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Accuracy of Sampling Procedures and Catch Rates in Sport Fishing

Charles W. Caillouet, Jr. and James B. Higman

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James B. Higman

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for

ACCURACY OF SAMPLING PROCEDURES AND CATCH RATES IN SPORT FISHING (An evaluation of procedures used in computing monthly mean catch rates and sample sizes of the Sport Fishery at Flamingo, Florida)

by

Charles W. Caillouet, Jr. and James B. Higman
University of Miami Sea Grant Program
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Page	Paragraph	Line	Correction
4	2	7	... effort tends to ...
6	1	1	... (seasonal) variation in ...
6	1	2	... than variation within ...
6	1	12	the least squares method of fitting a regression through the origin. We ...
17	Table 5		species headings should not contain the word "FISHERMEN", but should be: GRAY SNAPPER, SPOTTED SEATROUT, and RED DRUM Fisherman types are represented by the headings WEEKEND, CHARTER, and WEEKDAY
21	2	3-4	at levels of relative precision < 0.30 and confidence > 0.90. Our study further ...
22	2	2-3	This estimator is obtained by the least squares method of fitting a regression of catch on fishing effort and through the origin (see page 8).
22	2	6	... using the least squares estimator.
22	3	1-5	3. We believe that monthly mean ... with sufficient statistical precision (<u>viz</u>., $p < 0.10$) and confidence (<u>viz</u>., > 0.90), but these mean catch rates do provide a useful, though crude, index of seasonal trends in availability of the principal species. Extraneous variation has proved to be one of ...

Page	Paragraph	Line	Correction
22	4	4	... and a $p < 0.10$ level ...
23	1	3-8	We believe that our monthly catch rates are insufficiently precise. An increase in the sampling period would effectively increase the angler sample. This would reduce the standard error and would increase the confidence level for the mean catch rate based on the longer period.
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FOREWARD

The Sea Grant Coastal Zone Management Bulletin Series is being offered as a method of acquainting the public with advances in the fields of coastal zone engineering and research.

Further expansion of human population into the coastal zone is assured. As this happens, conflict over the uses of this limited area's natural resources will increase inasmuch as all uses are not compatible.

The purpose of the Coastal Zone Management Bulletin Series is to summarize new research results in the management context and to stimulate discussion of new management techniques which appear to offer possible solutions to complicated socio-environmental problems.

A further aim of this Series is to present sometimes complex thoughts and concepts in a semi-technical publication which can be used by planners, developers and persons in public office.

This Bulletin is published by the University of Miami Sea Grant Program in the belief that its contents will be helpful to those concerned with the problems of the coastal zone.

ACCURACY OF SAMPLING PROCEDURES AND CATCH RATES IN SPORT FISHING

(An Evaluation of Procedures Used in Computing Monthly Mean Catch Rates and Sample Sizes of the Sport Fishery at Flamingo, Florida)

INTRODUCTION

This study considers the problem of estimating monthly mean catch per unit effort and sample size in a mixed-species sport fishery. Monitoring of monthly catch rate was begun to provide baseline trends to guide the Everglades National Park in the management of the sport fishery resources at Flamingo, Florida (Higman, 1967). The methods used to estimate sample size and to increase precision in the catch rate estimates have application to other sport fisheries, and they are currently being used by a private corporation to evaluate the sport fishery of the Marco Island-Everglades City, Florida, area.

The sport fishery at Flamingo, Florida, has been described and fluctuations in the catch rate of principal species have been reported by Higman (1967). This limited-access fishery is the largest in Everglades National Park since most anglers fishing in central waters of the Park depart from and return to Flamingo (Figure 1). The number of fishing-party interviews required to estimate monthly catch rates for two of the most important sport fishes at Flamingo, gray snapper (*Lutjanus griseus*) and spotted seatrout (*Cynoscion nebulosus*), was determined early in these studies, but the level of sampling was limited to the maximum permitted by available funds (Higman, 1967). Interviewing was conducted on five days each month, usually three weekdays and two weekend days.

Catch and effort data collected from June 1958 through July 1967 were re-examined in the present study to determine: (1) the sample

