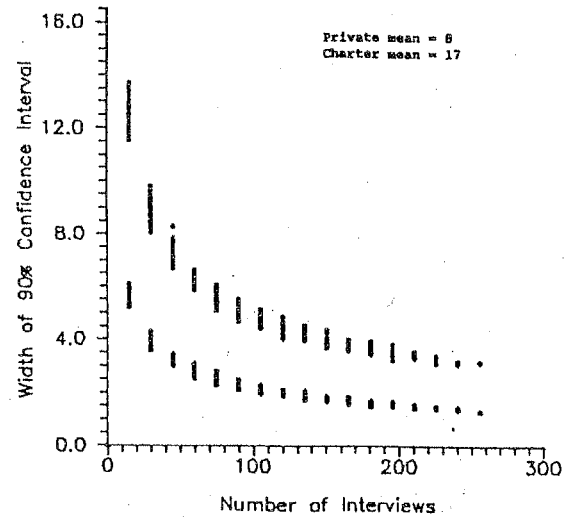


Figure 8. Confidence interval width of estimates for the mean CLUE of all species plotted against the number of bootstrap draws (interviews) taken from 1990 weekend data. The upper curve represents charter vessels.