American Fisheries Society Symposium 12:356–366, 1991

Effects of the Avidity Bias on Survey Estimates of Fishing Effort and Economic Value

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Abstract.—This paper describes the avidity bias (the disproportionate representation of avid anglers) in intercept surveys and shows how bias-corrected estimates of mean and variance can be computed. It compares bias-corrected participation rates with actual participation rates reported by California anglers in an economic survey conducted as a mail follow-up to a random telephone canvass, and in an on-site intercept survey. Although both samples contained this bias, it was much more pronounced in the on-site survey than in the mail survey. The findings indicate that failure to correct for avidity bias results in inflated estimates of per capita fishing expenditures and consumer surplus as well as fishing effort. In general, the effect of the avidity bias on estimates of economic value depends not only on the extent of the bias, but also on the relationship between angler expenditures and avidity, and on the functional form of the travel cost model underlying estimates of consumer surplus.

Deciding upon a method for identifying potential respondents is an important first step in designing angler surveys. This decision typically involves a trade-off between cost and bias. For instance, it is possible to obtain a representative sample of anglers by means of a random telephone canvass of the general population, but the search can be relatively costly. On-site surveys usually offer a less expensive alternative, which explains why they are commonly used to identify anglers for economic surveys; but they result in samples that may be biased in several ways.

One potential source of error is the length-of-stay bias. This bias arises when selection probabilities increase with the amount of time spent at the recreational site. In an on-site survey of Wyoming campers, Nowell et al. (1988) found that trip expenditures and willingness to pay for the opportunity to see a grizzly bear were correlated with length of stay. They provided techniques for obtaining unbiased statistics from length-biased samples.

Another potential source of bias arises when avid participants (those who participate more frequently) are disproportionately represented in on-site surveys. The overrepresentation of avid anglers in a sample is referred to as avidity bias. In this paper, I describe the derivation of mean and variance estimators used to correct for avidity bias, and I present a case study that illustrates the potential effect of this bias on estimates of per capita fishing effort and economic value.

Procedures to Correct for Avidity Bias

Suppose that n' samples are drawn from the angling population, with each sample size defined as $n = 1$.[1] If these are random replacement samples, the probability of selecting angler i in any given draw will be

$$\text{Prob(random selection of angler } i) = 1/N\,; \quad (1)$$

N is the number of anglers in the population. By contrast, if the draws result in a random sample of trips rather than a random sample of anglers (as is likely to occur with an intercept survey), the probability of selecting angler i in any given draw will be

$$\text{Prob(intercepting angler } i) = T_i/T\,. \quad (2)$$

T_i = number of trips taken annually by angler i, and
$T = \Sigma^N T_j$ = total number of trips taken annually by the population.

Suppose that we want to estimate the mean value per angler of a random variable z on the basis of data collected in an intercept survey. If z is correlated with angler avidity, its arithmetic mean, computed as

[1] When sampling probabilities are not uniform, the derivation of statistics for nonreplacement samples is considerably more complicated than for replacement samples. Thus the distinction between drawing n' samples with replacement, each sample being of size $n = 1$, and drawing a single sample of size n (nonreplacement sampling) is conceptually important.

$$\bar{z} = \sum^{n'} Z_i/n',$$

will be a biased estimate of the true mean $\bar{Z}$. This section describes estimators for the mean and variance of $\bar{Z}$ that correct for the avidity bias in intercept surveys. These and other statistics are discussed more thoroughly in Jessen (1978).

Mean and Variance Estimators: The General Case

If P_i is the probability of selecting individual i, then the number of individuals in the population (N), and the population total for the variable of interest

$$Z = \sum^{N} Z_i,$$

can be estimated respectively by

$$\hat{N} = \frac{1}{n'} \sum^{n'} \frac{1}{P_i}, \quad (3)$$

and

$$\hat{Z} = \frac{1}{n'} \sum^{n'} \frac{Z_i}{P_i}. \quad (4)$$

By substituting the selection probabilities from equation (2) for P_i, equations (3) and (4) can be expressed as

$$\hat{N} = \frac{T}{n'} \sum^{n'} \frac{1}{T_i}, \quad (5)$$

and

$$\hat{Z} = \frac{T}{n'} \sum^{n'} \frac{Z_i}{T_i}. \quad (6)$$

By using (5) and (6), $\bar{Z}$ can be estimated as

$$\hat{Z}/\hat{N} = \frac{\sum^{n'} (Z_i/T_i)}{\sum (1/T_i)}. \quad (7)$$

Although $\hat{Z}$ and $\hat{N}$ are unbiased estimators of Z and N, equation (7) is not an unbiased estimator of $\bar{Z}$. The bias of ratio estimators such as in equation (7), however, becomes negligible as sample size increases (Cochran 1977).