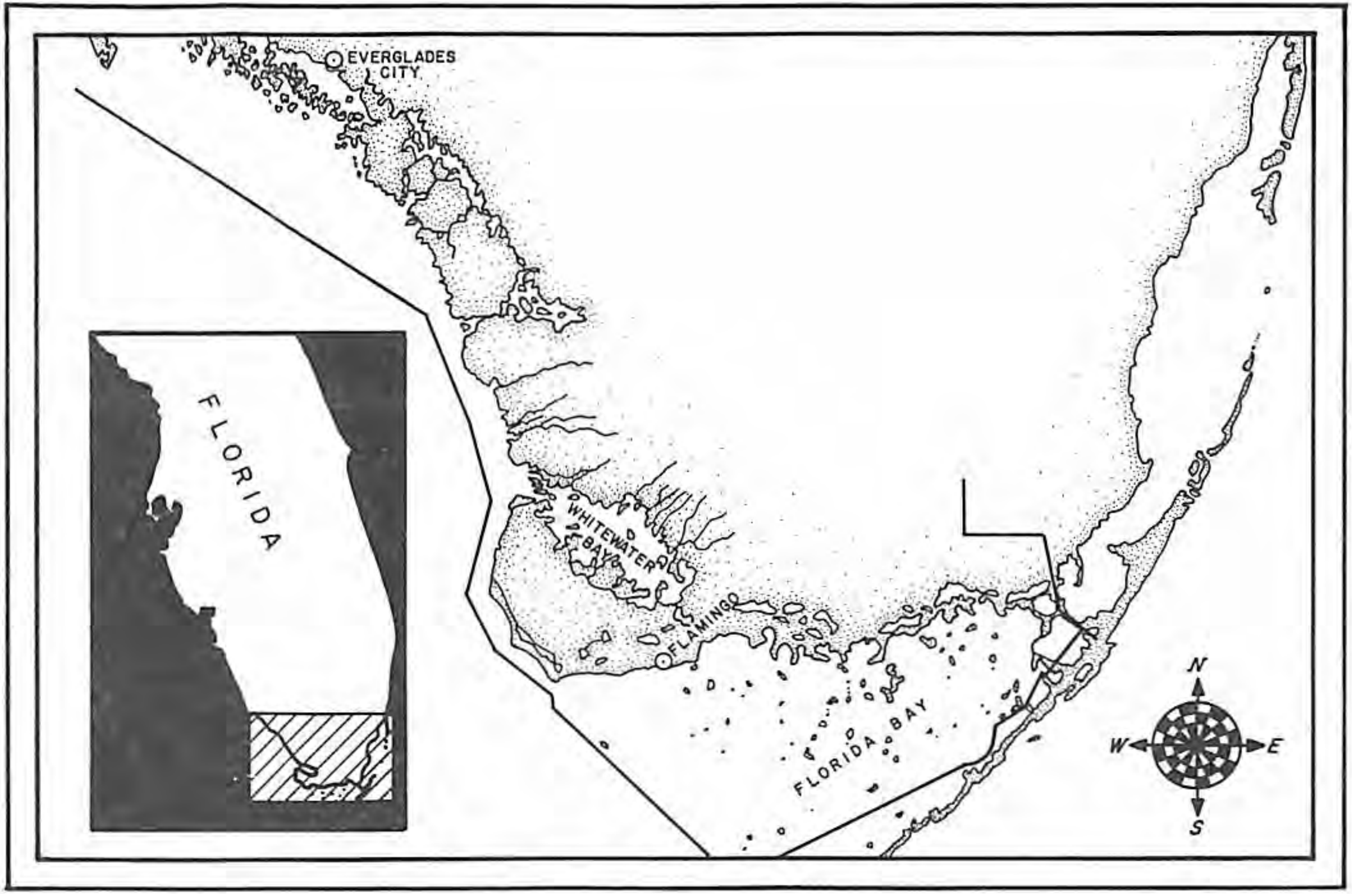

Figure 1. Boundaries of Everglades National Park, Florida, and interview site at Flamingo

size (number of interviews of fishing parties per month) needed to provide monthly mean catch rate estimates within acceptable levels of confidence for the important species at Flamingo and (2) whether the previously used method of calculating monthly mean catch rates was the most precise of three possible methods, and if not, to determine what method should be used in the future. In this statistical evaluation, we considered the monthly mean catch per fisherman per hour, hereafter referred to as monthly mean catch rate, to be a measure of fishing success.

Data Limitations

Procedures for estimating catch rate, total catch, total fishing effort and the many sources of bias inherent in sport fishing surveys have been discussed at length by Grosslein (1962). In the survey conducted at Flamingo, it was possible to achieve better accuracy by using biologists rather than fishermen to obtain and record the data, but complete accuracy was still not possible. The interviewer had to accept the fisherman's estimate for length of the fishing trip and the number of persons who fished. Fishermen who did not wish to be delayed at the landing area after returning to Flamingo were simply asked about species and numbers of fish caught. Even when fishermen did not leave immediately, it was not always possible to observe the catch directly. In such cases, the interviewers had to rely upon the fishermen to provide information on species and numbers of fish caught. Fish-cleaning tables were provided at the landing site, and interviewers could easily identify and count fish there.

The number of parties encountered by the interviewer on a given sampling day varied considerably. Larger numbers of interviews could be obtained in winter when fishing activity usually was greatest. Although interviewing was conducted on five days each month, the data were not recorded in a fashion which allowed day-to-day variation to be distinguished from interview-to-interview variation within a month. However, variation among interviews (including day-to-day variation) within a month was divided into three fishermen-type categories: those interviewed on weekends, those interviewed on weekdays and those who fished with guides on chartered boats (interviewed both on weekends and weekdays). These three categories were expected to vary with respect to catch rate.

