MARINE RECREATIONAL FISHING IN RHODE ISLAND

AUGUST-SEPTEMBER 1978, OCTOBER-NOVEMBER 1978 AND DECEMBER 1978-JANUARY 1979

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NOAA/Sea Grant
University of Rhode Island
Marine Memorandum 62

This publication is the result of research partially sponsored by NOAA Office of Sea Grant, U.S. Department of Commerce, under Grant #04-80M01-147. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon.

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I. Introduction

This paper is the fourth progress report on a study of marine recreational fishing in Rhode Island. The study included two independent surveys, a field survey of anglers and a random telephone survey of households. Both surveys covered the period February 1, 1978 to January 31, 1979. The field survey permits estimates of catch rates by species and individual angler characteristics. The telephone survey uses the random selection of Rhode Island households to estimate participation in salt water angling in Rhode Island.[1]

This report provides descriptive statistics for marine recreational fishing for three sample periods in 1978-1979: August-September, October-November, and December-January. The report estimates aggregate measures of sportfishing catch and effort as well as descriptive statistics for representative anglers during the three periods. Methods for estimation and expansion are presented in Appendix A.

[1] A more complete description of the survey approach can be found in the second progress report, published as "Marine Recreational Fishing in Rhode Island - April and May, 1978," Marine Memorandum Number 56, by the University of Rhode Island Marine Advisory Service, Narragansett, R.I. 02882.

II. Catch and Effort Estimates

The catch and effort estimates are based on stratified samples of fishermen in the field as well as simple random telephone samples of households in Rhode Island. The field survey gathers data which permits estimates of catch by species by mode per trip. The telephone survey permits estimates of the proportion of households participating in marine recreational fishing as well as the mean number of trips by mode of fishing and season per household. Table 1 shows the number of telephone and field interviews by season. The telephone survey contacts only Rhode Island households.

TABLE 1

Interviews of Rhode Island Residents

	Telephone Survey		
Season	Households Contacted	Households Containing Anglers	Field Survey
August-September	2,413	249	761
October-November	1,526	89	815
December-January	506	7	23
			1599

Since the field survey requires that anglers be selected randomly, many out-of-state fishermen are interviewed. Table 1 gives interviews of Rhode Island residents only.

In Table 2 we present estimates of catch and effort for Rhode Island residents fishing in Rhode Island marine waters for the three periods. The participation rate is the proportion of households having at least one finfishing trip during the two-month period. As one would expect, the participation rate declines from 10.3% in August-September to 1.4% in January-February. The estimate of trips per participating household also declines substantially from August-September to January-February. The estimate of total participating households is the product of the participation rate and the U.S. Census Bureau's estimate of 307,000 households residing in Rhode Island. The total trip estimate is the product of the estimate of trips per participating household and total participating households. Naturally the number of total trips per two-month period declines drastically from August-September, the peak fishing season, to January-February, the period with minimum effort. This decline is caused by worsening weather, less daylight, and the decreased availability of fish.

The estimate of the aggregate catch in numbers of fish is the product of total trips and the weighted mean catch per trip. The catch rates and the aggregate number of trips are highest in August-September, resulting in an estimated total catch of 1,287 million fish by Rhode Island residents. The substantial decline in trips from August-September to October-November resulted in a decrease of estimated catch to 454,000 fish.

TABLE 2

Catch and Effort Estimates for Finfishing in Rhode Island by Rhode Island Households; August-September, October-November 1978; and December 1978-January 1979.

Variable	August-September	October-November	December-January
Participation Rate	.103 (.006)[a]	.058 (.006)	.014 (.005)
Trips per Participating Household	8.45 (.80)	6.07 (.98)	1.71 (.42)
Total Participating Households[b]	31,680 (1,901)	17,905 (1,842)	4,247 (1,594)
Total Trips	267,630 (30,048)	108,629 (20,786)	7,279 (3,198)
Catch per Trip Numbers of Fish	4.810 (1.400)	4.180 (.978)	c
Total Catch Numbers of Fish	1,287,300 (398,850)	454,069 (135,751)	c

[a]Parentheses enclose the standard error of the estimate.

[b]Based on the U.S. Census Bureau's estimate of 307,000 households in Rhode Island in 1975.

[c]Estimates of total catch for December-January are available but are not reported due to small sample size. In general, both catch rates and participation are at an annual minimum.