The variance of equation (7) is

$$\text{var}(\hat{Z}/\hat{N}) = \frac{(N-1)}{Nn'} \bar{Z}^2 \left[\frac{S^2_{z/t}}{\bar{Z}^2} + \frac{S^2_{1/t}}{\bar{N}^2} - \frac{2S_{(z/t)(1/t)}}{\bar{Z}\,\bar{N}}\right]$$
$$= \frac{(N-1)}{Nn'} \bar{Z}^2 \left[\frac{S^2_{z/t}}{\bar{Z}^2} + \frac{S^2_{1/t}}{1} - \frac{2S_{(z/t)(1/t)}}{\bar{Z}}\right]; \quad (8)$$

$$S^2_{z/t} = \frac{T^2}{N(N-1)} \sum^{N} \frac{T_i}{T}\left(\frac{Z_i}{T_i} - \frac{Z}{T}\right)^2,$$

$$S^2_{1/t} = \frac{T^2}{N(N-1)} \sum^{N} \frac{T_i}{T}\left(\frac{1}{T_i} - \frac{N}{T}\right)^2,$$

and

$$S_{(z/t)(1/t)} = \frac{T^2}{N(N-1)} \sum^{N} \frac{T_i}{T}\left(\frac{Z_i}{T_i} - \frac{Z}{T}\right)\left(\frac{1}{T_i} - \frac{N}{T}\right).$$

The relative variance (the squared coefficient of variation) associated with equation (8) is

$$\text{rel var}(\hat{Z}/\hat{N}) = \frac{N-1}{Nn'} [V^2_{z/t} + V^2_{1/t} - 2V_{(z/t)(1/t)}]; \quad (9)$$

$$V^2_{z/t} = \frac{S^2_{z/t}}{\bar{Z}^2},\ V^2_{1/t} = \frac{S^2_{1/t}}{1},\ \text{and}\ V_{(z/t)(1/t)} = \frac{S_{(z/t)(1/t)}}{\bar{Z}}.$$

Equation (8) can be estimated from a sample by

$$\widehat{\text{var}}(\hat{Z}/\hat{N}) = \left[\frac{\sum^{n'} (Z_i/T_i)}{\sum (1/T_i)}\right]^2 \frac{1}{n'} \cdot \left[\frac{s^2_{z/t}}{(\hat{Z}/\hat{N})^2} + \frac{s^2_{1/t}}{1} - \frac{2s_{(z/t)(1/t)}}{\hat{Z}/\hat{N}}\right]; \quad (10)$$

$$s^2_{z/t} = \frac{\hat{T}^2}{n'-1} \sum^{n'} \left(\frac{Z_i}{T_i} - \frac{\hat{Z}}{T}\right)^2 = \frac{\hat{T}^2}{n'-1}\left[\sum^{n'} \left(\frac{Z_i}{T_i}\right)^2 - \frac{1}{n'}\left(\sum^{n'} \frac{Z_i}{T_i}\right)^2\right],$$

$$s^2_{1/t} = \frac{\hat{T}^2}{n'-1} \sum^{n'} \left(\frac{1}{T_i} - \frac{\hat{N}}{T}\right)^2 = \frac{\hat{T}^2}{n'-1}\left[\sum^{n'} \left(\frac{1}{T_i}\right)^2 - \frac{1}{n'}\left(\sum^{n'} \frac{1}{T_i}\right)^2\right], \quad (11)$$

and

$$s_{(z/t)(1/t)}$$

$$= \frac{\bar{T}^2}{n'-1} \sum^{n'} \left(\frac{Z_i}{T_i} - \frac{\hat{Z}}{T}\right)\left(\frac{1}{T_i} - \frac{\hat{N}}{T}\right)$$

$$= \frac{\bar{T}^2}{n'-1} \left[\sum^{n'} \left(\frac{Z_i}{T_i} \cdot \frac{1}{T_i}\right) - \frac{1}{n'} \sum^{n'} \frac{Z_i}{T_i} \sum^{n'} \frac{1}{T_i}\right].$$

Equation (9) can be estimated by

$$\text{rel } \widehat{\text{var}}(\hat{Z}/\hat{N}) = \frac{1}{n'} [v_{z/t}^2 + v_{1/t}^2 - 2v_{(z/t)(1/t)}]; \quad (12)$$

$$v_{z/t}^2 = \frac{s_{z/t}^2}{\bar{T}^2[(1/n') \sum (Z_i/T_i)]^2}$$

$$= \left(\frac{n'^2}{n'-1}\right) \frac{\sum^{n'} (Z_i/T_i)^2 - (1/n')\left[\sum^{n'} (Z_i/T_i)\right]^2}{[\sum (Z_i/T_i)]^2},$$

$$v_{1/t}^2 = \frac{s_{1/t}^2}{\bar{T}^2[(1/n') \sum (1/T_i)]^2}$$

$$= \left(\frac{n'^2}{n'-1}\right) \frac{\sum^{n'} (1/T_i)^2 - (1/n')\left[\sum^{n'} (1/T_i)\right]^2}{[\sum (1/T_i)]^2}, \quad (13)$$

and

$$v_{(z/t)(1/t)} = \frac{s_{(z/t)(1/t)}}{\bar{T}^2[\sum (Z_i/T_i) \sum (1/T_i)]/n'^2}$$

$$= \left(\frac{n'^2}{n'-1}\right)$$

$$\cdot \frac{\sum^{n'} [(Z_i/T_i) \cdot (1/T_i)] - (1/n')\left[\sum^{n'} (Z_i/T_i)\right]\left[\sum^{n'} (1/T_i)\right]}{\sum (Z_i/T_i) \sum (1/T_i)}.$$