Interviewing usually was conducted from about 1100 hours until sunset, because most fishermen returned during these hours. Fishermen returning at night or in the morning before interviewing began were not contacted. The unit of fishing effort used by Higman (1967) and in this study was based on the duration of the fishing trip in hours. Non-fishing time (i.e., traveling, scouting and other activities) included in the estimates of effort tend to lower estimates of mean catch rate (see Grosslein 1962, p. 13). The results of this study should be evaluated in terms of these limitations in the data.

Estimation of Monthly Mean Catch Rates

The problem of estimating mean catch rate from a sample of catch and effort data can be likened to that of fitting a straight line through points (Y,X) and through the origin according to the following regression model (see Snedecor and Cochran, 1967; p. 166-171):

$$Y = \beta X + \varepsilon \qquad (1)$$

where,

Y = dependent variable

X = independent variable

β = slope of the line

ε = residual or deviation from regression.

It is clear that the model is applicable for data in which $Y = 0$ when $X = 0$, and in which Y increases directly (straight line) with X.

There are three possible estimates (b) of β, and the choice among these depends upon the distribution of the residuals, ε (see Snedecor and Cochran, 1967; p. 170). The three possible estimates[1] of β as applied to catch and effort data are:

$$b_1 = \Sigma XY / \Sigma X^2 \qquad (2)$$

$$b_2 = \Sigma Y / \Sigma X \qquad (3)$$

$$b_3 = \Sigma (Y/X) / n \qquad (4)$$

where,

Y = catch (number of fish, by species)

X = effort (number of fisherman hours)

β = true monthly mean catch rate (= slope of the line)

ε = residual or deviation from regression

n = number of paired observations (interviews) of Y and X

It is assumed that there is no change in real abundance of fish within a month, so that variations in catch depend solely upon variations in effort. We recognize that this assumption is not rigidly met. However,

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[1]In these formulae and most of those to follow, Σ implies $\sum_{i=1}^{n}$ where, i represents the ith observation (interview), Y implies Y_i and X implies X_i.

month to month (seasonal) variations in real abundance of fish are likely to be far greater than variations within months, so failure of the assumption does not preclude use of the method.

Equation (3) represents a ratio of the means of Y and X, since

$$b_2 = \Sigma Y/\Sigma X = \frac{\Sigma Y/n}{\Sigma X/n} = \overline{Y}/\overline{X}$$

and it has been used to estimate monthly catch rates for the Flamingo sport fishery (Higman, 1967). Equation (4) represents a mean of the ratios Y/X. Equation (3) is considered by Grosslein (1962) to be affected less by biases than is the mean catch rate calculated according to equation (4), and he considered it to be the most appropriate to estimate total catch by multiplying total effort by mean catch rate. Equation (2) represents the usual manner of fitting a regression through the origin. We know of no application other than ours of equation (2) to analyses of catch and effort data.

The relationship between the variance of ε and X, according to Snedecor and Cochran (1967; p. 170), determines whether equation (2), (3) or (4) is most appropriate. The most precise estimator of mean catch rate would be (2), (3) or (4) according as the variance of ε is constant, proportional to X, or proportional to X^2, respectively. The appropriate measure of ε is d, the observed deviation from regression. Catch and effort data are not usually taken in a way that permits determination of the relationship between d and X as an estimate of the relationship between ε and X. The data required would be multiple measures of Y at several constant levels of X. Since X is not usually held constant in studies of catch and effort, the required data are not available. Thus another approach was required to determine the precision of equations (2), (3) and (4) as applied to the estimation of monthly mean catch rate. We calculated monthly mean catch rate, b, by all three methods, equations (2), (3) and (4), using the same data. Then we calculated the standard errors, s_b, of these monthly mean catch rates, assuming that the method which produced the smallest standard error represented the "best" fit to the data or most precise estimator.

From monthly mean catch rates, b, calculated with all three equations, (2), (3) and (4), we estimated the corresponding standard errors, s_b, of the monthly mean catch rates with equations (5), (6) and (7), respectively, for three species (gray snapper, spotted seatrout and red drum, Sciaenops ocellata) and for each fisherman type (weekend, charter and weekday) from data collected during June 1958 through June 1967.

$$s_{b_1} = (s_{y.x}{}^2/\Sigma X^2)^{1/2} \qquad (5)$$

where,

$$s_{y.x}{}^2 = (\Sigma Y^2 - [\Sigma XY]^2/\Sigma X^2)/(n - 1)$$

and,

$$s_{b_2} = (s'_{y.x}{}^2/\Sigma X)^{1/2} \qquad (6)$$

where,

$$s'_{y.x}{}^2 = (\Sigma[Y^2/X] - [\Sigma Y]^2/\Sigma X)/(n - 1)$$

and,

$$s_{b_3} = (s''_{y.x}{}^2/n)^{1/2} \qquad (7)$$

where,

$$s''_{y.x}{}^2 = (\Sigma[Y/X)]^2 - [\Sigma(Y/X)]^2/n)/(n - 1)$$

Only gray snapper, spotted seatrout and red drum were used in these analyses (Table 1) since these three species are of greatest importance in the sport fishery at Flamingo.