We do not report estimates of total catch for December-January because we encountered very few fishermen who actually caught fish during this period. The resultant small sample size coupled with the poor precision of the catch rate estimates do not allow a meaningful expansion to total catch. The only successful fishing measured by the field survey took place on party boats. However, our phone survey contacted no households who went party boat fishing. Statistically, it is no surprise that no party boat trips were reported on the phone survey. For example, suppose that the true (population) proportion of households engaging in party boat fishing is in the neighborhood of .03% (3 out of 10,000, based on estimates from October-November and February-March). Then the probability of finding no sample households who went on a headboat trip out of a sample of 506 (sample size for December-January) is about 86% (see Cochran, p. 55). The sample size required for reasonably plausible estimates in December-January is enormous, costing much more than it is worth.

Catch by Species

Table 3 gives estimates of total catch and standard errors of total catch by season and species for the nine most important species. Interviewers observed over twenty species of finfish caught during this period. No estimates of total catch are given for December-January for the reasons already stated. Because of the severe weather, short days, and decreased availability of fish, the total catch by species for December-January is negligible compared with other periods.

TABLE 3

Catch by Species in Rhode Island Waters by Rhode Island Households, August-September and October-November[a]

Species	August-September	October-November
Cod	5,889 (2,224)[b]	12,194 (8,006)
Winter Flounder	15,866 (8,671)	166,159 (55,698)
Tautog	122,342 (46,981)	128,420 (56,244)
Mackerel	48,705 (31,956)	39,256 (16,118)
Striped Bass	11,645 (7,000)	891 (398)
Summer Flounder	31,917 (12,170)	3,218 (2,596)
Weakfish	3,179 (1,501)	1,359 (779)
Scup	456,164 (206,612)	24,629 (12,288)
Bluefish	219,156 (61,714)	69,465 (22,815)

[a]Estimates of total catch by species are not made for December-January because of the small telephone and field sample sizes.

[b]Standard errors in parentheses - assuming that the product of two normally distributed variables is approximately normally distributed.

The catch estimates are sums of the estimates by mode of fishing. The modes are:

1) fixed structures,

2) shore,

3) private boats,

4) party boats, and

5) underwater fishing.

Underwater fishing represents only a tiny fraction of catch and effort but was included to assure completeness. The catch by mode is the product of the estimates of catch rate and number of trips by mode. The estimate of the catch rate by mode and by species is computed by dividing the number of fish of a species measured or observed by the number of intercepts from the field for that mode. For the details of all estimates, see the appendix.

For August-September (Table 4), the largest catches were of scup and bluefish. For October-November (Table 5), winter flounder and tautog rebounded to their spring levels.

Catch Rates by Mode of Fishing

The rate of catching fish per unit of time is a valuable piece of information about the success of fishermen. The catch per unit effort (CPUE) is highest for fixed structures in August-September and for private boat fishing for October-November (Table 6). The late summer presence of large numbers of snapper blues explains the high fixed structure CPUE for August-September. In general, unless

TABLE 4

Total Catch by Mode and Species and Total Trips by Mode:
Rhode Island Anglers Only, August-September

Species	Mode			
	Fixed Structure	Shore	Private Boat	Party Boat
Cod	0	0	0	5,889
	-	-	-	(2,224)
Winter Flounder	2,347	12,342	784	393
	(1,231)[a]	(8,539)	(784)	(393)
Tautog	9,566	14,664	98,112	0
	(1,626)	(6,599)	(46,230)	-
Mackerel	40,500	368	7,836	0
	(30,978)	(368)	(7,836)	-
Striped Bass	217	2,025	9,404	0
	(164)	(1,710)	(6,786)	-
Summer Flounder	2,138	0	29,778	0
	(1,532)	-	(12,073)	-
Weakfish	0	828	2,351	0
	-	(600)	(1,376)	-
Scup	26,689	42,787	386,492	196
	(13,043)	(17,848)	(205,426)	(196)
Bluefish	2,927	16,566	184,156	15,508
	(1,414)	(8,844)	(60,519)	(8,117)
Total Trips	25,425	110,799	124,716	6,958
	(9,563)	(21,949)	(17,793)	(1,933)

[a]Standard errors in parentheses.