Mean and Variance Estimators for Fishing Effort per Angler

When fishing effort per angler is itself the variable of interest, a bias-corrected estimate of its mean value can be computed as

$$T/\hat{N} = \frac{T}{(T/n') \sum (1/T_i)} = \frac{n'}{\sum (1/T_i)}; \quad (14)$$

$\hat{N}$ is estimated according to equation (5). The sample variance of $T/\hat{N}$ is

$$\widehat{\text{var}}(T/\hat{N}) = \left\{\frac{n'}{[\sum (1/T_i)]^2}\right\} s_{1/t}^2,$$

which is a special case of equation (10) for which $s_{t/t}^2 = 0$, $s_{(t/t)(1/t)} = 0$, and $s_{1/t}^2$ is defined by equation (11).

The relative variance associated with equation (14) can be estimated by

$$\text{rel } \widehat{\text{var}}(T/\hat{N}) = \frac{1}{n'} v_{1/t}^2$$

$$= \frac{n'}{n'-1} \left\{\frac{\sum^{n'} (1/T_i)^2}{[\sum (1/T_i)]^2} - \frac{1}{n'}\right\}; \quad (15)$$

$v_{1/t}^2$ is defined by equation (13). The estimates produced by equation (15) generally will fall in the range (0, +1) for any reasonable sample size n', because

$$\sum^{n'} (1/T_i)^2 < \left[\sum^{n'} (1/T_i)\right]^2.$$

Thus the application of equation (14) to intercept data produces bias-corrected (consistent) estimates of mean fishing effort per angler that are characterized by relatively high precision.

A Case Study

This case study focuses on two surveys: the Marine Recreational Fishery Statistics Survey and the Bay Area Sportfish Economic Survey.

The Marine Recreational Fishery Statistics Survey (MRFSS) is an annual survey of saltwater anglers that has been sponsored by the National Marine Fisheries Service since 1979. Its major purpose is to estimate catch and effort of marine anglers on a state-by-state basis. The MRFSS comprises telephone and on-site sampling components.

- MRFSS—TEL is a random telephone canvass of the general population of coastal counties. Its purpose is to determine (among other things) the proportions of households with at least one person who has gone saltwater fishing in the previous 12 months and in the previous 2 months, the average number of such 12-month and 2-month anglers per angling household, and selected details of each trip made by each angler in the 2 months preceding the telephone contact. The telephone survey is repeated with a new sample every 2 months throughout the year. Results are expanded to estimate aggregate fishing effort by mode and area during each 2-month survey wave.

- MRFSS—INT is an on-site creel survey conducted throughout the year at four mutually exclusive fishing modes: (1) beaches and banks, (2) piers and other constructions, (3) party and charter boats, and (4) private and rental boats. The main purpose of this creel survey is to determine the number, weight, and species composition of fish caught in different modes, areas, and times of year. Estimates of catch per unit effort are combined with estimates of fishing effort from the MRFSS—TEL to estimate aggregate catch.

In 1985–1986, the Southwest Fisheries Center of the National Marine Fisheries Service sponsored the Bay Area Sportfish Economic Survey (BASES). This survey sampled marine anglers residing in the 19 coastal counties of central and northern California for information about fishing expenditures and demographics as well as on participation.

The BASES survey was conducted as a mail follow-up to the central–northern California portion of the nationwide MRFSS—TEL (hereafter referred to as MRFSS—TEL*). Specifically, 12-month anglers in MRFSS—TEL* who agreed to answer additional questions were mailed a BASES questionnaire. This solicitation was repeated over seven 2-month survey waves, beginning with July–August 1985 and ending with July–August 1986. Of the 4,031 anglers identified in the MRFSS—TEL* over the BASES survey period, 3,184 agreed to fill out the mail questionnaire and 1,543 actually completed and returned it.

Because of the length of the BASES questionnaire, it would not have been feasible to collect BASES data at on-site interviews. However, one option considered during the survey design phase was to conduct BASES as a mail follow-up to the central–northern California portion of MRFSS—INT; given the large sample size of MRFSS—INT, this would have greatly expanded the number of potential BASES respondents at relatively low cost. However, a major concern (and a deciding factor in the decision to use MRFSS—TEL* for initial respondent identification) was that on-site intercept techniques tend to generate samples heavily biased toward avid anglers.

The following sections compare bias-corrected estimates of the mean number of trips per angler with arithmetic mean values computed from the BASES and MRFSS—INT data. They describe the relationship between angler avidity and various components of economic value. Finally, they provide a numerical example to illustrate the potential effect of the avidity bias on estimates of annual economic value per angler.[2]

Effect of the Avidity Bias on Estimates of Fishing Effort

Ordinarily, all anglers contacted in MRFSS—INT, regardless of state or county of origin, are eligible for inclusion in the survey. In contrast, potential BASES respondents were limited to anglers residing in 19 designated counties. To ensure comparability of the two samples, all analysis of MRFSS—INT in this paper is limited to respondents who were interviewed at fishing sites in central and northern California over the BASES survey period and who reside in the counties from which the BASES sample was drawn. This subset of MRFSS—INT respondents is hereafter referred to as MRFSS—INT*.