The standard error s_{b_1} was consistently the smallest of the three possible estimators (Table 1). Thus, b_1 seemed to provide the most precise estimate of the monthly mean catch rate. On a similar basis, b_3 appeared to be the least precise of the three possible monthly mean catch rate estimates, and b_2 was of intermediate precision.

To determine the relationships among the three monthly standard error estimates, s_{b_1}, s_{b_2} and s_{b_3}, and among the three monthly mean catch rate estimates, b_1, b_2 and b_3, regression analyses were conducted (Tables 2 and 3). These relationships were calculated from 109 months of data. Months for which the monthly mean catch rate could not be calculated (no data) or equaled 0 and months for which the monthly standard error equaled 0 were excluded from these analyses. Slopes of the regressions of s_{b_3} on s_{b_1} and of s_{b_2} on s_{b_1} were in most cases significantly different from 1 (a slope of 1 would have indicated that the standard errors in question were, on the average, equal to each other), and all of the slopes that differed significantly from 1 were larger than 1. This lends further support to the conclusion that s_{b_1} was the smallest of the three monthly standard error estimates, indicating that b_1 was the most precise estimate of the monthly mean catch rate.

Results of the regressions of b_3 on b_1 and of b_2 on b_1 (Table 3) were more variable than those involving the standard errors. Most of the slopes of the regressions concerning monthly mean catch rate estimates differed significantly from 1, and most of these were less than 1,

Table 1. Ranges and averages* of monthly mean catch rates, b, and standard errors, s_b, of monthly mean catch rates for gray snapper, spotted seatrout and red drum during the period June 1958 through June 1967, Flamingo, Everglades National Park, Florida

	WEEKEND			CHARTER			WEEKDAY		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
				GRAY SNAPPER					
b_1	0.0060	1.0622	0.3254	0.0267	3.2722	0.8446	0.0172	1.8382	0.3681
b_2	0.0083	1.0225	0.3530	0.0511	3.5168	0.8577	0.0331	1.6250	0.3832
b_3	0.0097	0.9838	0.3817	0.0723	3.7631	0.8703	0.0392	1.7471	0.4102
s_{b_1}	0.0051	0.3270	0.0799	0.0330	1.3054	0.2699	0.0118	0.8529	0.1336
s_{b_2}	0.0056	0.3328	0.0881	0.0427	1.2787	0.2973	0.0133	0.9360	0.1494
s_{b_3}	0.0057	0.3226	0.0971	0.0507	1.2955	0.3194	0.0144	0.9667	0.1679
				SPOTTED SEATROUT					
b_1	0.0203	1.0219	0.3126	0.0123	2.6523	0.5722	0.0390	1.8087	0.4182
b_2	0.0200	1.0341	0.3430	0.0303	2.1918	0.6091	0.0798	1.8406	0.4516
b_3	0.0276	1.1179	0.3913	0.0579	3.2025	0.6945	0.0785	1.6558	0.4769
s_{b_1}	0.0064	0.5539	0.0834	0.0252	1.4584	0.2050	0.0220	0.8931	0.1532
s_{b_2}	0.0076	0.6032	0.0950	0.0299	1.7468	0.2410	0.0280	0.8901	0.1711
s_{b_3}	0.0089	0.6156	0.1070	0.0298	2.1963	0.2905	0.0291	0.8489	0.1839
				RED DRUM					
b_1	0.0008	0.4606	0.0848	0.0015	1.1654	0.1894	0.0027	0.4972	0.1041
b_2	0.0010	0.4282	0.0917	0.0035	1.9568	0.2193	0.0020	0.4697	0.1068
b_3	0.0010	0.3849	0.0958	0.0060	2.4973	0.2563	0.0008	0.4332	0.1064
s_{b_1}	0.0009	0.2155	0.0288	0.0026	1.2436	0.0998	0.0016	0.1850	0.0392
s_{b_2}	0.0010	0.2214	0.0320	0.0030	1.4766	0.1163	0.0012	0.1745	0.0425
s_{b_3}	0.0010	0.2110	0.0342	0.0034	1.4721	0.1285	0.0008	0.1567	0.0443

*Averaged over the entire 109-month period, June 1958 through June 1967, but zero values for monthly mean catch rates and standard errors were excluded from the calculations. See Table 2 which shows the number of months of data used to calculate averages for each fisherman-type (weekend, charter and weekday) and species (gray snapper, spotted seatrout and red drum).

Table 2. Regressions of s_{b_3} on s_{b_1} and s_{b_2} on s_{b_1}, the three standard errors of the monthly mean catch rates, calculated from sport fishery survey data collected during June 1958 through June 1967, Flamingo, Everglades National Park, Florida

Regression	Fisherman-Type	Slope	Intercept	Correlation Coefficient, r	Number of Months, m
		GRAY SNAPPER			
s_{b_3} on s_{b_1}	Weekend	0.9963	0.0175	0.887	109
	Charter	1.1100*	0.0198	0.913	85
	Weekday	1.1891*	0.0090	0.858	97
		SPOTTED SEATROUT			
	Weekend	1.0657	0.0181	0.908	109
	Charter	1.2572*	0.0328	0.739	85
	Weekday	0.9248	0.0428	0.925	97
		RED DRUM			
	Weekend	1.0240	0.0048	0.937	109
	Charter	1.2255*	0.0061	0.977	85
	Weekday	1.0024	0.0050	0.895	92
		GRAY SNAPPER			
s_{b_2} on s_{b_1}	Weekend	1.0124	0.0072	0.979	109
	Charter	1.0795*	0.0059	0.980	85
	Weekday	1.1196*	-0.0002	0.963	97
		SPOTTED SEATROUT			
	Weekend	1.0575*	0.0068	0.984	109
	Charter	1.1532*	0.0046	0.960	85
	Weekday	1.0049	0.0171	0.986	97
		RED DRUM			
	Weekend	1.0433*	0.0020	0.989	109
	Charter	1.1850*	-0.0020	0.995	85
	Weekday	1.0288	0.0022	0.975	92

*Slope is significantly different from 1 at the 95% level of confidence

Table 3. Regressions of b_3 on b_1 and b_2 on b_1, the three monthly mean catch rates calculated from sport fishery survey data collected during June 1958 through June 1967, Flamingo, Everglades National Park, Florida

Regression	Fisherman-Type	Slope	Intercept	Correlation Coefficient, r	Number of Months, m
		GRAY SNAPPER			
b_3 on b_1	Weekend	1.0106	0.0528	0.903	109
	Charter	0.9275	0.0869	0.877	85
	Weekday	0.8411*	0.1006	0.782	97
		SPOTTED SEATROUT			
	Weekend	1.0033	0.0777	0.886	109
	Charter	0.7666*	0.2559	0.640	85
	Weekday	0.7771*	0.1519	0.844	97
		RED DRUM			
	Weekend	0.9914	0.0117	0.924	109
	Charter	1.3664*	-0.0025	0.858	85
	Weekday	0.8214*	0.0210	0.881	92
		GRAY SNAPPER			
b_2 on b_1	Weekend	0.9988	0.0280	0.976	109
	Charter	0.9679	0.0403	0.974	85
	Weekday	0.9256*	0.0424	0.954	97
		SPOTTED SEATROUT			
	Weekend	0.8275*	0.0843	0.835	109
	Charter	0.9321*	0.0757	0.955	85
	Weekday	0.9313*	0.0621	0.971	97
		RED DRUM			
	Weekend	1.0152	0.0055	0.987	109
	Charter	1.2082*	-0.0095	0.949	85
	Weekday	0.9231*	0.0107	0.973	92

*Slope is significantly different from 1 at the 95% level of confidence suggesting that b_1 provided a monthly mean catch rate estimate higher than those of b_2 and b_3.

These analyses suggest that b_1 is a more precise estimate of the monthly mean catch rate than are b_2 or b_3. For Flamingo in the Everglades National Park this means that monthly mean catch rates calculated from b_2 and published in the past (Higman 1967) were not the most precise of the possible estimates, but Grosslein (1962) believes that such estimates are less subject to bias than those obtained with b_3.

As expected, charter fishermen produced the highest catch rates for all three species (Table 1), because they were accompanied by guides whose general knowledge of fishing areas and methods exceeded that of the average fisherman. Weekday fishermen had the next highest catch rates, and weekend fishermen had the lowest.

It should be emphasized that species preference was not considered in these analyses. Estimated mean catch rates may thereby be lower and standard errors of mean catch rates higher than those that might have been based on an analysis by species preference. However, accurate information on species preference would be difficult if not impossible to obtain, especially if it were based upon post-fishing interviews. These analyses were also conducted without consideration of the area of capture of the fish within the Park, so they simply represent catches reported at Flamingo.