The level of fishing effort reported by a sample of anglers can be affected not only by avidity bias but by respondents' proximity to fishing opportunities and by mode preferences. To isolate the latter effects from the effect of the avidity bias, the BASES and MRFSS—INT* samples were divided into subsamples.

Eighteen of the 19 counties of residence covered by BASES were grouped into five areas: inland, east bay, north coast, central coast, and south coast.[3] Each area is a group of contiguous counties with similar access to fishing opportunities. Specifically, north and south coast anglers have ready access to ocean fishing. Central coast anglers are close to both the ocean and San Francisco Bay, whereas east bay anglers have good access to the bay but not to the ocean. Inland anglers generally have poor access to all marine fishing opportunities.

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[2]The issue of length-of-stay bias is not addressed in this paper. For the most part, MRFSS—INT is an access point rather than a roving creel survey, so the probability of being sampled is related to the frequency of participation rather than length of stay.

[3]The counties included in each area were as follows: inland—Sacramento, San Joaquin, Yolo; east bay—Alameda, Contra Costa, Napa, Santa Clara, Solano; north coast—Del Norte, Humboldt, Mendocino, Trinity; central coast—Marin, San Francisco, San Mateo, Sonoma; south coast—Monterey, Santa Cruz. San Benito county was also included in the BASES survey but not covered in this analysis. It was deemed too far south to be included with the east bay counties and too far inland to be included with the south coast counties.

TABLE 1.—Comparison of bias-corrected, BASES, and MRFSS—INT* statistics on annual number of trips per angler, by fishing mode and area of residence.[a]

Area of residence and data source	Beach			Pier			Party boat			Private boat		
	Mean	CV	*N*	Mean	CV	*N*	Mean	CV	*N*	Mean	CV	*N*
Inland												
Bias-corrected	2.41	0.08	113	2.03	0.07	149	1.36	0.03	215	2.86	0.11	126
BASES	6.46	1.15	35	6.59	2.90	22	3.48	1.31	46	12.13	1.37	60
MRFSS—INT*	7.90	1.38	113	9.81	3.52	149	4.22	3.19	215	12.83	1.54	126
East bay												
Bias-corrected	3.87	0.05	690	3.59	0.04	863	1.95	0.03	615	4.20	0.04	1,316
BASES	8.98	1.45	111	11.05	1.92	55	3.59	1.53	145	12.25	1.65	199
MRFSS—INT*	23.67	1.69	690	21.99	1.67	863	9.04	1.93	615	19.77	1.15	1,316
North coast												
Bias-corrected	4.00	0.06	507	4.20	0.05	885	1.31	0.10	21	4.59	0.06	535
BASES	9.64	0.98	25	6.00	0.87	11	2.97	0.86	34	16.24	1.86	46
MRFSS—INT*	27.83	1.69	507	30.87	1.65	885	2.76	1.53	21	20.89	1.22	535
Central coast												
Bias-corrected	4.53	0.08	379	3.64	0.05	555	2.01	0.05	241	4.02	0.06	588
BASES	9.79	1.17	75	8.17	1.20	41	4.92	1.99	87	9.44	1.04	134
MRFSS—INT*	45.33	1.65	379	26.67	1.87	555	10.17	2.49	241	29.11	1.72	588
South coast												
Bias-corrected	5.05	0.08	342	4.81	0.09	258	1.73	0.06	157	4.46	0.08	312
BASES	18.35	1.58	26	5.68	1.02	16	4.03	0.95	35	10.53	1.46	47
MRFSS—INT*	38.69	1.58	342	39.42	1.65	258	14.18	3.08	157	24.92	1.71	312
All areas												
Bias-corrected	4.14	0.03	2,031	3.83	0.02	2,710	1.82	0.02	1,249	4.21	0.03	2,877
BASES	9.84	1.43	282	8.52	1.70	147	3.87	1.66	352	11.68	1.56	502
MRFSS—INT*	30.40	1.76	2,031	26.84	1.78	2,710	8.97	2.62	1,249	22.14	1.50	2,877

[a]Bias-corrected estimates of mean and coefficient of variation (CV) were computed according to equation (14) and the square root of equation (15), respectively.

Both BASES and MRFSS—INT* respondents were classified according to their "predominant" mode of fishing. For the BASES respondents, who provided detailed information (including mode) for the three most recent fishing trips made in the previous year, this was considered the mode of the last trip.[4] For the MRFSS—INT* respondents, who provided the number of fishing trips made in the previous year but did not identify them by mode, this was considered the mode of intercept.[5]

For each area–mode combination, I obtained an unbiased estimate of mean fishing effort per angler by applying equation (14) to the appropriate MRFSS—INT* subsample. I computed the associated coefficient of variation by taking the square root of equation (15). These statistics, as well as the arithmetic means and coefficients of variation for the corresponding BASES and MRFSS—INT* samples, are shown in Table 1.

The small BASES sample sizes associated with some area–mode combinations may make the reliability of some tabulated statistics questionable. The results, however, consistently indicate overrepresentation of avid anglers in the BASES and MRFSS—INT* samples relative to the angling population as a whole.[6] Another notable result is that the coefficients of variation associated with the bias-corrected estimates are uniformly close to 0, which reflects a substantial gain in precision over the BASES and MRFSS—INT* estimates.

The bias in the BASES sample can be attributed to a systematic pattern of nonresponse to the mail

[4]For 89% of the BASES sample, at least half of the three most recent trips were made in the mode of the most recent trip.

[5]MRFSS—INT defines a trip as a fishing day. The BASES definition of a trip includes both single- and multiple-day fishing excursions. To make the samples comparable, I excluded multiple-day trips from the analysis of the BASES data. Only 6% of the three most recent trips reported by BASES respondents were multiple-day trips.

[6]Table 1 also points up differences in avidity among modes and areas. For instance, inland residents, whose access to marine fishing opportunities is most limited, fish less frequently than other anglers in all modes. Also, party-boat anglers tend to fish less frequently than anglers associated with other modes. The relatively high costs associated with party-boat trips may limit participation to some extent. Supply may be a limiting factor as well, particularly in the north coast area, where party-boat vessels only operate seasonally.

questionnaire. According to Thomson and Huppert (1987), anglers contacted in the MRFSS—TEL* who fished frequently in the previous 2 months were much more likely to complete the BASES mail questionnaire than those who fished infrequently or not at all during those 2 months. Two-month avidity was considerably higher for the BASES respondents than for the original telephone sample from which they were drawn, but it was impossible to determine whether nonresponse to the BASES questionnaire was related to 12-month avidity, because information on the number of trips made in the past 12 months is not collected in the MRFSS—TEL.[7] The differences between the unbiased and BASES estimates of mean fishing effort reported in Table 1, however, suggest the presence of a 12-month as well as a 2-month bias in the BASES sample associated with nonresponse to the mail questionnaire.

The differences between the bias-corrected and MRFSS—INT* estimates are even more pronounced, which suggests that failure to correct for avidity bias in the MRFSS—INT* can result in gross overestimates of fishing effort per angler. The differences also suggest that the BASES sample of mail respondents would have been even more biased toward avid anglers if it had been collected as an add-on to MRFSS—INT* rather than to MRFSS—TEL*.

Effect of the Avidity Bias on Estimates of Economic Value

The economic value of fishing comprises two components: expenditures related to fishing, and the maximum amount over and above actual expenditures that the angler is willing to pay to participate in the activity. The sum of the two components is referred to as the gross benefit associated with fishing; the latter component is referred to as net benefit or consumer surplus.

Estimates of economic value are affected by the avidity bias only to the extent that they are correlated with angler avidity. This section describes the relationship of avidity to annual trip-related expenditures, annual fishing-gear expenditures, and annual consumer surplus.

Annual trip-related expenditures.—The BASES questionnaire does not directly ask for information on annual trip-related expenditures. Instead, it asks respondents to describe expenditures for each of their three most recent trips in each of the following categories: (1) tackle (lures, sinkers, lines, rental equipment, licenses, and fish cleaning), (2) boat fees (for party-boat trips), (3) boat fuel (for private boat trips), and (4) amenities (food, beverages, lodging).

To determine whether expenditures per trip were related to avidity, I divided the trip data into four subsamples, one for each trip mode For each trip expenditure category within each of the four modes, I used regression analysis to determine the effect of fishing avidity on the level of spending. I was unable to find a statistically significant relationship for any of the expenditure categories in the four modes. Costs per trip were invariant with respect to avidity, so annual trip-related expenditures per angler can be expected to be proportional to the frequency of participation.

Annual gear expenditures.—Another category of expenditures covered by the BASES survey was annual purchase and repair of saltwater fishing gear and equipment (excluding boats, motors, trailers, and boat-related equipment). To determine the effect of avidity on annual gear expenditures, I divided the BASES sample of anglers into four different subsamples, each consisting of respondents sharing the same predominant mode (the mode of the most recent fishing trip). The regression results associated with the best fitting functional form for each subsample are reported in Table 2.

For each predominant mode, the relationship between annual gear expenditures and avidity was quadratic, with gear expenditures first increasing and then declining as avidity increased. Up to some point, more frequent participation implied greater investment in equipment and therefore higher expenditures. Beyond that point, however, anglers appeared to have accumulated sufficient equipment and their expenditures declined.

Annual consumer surplus.—Three standard assumptions in demand theory are (1) the satisfaction individuals derive from a good, as well as the maximum amount that they are willing to pay for it, declines with each additional unit consumed per unit time; (2) individuals consume additional units so long as their willingness to pay is greater than or equal to the price of the good; and (3) willingness to pay is equal to price for the final unit consumed per unit time. Because individuals generally are required to pay the same unit price regardless of the quantity consumed, they derive

[7]If annual participation data were collected in MRFSS—TEL, I would expect to find no statistically significant differences between the arithmetic mean of this variable from MRFSS—TEL and the bias-corrected mean from MRFSS—INT.