Determination of Sample Size

To determine the sample size (number of interviews per month) required for acceptable levels of confidence and relative precision in estimation of monthly mean catch rates, the following formula was adapted from Snedecor and Cochran (1967; p. 516):

$$n = \frac{t_\alpha^2 s''^2_{y.x}}{L^2} \qquad (8)$$

where,

n = sample size

L = allowable error in the sample mean (monthly mean catch rate, b)

t_α = student's t with infinite degrees of freedom and chosen level of confidence, 100 (1−α) (Snedecor and Cochran, 1967; p. 549, Table A4)

$s''^2_{y.x}$ = variance as calculated for use in equation (7)

This equation is based upon the standard error s_{b_3} rather than s_{b_1} or s_{b_2} for two reasons: (1) s_{b_3} is the only one of the three standard error estimates which can be expressed as a simple function of n and variance,

$$s_{b_3} = (s''^2_{y.x}/n)^{1/2}$$

(2) s_{b_3} is the largest of the three standard error estimates and would be expected to produce the largest estimates of sample size, n. The resulting sample sizes would be at least as good for measuring the monthly mean catch rates b_1 and b_2 as for b_3.

In the case of all three monthly mean catch rates, b_1, b_2 and b_3, the variance (respectively $s_{y.x}^2$, $s'^2_{y.x}$ and $s''^2_{y.x}$), increases with increase in monthly mean catch rate. Because, in equation (8), sample size is a function of variance ($s''^2_{y.x}$ in the sample-size formula), larger samples are required when the catch rate is high than when the catch rate is low. In order to avoid the problem of dependence of sample size on the magnitude of the monthly mean catch rate, the following were done (see also Caillouet and Higman, _in press_):

1. Allowable error, L, was replaced by K in the sample size formula

$$n = \frac{t_{\alpha}^{2} s''^{\,2}_{y.x}}{K^2} \qquad (9)$$

where,

$K = pb_3$

p = constant representing a proportion of the mean monthly catch rate, b_3; e.g., if p = 0.50, the sample size required to measure the monthly mean catch rate with a relative precision of 50% is calculated by equation (9).

2. The relationship between $s''_{y.x}$ (the standard deviation from regression) and b_3 was determined to be,

$$s''_{y.x} = zb_3 \qquad (10)$$

where,

$$z = \sum_{j=1}^{m} (s''_{y.x})\ (b_3) / \sum_{j=1}^{m} b_3^{\,2}$$

m = number of months involved in the calculation, j = 1, 2, ..., m.

Equation (10) thus provides a means of expressing $s''_{y.x}$ as a function of b_3.

By substituting for $s''^{\,2}_{y.x}$ and K^2 in equation (9) the quantities $(zb_3)^2$ and $(pb_3)^2$, respectively, the following sample size formula was obtained:

$$n = \frac{t_\alpha^2 s''^2_{y.x}}{K^2} = \frac{t_\alpha^2 (zb_3)^2}{(pb_3)^2} = \frac{t_\alpha^2 z^2}{p^2} \qquad (11)$$

In equation (11), the sample size is no longer a function of the monthly mean catch rate, b_3, but it is a function of three easily obtained quantities:

1. t_α, Student's t (at infinite degrees of freedom) which is determined by the desired level of confidence, 100 (1 - α), (from p. 549, Table A4, Snedecor and Cochran, 1967).

2. z, derived from the empirical relationship between $s''_{y.x}$ and b_3, equation (10).

3. p, representing the desired proportion of the monthly mean catch rate.

Table 4 gives the calculated relationships between $s''_{y.x}$ and b_3 for the nine species-fisherman type combinations for use in determining sample size according to equation (11). For each of these combinations, a sample size was calculated at two different levels of confidence and five different levels of precision (Table 5). Each species-fisherman type combination requires a different sample size under similar chosen conditions of relative precision and level of confidence, but practical application of these results necessitates choosing a single sample size to measure mean catch rate for all species-fisherman type combinations. Thus, mean catch rate would be measured with greater confidence and precision for some combinations and lesser confidence and precision for other combinations.

In the course of estimating total fishing effort at Flamingo, we have noted that there would not be sufficient fishing parties to fulfill the samole size requirements for the higher levels of relative precision

Table 4. Regressions* of $s''_{y.x}$ on b_3 to be used to estimate sample size, n, according to equation (11)

Fisherman-Type	Slope, (z)	Number of Months, m
	GRAY SNAPPER	
Weekend	1.7797	109
Charter	1.2213	85
Weekday	1.8041	97
	SPOTTED SEATROUT	
Weekend	1.9099	109
Charter	1.5975	85
Weekday	1.8292	97
	RED DRUM	
Weekend	2.4254	108
Charter	1.5915	85
Weekday	2.0735	91

*Line fitted through the origin. The slope, z, was estimated according to,

$$z = \sum_{j=1}^{m} (s''_{y.x})(b_3) / \sum_{j=1}^{m} b_3^2$$

where m = number of months, and j=1, 2, ..., m.