TABLE 2.—Results (coefficients) of regression analysis that describe the effect of angler avidity on annual gear expenditures (*t*-values in parentheses).[a]

Explanatory variables[b]	Fishing mode: Beach	Pier	Party boat	Private boat
T	10.994	4.207	18.520	14.452
	(9.779)	(5.286)	(7.157)	(6.239)
T^2	−0.162	−0.035	−0.270	−0.071
	(−5.021)	(−4.065)	(−4.999)	(−4.885)
INCOMEHI		40.708	48.515	136.092
		(2.921)	(2.531)	(2.817)
BOATOWNR				93.167
				(2.227)
Adjusted r^2	0.39	0.26	0.22	0.26
Sample size	251	131	314	447

[a]Annual gear expenditures cover purchase and repair of saltwater fishing gear and equipment (excluding boats, motors, trailers, and boat-related equipment).

[b]T is the number of fishing trips made in the previous 12 months. INCOMEHI = 1 if annual household income > $50,000, 0 otherwise. BOATOWNR = 1 if angler owns a boat that can be used for saltwater fishing, 0 otherwise.

benefits over and above actual expenditures for all of the units consumed before the last one. This additional benefit is known as consumer surplus.

One commonly used method for measuring consumer surplus involves estimation of a demand or travel cost model $T = f(P, Z)$ that relates the number of trips (T) made per unit time with the travel cost or price per trip (P) and other relevant variables (Z). Consumer surplus is measured as the area under the demand curve above price. The general formula for consumer surplus is

$$\text{CS} = \int_{P^*}^{P^{**}} f(P, Z)\, dP\,;$$

P^* is the actual price paid by the angler and P^{**} is the "choke price" that would cause the angler to stop fishing altogether.

I estimated a separate travel cost model for four subsets of the BASES sample, with each subset consisting of respondents sharing the same predominant mode (the mode of the most recent fishing trip). For the beach, pier, and party-boat modes, the final model specification took the form

$$T_i = \beta_0 + \beta_1 P_i + \beta_2 P_i^2 + \beta_3 \text{ABIL}_i + u_i\,; \qquad (16)$$

T_i is the number of fishing trips made in the previous 12 months by angler i, P_i is the price or travel cost per trip incurred by angler i, ABIL_i is a dummy variable denoting angler i's self-described fishing ability (0 if fishing ability is average or less, 1 if fishing ability is greater than average), and u_i is a random error term. The quadratic term in P_i was excluded from the model specification for the private boat mode, because the coefficient β_2 was not statistically significant.

I computed P_i as the sum of mileage and time costs per trip. I estimated mileage costs by the number of round-trip highway miles between the angler's ZIP code of residence and the site of the most recent fishing trip, multiplied by vehicle operating costs of $0.20/mi. I estimated travel time by assuming that travel distance was covered at a rate of 40 mph. Following Cesario (1976), I estimated the opportunity cost of time by multiplying travel time by one-third of the angler's reported wage rate.

The sample used to estimate the demand function was truncated (limited to anglers who made at least one fishing trip over the previous year), so I used a maximum-likelihood procedure based on a truncated normal distribution to obtain consistent parameter estimates (Maddala 1983). The empirical results appear in Table 3.

For the beach, pier, and party-boat equations, the change in the number of trips taken associated with a change in price was measured by $\delta T/\delta P = \beta_1 + 2\beta_2$; for the private boat equation, it was $\delta T/\delta P = \beta_1$. The parameter estimates in Table 3 produced the expected negative relationship between T and P for all four fishing modes. The estimated coefficient of ABIL was positive and significant for all four modes, which suggested that skilled anglers tended to fish more frequently.

Equation (16) can be used to compute annual consumer surplus,

$$\begin{aligned} \text{CS}_i &= \int_{P_i^*}^{P_i^{**}} (\beta_0 + \beta_1 P_i + \beta_2 P_i^2 + \beta_3 \text{ABIL}_i + u_i)\, dP_i \\ &= \frac{(\beta_0 + \beta_1 P_i + \beta_2 P_i^2 + \beta_3 \text{ABIL}_i + u_i)}{2(\beta_1 + 2\beta_2)}\Bigg|_{P_i^*}^{P_i^{**}} \\ &= -\frac{T_i^2}{2(\beta_1 + 2\beta_2)}\,, \end{aligned} \qquad (17)$$

for anglers whose predominant mode is beach, pier, or party boat. For anglers whose predominant mode is private boat (for which $\beta_2 = 0$), consumer surplus takes the form

$$\text{CS}_i = -\frac{T_i^2}{2\beta_1}\,. \qquad (18)$$

TABLE 3.—Results of travel cost model estimation (asymptotic t-values in parentheses).

Independent variables[a]	Fishing mode			
	Beach	Pier	Party boat	Private boat
CONSTANT			3.446 (4.862)	
P	−0.767 (−4.727)	−3.206 (−12.050)	−0.694E−1 (−2.234)	−0.498 (−25.091)
P^2	0.506E−2 (3.948)	0.197E−1 (7.024)	−0.647E−3 (−3.519)	
ABIL	19.977 (10.516)	16.332 (2.254)	5.557 (6.541)	17.867 (8.042)
Maximum log likelihood	−688.90	−413.12	−801.65	−1,377.60
Restricted log likelihood	−807.67	−510.47	−936.99	−1,594.20
Chi-square	237.54	194.70	270.68	433.20
Sample size	209	122	291	373

[a] P includes mileage costs and opportunity cost of travel time. ABIL is a dummy variable for the angler's self-described fishing ability (0 = intermediate or lesser ability, 1 = greater than intermediate ability).