Table 5. Number of interviews required to determine monthly mean catch rate of gray snapper, spotted seatrout and red drum at various levels of relative precision, p, and at two confidence levels, 100 (1 - α)

p	WEEKEND α = 0.05	WEEKEND α = 0.10	CHARTER α = 0.05	CHARTER α = 0.10	WEEKDAY α = 0.05	WEEKDAY α = 0.10
			GRAY SNAPPER FISHERMEN			
0.10	1217	857	573	404	1250	880
0.20	304	214	143	101	313	220
0.30	135	95	64	45	139	98
0.40	76	54	36	25	78	55
0.50	49	34	23	16	50	35
			SPOTTED SEATROUT FISHERMEN			
0.10	1401	987	980	690	1285	905
0.20	350	247	245	173	321	226
0.30	156	110	109	77	143	101
0.40	88	62	61	43	80	57
0.50	56	39	39	28	51	36
			RED DRUM FISHERMEN			
0.10	2260	1591	973	685	1652	1163
0.20	565	398	243	171	413	291
0.30	251	177	108	76	184	129
0.40	141	99	61	43	103	73
0.50	90	64	39	27	66	47

(i.e., p = 0.20 and 0.10) and confidence (95%), even with an increase in the number of days of interviewing per month. A concommittent problem is the reduction in fishing by tourists and local fishermen during the summer. This means that catch rates can be measured at only moderately large levels of precision (>0.20) and with 90% confidence with the formerly employed sampling methods. However, we included the larger sample sizes (Table 5) for comparison and to emphasize the relationships among sample size, relative precision, and level of confidence for measuring mean monthly catch rates. Of greatest importance is the exponential increase in sample size required to increase precision.

Reliability of Past Sampling

A general picture of reliability of the past sampling program is provided by Table 6 in which relative precision, p, actually attained in the past is shown for each species and fisherman type. These values of p were based upon the average number of interviews per month for each fisherman type over the 109-month period, since the number of interviews varied considerably. The range of numbers of interviews per month is also given for each fisherman type, but represents only those months in which interviews were obtained (months in which no interviews were obtained for a given fisherman type are excluded, otherwise the lower limit of the ranges would be zero).

At the 90% level of confidence, the mean monthly catch rate of all three species was measured with better precision by the sample of weekend fishermen (Table 6). This was partly due to the greater sample size. Because charter fishermen interviews were fewest in number, mean

Table 6. Attained relative precision, p, at the 90% level of confidence and based on the average number of interviews per month* during the 109-month period of the Flamingo sport fishery survey

Fisherman Type	No. of Interviews Per Month Range	Average	Attained Relative Precision Gray Snapper	Spotted Seatrout	Red Drum
Weekend	7-202	67	0.36	0.39	0.49
Charter	4- 79	16	0.54	0.70	0.70
Weekday	2- 70	30	0.56	0.57	0.64

*The t_α used to calculate these relative precision values was $t_{0.10(n-1)}$, in which the average number of interviews per month was substituted for n. Note that n varied by fisherman-type.

catch rates of spotted seatrout and red drum based on these interviews were measured with less precision than those of the other two fisherman types. Precision was about the same for gray snapper catch rates derived from charter and weekday interviews.

These conclusions are based on b_3, the least precise estimate of the monthly mean catch rate. Therefore, the past sampling is believed to be better in terms of catch rate estimates b_1 and b_2 which are more precise; i.e., fewer interviews would be required to estimate b_1 and b_2 (at given levels of relative precision and confidence) than are required for b_3.

Applied to a practical sampling program these data indicate that interviewing effort concentrated on weekend anglers would produce the highest level of relative precision and confidence in the mean monthly catch rates. During the present study, interviewing usually was conducted for two weekend days each month and averaged 67 interviews per month (Table 6). At this sampling rate, it is possible to obtain 268 weekend interviews in four weekends per month. Hence, for gray snapper and spotted seatrout, a sample having a relative precision of 20% at 90% confidence level could be attained at Flamingo (Table 5), but only a 30% relative precision could be attained for red drum at the 90% confidence level. Using the average number of interviews obtained in the past as the basis for sample size attainable in the future, we find for charter boat fishing that 30 consecutive days of interviewing should produce 96 interviews per month or a level of precision near 30% at the 90% confidence level for all three major species. About the same level of precision and confidence could be attained from 20 consecutive days of interviewing weekday fishermen. While these sampling intensities may be possible, the costs may be prohibitive.

Considering that the major objectives of the sport fishery survey in Everglades National Park were to estimate total annual catch and effort and to monitor annual catch rate, the annual results were sufficiently precise and within levels of confidence to establish trends in annual mean catch rate for the three major species. We make this assumption because the range of catch per unit of effort over an annual cycle is no greater than that within a month. Thus the increased number of interviews in an annual survey should reduce the standard error sufficiently to produce the desired precision and confidence.

However, this statistical evaluation shows that the monthly sampling has not been sufficient to measure mean monthly catch rate by fisherman type at levels of precision and confidence required to detect changes caused by fishing effort in individual species. Our study further suggests that monthly sample size cannot be increased sufficiently, with past sampling techniques and at past levels of fishing effort, so that relative precision can be improved to a level of ($p<0.30$) for all three major species. Other approaches must be tried to reduce extraneous variation in the mean monthly catch rates concommittent with increase in sample size. Some additional precision can be attained by using equation (2) in calculating monthly mean catch rate, but reduction of variability in the samples which reflect the skill of the angler is the greater problem.

CONCLUSIONS AND RECOMMENDATIONS

1. Interviewing of anglers from the Flamingo sport fishery (annual sample size) has been adequate to provide statistically reliable trends in annual catch rate for the major species. These baseline data can be used to evaluate the future condition of the fishery providing the sampling methods and catch rate calculations conform to past procedures.

2. There is a more precise estimator of the mean monthly catch rate than the one conventionally used. This equation represents the usual manner of fitting a regression through the origin (see page 8). Future catch rates calculated by this estimator are not directly comparable with catch rates calculated by any other means, but previously reported catch rates can readily be recalculated using this new equation.

3. Monthly mean catch rates by fisherman type (weekend, charter and weekday) have not been measured, in the Flamingo fishery, with sufficient statistical precision ($p>.10$ at the 90% confidence level) to detect meaningful monthly changes in relative abundance of the principal species. This has proved to be one of the major difficulties of sampling a mixed species sport fishery, where the angler population is comprised of fishermen with greatly variable angling skill.

4. If monthly interviewing were to be increased to the maximum for weekend, weekday and charter categories, there would still be insufficient fishing effort in these individual categories to provide a sample size giving a 90% confidence limit and a $p>.10$ level of precision in monthly mean catch rates. This means that statistically significant monthly sample sizes for these categories or fisherman types cannot be attained at present levels of fishing effort with observed variability of the catch rates.

5. Catch rates usually are determined to monitor the status of a fishery. Continuing decreases signal the need for corrective action. Therefore, we believe that monthly catch rates are unnecessary for this purpose and that catch rates reported for a longer period would be more meaningful. Since variation in catch rate within a month is about the same as month to month variation, an increase in the sampling period will effectively increase the angler sample. This will reduce the standard error and permit more precise estimate of catch rate. Depending on the species, longer catch rate periods, quarterly or greater, bracketing the peak periods of seasonal abundance should be used. Such seasonal peaks have been determined for the major species at Flamingo.

6. The sources of variance in the samples must be reduced. The following recommendations are offered:

(a) calculate catch rates only from those anglers expressing a true species preference; this assumes pre-fishing as well as post-trip interviewing of anglers

(b) institute a log-book system for reporting charter-boat and guided fishing effort with a breakdown of fishing effort by species. Fishing effort by specialized anglers (e.g. guides going out only for tarpon or snook) should not be included in the totals. Catch rates of the "professional" fishermen who use a special technique should be calculated separately and evaluated against the composite group catch rate and other fisherman types

(c) identify and solicit records from the skilled fishermen who consistently fish from Flamingo. The catch rate of this group should be evaluated against the professional guides.

7. Managers should clearly recognize that extremely elaborate (time and manpower) sampling is required to provide statistically reliable estimates of fish population size for management of a sport fishery for mixed species of the type pursued in South Florida. The sample sizes (i.e., number of interviews) required are so large as to preclude using the desirable 90% confidence level and precision of 0.10 for month to month samples of most species. The alternative to a program which is not able to provide statistically reliable data is one, less time and labor-intensive, which will provide the following useful interpretive data:

(a) types of fisherman effort

(b) origin of anglers

(c) financial contribution per fishing day

(d) reasonably accurate comparison of year-to-year fishing success (i.e., implied population stability or instability)

(e) dominant species in the catch

(f) seasonal availability

8. Length frequency and age distribution studies must be conducted simultaneously with catch rate studies. Catch rates signal when changes occurred in fish stocks. Length and age studies provide assistance in understanding why changes occur thereby suggesting correct remedial action.

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LITERATURE CITED

Caillouet, C. W., Jr. and James B. Higman

In press. Sample size in sport fishery surveys. Trans. Amer. Fish. Soc.

Grosslein, M. D.

1962. Estimation of angler harvest on Oneida Lake, New York. Ph.D. Dissertation, Cornell University, Ithaca, New York. 296 p. (processed)

Higman, J. B.

1967. Relationships between catch rates of sport fish and environmental conditions in Everglades National Park, Florida. Proc. Gulf & Carib. Fish. Inst. 19th Ann. Sess. (November 1966), p. 129-140.

Snedecor, G. W. and W. G. Cochran

1967. Statistical methods. 6th Edition. Iowa State Univ. Press, Ames, Iowa. 593 pp.