Because the square of T_i appears in the numerator of equations (17) and (18), consumer surplus estimates derived from these equations are likely to be highly sensitive to the presence of avidity bias in an on-site intercept survey.

In general, the effect of the avidity bias on estimates of consumer surplus depends not only on the extent of the bias but on the functional form of the travel cost model. For instance, Bockstael et al. (no date) showed consumer surplus per angler associated with the commonly used semilog functional form

$$\log_e(T_i) = \beta_0 + \beta_1 P_i + \beta_2 Z_i + u_i$$

to be

$$CS_i = -\frac{T_i}{\beta_1}. \quad (19)$$

Use of this semilog model produces consumer surplus estimates that are less sensitive to the avidity bias of an intercept sample than is the linear model specified in equation (16). This is due to the appearance of T_i rather than T_i^2 in the numerator of equation (19). However, attempts to estimate a semilog version of the travel cost model with the BASES data produced uniformly poor results for all modes.

Case Study Results

Table 4 provides a numerical example that describes the effects of the avidity bias in the MRFSS—INT* survey and the nonresponse bias in the BASES survey on various components of economic value. The data focus on east bay anglers, who make up approximately 46% of the angling population residing in the coastal counties covered by the BASES survey (Thomson and Huppert 1987).

The analysis underlying Table 4 is based on the assumption that the relationship of fishing avidity to annual gear expenditures (as described in Table 2) and to annual consumer surplus (as described in equations 17 and 18) applies to the angling population as a whole and to the MRFSS—INT* and BASES samples. Proceeding from this assumption, I estimated the following value components.

Annual Trip-Related Expenditures

I computed annual trip-related expenditures by multiplying mean cost per trip (as described in the following paragraphs) by the bias-corrected, BASES, and MRFSS—INT* estimates of mean number of trips per angler (from Table 1). The categories of cost included here are travel, tackle, party-boat fees, boat fuel, and amenities.

The same estimates of travel cost per trip that were used to estimate the travel cost model in Table 3 also were used for this numerical example. This includes (1) mileage costs, with travel distance valued at $0.20/mi, and (2) the opportunity cost of time, with travel time valued at one-third the angler's wage rate. By dividing the east bay residents in the BASES sample according to the predominant mode of each respondent, I computed mean travel cost per trip for each mode. I applied these same estimates to the east bay residents in MRFSS—INT*. This is a reasonable assumption for the mileage component, because all east bay residents are roughly equi-

TABLE 4.—Comparison of estimates of annual economic value per angler (corrected for avidity bias) with BASES and MRFSS—INT* estimates, for east bay residents.[a]

Fishing mode and quantity	Bias corrected	BASES mail survey	MRFSS—INT*
Beach			
Number of trips/year	3.87	8.98	23.67
Mean cost/trip			
Travel	$ 19.37	$ 19.37	$ 19.37
Tackle	$ 9.07	$ 9.07	$ 9.07
Amenities	$ 9.76	$ 9.76	$ 9.76
Total	$ 38.20	$ 38.20	$ 38.20
Annual trip-related costs	$147.83	$ 343.04	$ 904.19
Annual consumer surplus	$ 60.47	$ 164.16	$1,424.67
Annual gear expenditures	$ 27.69	$ 71.36	$ 83.22
Annual economic value	$235.99	$ 578.56	$2,412.08
Pier			
Number of trips/year	3.59	11.05	21.99
Mean cost/trip			
Travel	$ 13.76	$ 13.76	$ 13.76
Tackle	$ 9.19	$ 9.19	$ 9.19
Amenities	$ 10.18	$ 10.18	$ 10.18
Total	$ 33.13	$ 33.13	$ 33.13
Annual trip-related costs	$118.94	$ 366.09	$ 728.53
Annual consumer surplus	$ 12.48	$ 89.28	$ 288.52
Annual gear expenditures	$ 22.13	$ 53.63	$ 53.44
Annual economic value	$153.55	$ 509.00	$1,070.49
Party boat			
Number of trips/year	1.95	3.59	9.04
Mean cost/trip			
Travel	$ 12.69	$ 12.69	$ 12.69
Tackle	$ 15.39	$ 15.39	$ 15.39
Partyboat fees	$ 31.37	$ 31.37	$ 31.37
Amenities	$ 12.64	$ 12.64	$ 12.64
Total	$ 72.09	$ 72.09	$ 72.09
Annual trip-related costs	$140.58	$ 258.80	$ 651.69
Annual consumer surplus	$124.91	$ 303.94	$2,739.84
Annual gear expenditures	$ 44.34	$ 45.58	$ 95.48
Annual economic value	$309.83	$ 608.32	$3,487.01
Private boat			
Number of trips/year	4.20	12.25	19.77
Mean cost/trip			
Travel	$ 20.54	$ 20.54	$ 20.54
Tackle	$ 13.70	$ 13.70	$ 13.70
Boat fuel	$ 15.74	$ 15.74	$ 15.74
Amenities	$ 9.16	$ 9.16	$ 9.16
Total	$ 59.14	$ 59.14	$ 59.14
Annual trip-related costs	$248.39	$ 724.47	$1,169.20
Annual consumer surplus	$ 83.37	$ 558.23	$ 908.90
Annual gear expenditures	$148.80	$ 239.90	$ 315.47
Annual economic value	$480.56	$1,522.60	$2,393.57

[a]Number of trips per year taken from Table 1 for east bay residents. Travel costs were computed from data provided by east bay residents in the BASES sample; they include mileage costs (valued at $0.20/mi) and the opportunity cost of travel time (valued at one-third the angler's wage rate). Expenditures per trip on tackle, boat fees (for party-boat anglers), boat fuel (for private boat anglers), and amenities (food, beverage, and lodging) were obtained by averaging values reported for the three most recent trips by east bay residents in the BASES sample. Annual consumer surplus for the BASES and MRFSS—INT* samples were computed from equations (17) and (18) and the parameter estimates in Table 3. Annual gear expenditures for east bay residents in the BASES sample were computed by taking sample average. Annual gear expenditures for the MRFSS—INT* sample were estimated from Table 2. Bias-corrected consumer surplus and gear expenditures were computed by weighting the MRFSS—INT* values according to the formula in equation (7).

distant from fishing opportunities. For the opportunity cost component, I assumed that the opportunity cost of travel time is not a function of avidity.

The BASES questionnaire asked respondents for information regarding expenditures on tackle, party-boat fees, boat fuel, and amenities for their three most recent fishing trips. I divided the trip data provided by east bay residents into four subsets that corresponded to the mode of the trip; then I obtained an average expenditure value for each combination of mode–expenditure category. The same per trip expenditures were assumed for the east bay residents in the MRFSS—INT* sample. This assumption appears reasonable because of the lack of any statistically significant relationship between per trip expenditures and avidity.

Annual Gear Expenditures

I divided the east bay residents in the BASES sample into four subsamples, each consisting of respondents who shared the same predominant mode (the mode of the most recent fishing trip). I computed average annual gear expenditures for each mode on the basis of actual figures reported by the respondents.

Information on gear expenditures was not collected from MRFSS—INT* respondents. Therefore, for each east bay resident i in the MRFSS—INT* sample, I estimated annual gear expenditures by evaluating the equation in Table 2 that corresponded to the angler's predominant mode (the mode of the intercepted trip) at T_i. I then averaged these estimated values for all respondents associated with each mode.

I computed the bias-corrected estimate of average annual gear expenditures associated with each mode by applying the formula in (7) to the estimated values for the east bay residents in the MRFSS—INT* sample.

Annual Consumer Surplus

I estimated consumer surplus for each east bay resident in the BASES sample on the basis of formula (17) or (18), depending on the predominant mode of the respondent and the parameter estimates in Table 3. The values reported in Table 4 are the sample averages that correspond to each mode. The same procedure was used for the MRFSS—INT* sample. The bias-corrected estimates were obtained by applying the formula in equation (7) to the consumer surplus estimates for the MRFSS—INT* sample.

Magnitude of Bias

The differences in annual trip costs among the three samples were proportional to the differences in mean avidity levels. The BASES estimates were 0.8–2.1 times larger and the MRFSS—INT* estimates were 3.6–5.1 times larger than the bias-corrected values.

The differences in average annual gear costs were of lesser magnitude, with BASES estimates 0–1.6 times larger and MRFSS—INT* estimates 1.1–2.0 times larger than the bias-corrected estimates.

The differences in average annual consumer surplus were sizeable. The BASES estimates were 1.4–6.2 times larger and the MRFSS—INT* estimates were 9.9–22.6 times larger than the bias-corrected estimates. As discussed previously, this result is due in part to the use of a functional specification for the travel cost model that is linear in parameters.

When all components of value were summed, the BASES estimates of total value were 1.0–2.3 times larger and the MRFSS—INT* estimates were 4.0–10.3 times larger than the bias-corrected estimates.

Conclusions and Recommendations

Although on-site intercepts can be a relatively inexpensive way to locate potential respondents for economic surveys, the resulting sample will be biased toward avid anglers. The bias may not equal the magnitude of the case study reported here; yet it must be considered whenever intercept surveys are used to collect economic information.

By taking into account the nonuniform selection probabilities associated with intercept surveys, it is possible to derive bias-corrected (consistent) and relatively precise estimates of mean number of trips per angler from intercept data. When the sample size is sufficiently large, it is possible also to obtain unbiased statistics for other variables correlated with angler avidity.

Some functional forms for the travel cost model (such as the linear-in-parameters model) yield estimates of consumer surplus that are more sensitive to avidity bias than others (e.g., the semilog model).

Avidity bias may be present among mail survey respondents drawn from a random sample of anglers (such as BASES). In this case, the bias is caused by nonresponse to the mail questionnaire rather than by the sample selection procedure.

Although I have only peripherally addressed the issue of nonresponse bias, I do not mean to minimize its importance.

Acknowledgments

Comments by Daniel Talhelm, Warren Fisher, and an anonymous reviewer have significantly improved the clarity and statistical rigor of the paper. Mark Holliday of the National Marine Fisheries Service kindly provided the MRFSS intercept data used in this analysis.

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