TABLE 5

Total Catch by Mode and Species and Total Trips by Mode:
Rhode Island Anglers Only, October-November

Species	Mode			
	Fixed Structure	Shore	Private Boat	Party Boat
Cod	0	113 [a]	7,684	4,397
	-	(113)	(7,684)	(2,243)
Winter Flounder	19,942	30,824	115,263	129
	(10,142)	(8,792)	(54,056)	(129)
Tautog	11,286	10,354	105,530	647
	(6,314)	(4,235)	(55,721)	(173)
Mackerel	27,989	10,755	512	0
	(15,223)	(5,270)	(512)	-
Striped Bass	190	600	0	0
	(190)	(335)	-	-
Summer Flounder	0	656	2,561	0
	-	(425)	(2,561)	-
Weakfish	84	762	512	0
	(84)	(581)	(512)	-
Scup	12,345	2,794	8,197	1,293
	(8,730)	(2,638)	(8,197)	(803)
Bluefish	1,217	14,170	50,716	3,363
	(835)	(4,328)	(22,296)	(1,984)
Total Trips	22,160	34,761	49,643	1,847
	(10,687)	(8,499)	(15,530)	(778)

[a] Standard error in parentheses.

there is a strong seasonal influx of a species such as bluefish, the most successful fishing occurs on private boats, as in October-November.

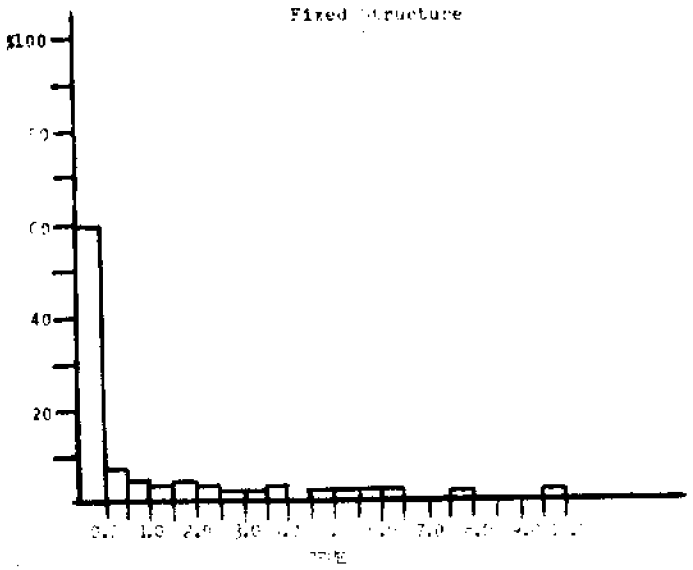
The distribution of the catch rates by mode is perhaps more descriptive of the type of fishing anglers experience than the mean catch rate. The distributions of the CPUE's are given as histograms (Figure 1,2). We have not given histograms for December-January because the CPUE's are all equal or nearly equal to zero. For any season, a substantial proportion of anglers catch nothing. The probability of not catching fish is highest (over 60%) for fixed structure and shore fishing in both seasons. As in the previous seasons, an angler is most likely to catch a fish on a party boat and is most likely to catch many fish on a private boat.

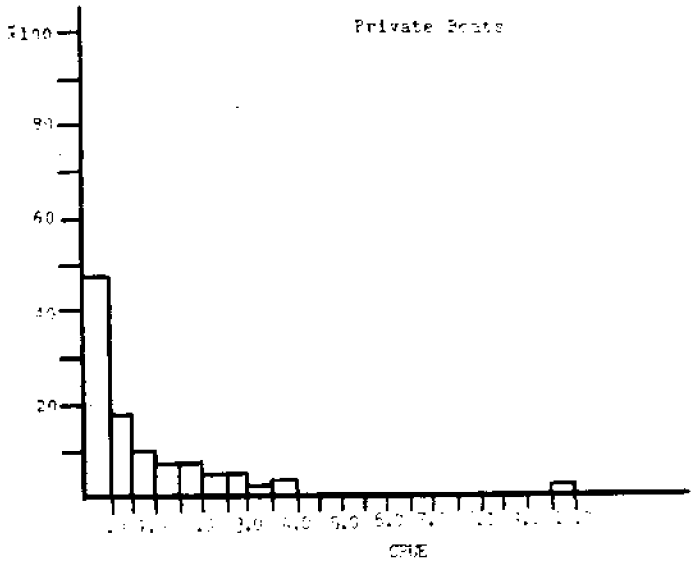
TABLE 6

Number of Fish Caught per Hour (CPUE) of Fishing by Mode, August-September, October-November, and December-January

Mode	August-September	October-November	December-January
Fixed Structure	2.63	1.22	0
	(.53)	(.19)	-
Shore	1.05	.69	0
	(.25)	(.09)	-
Private Boats	1.44	1.36	0
	(.37)	(.29)	-
Party Boats	.92	1.20	.74
	(.34)	(.26)	(.16)

FIGURE 1. August - September





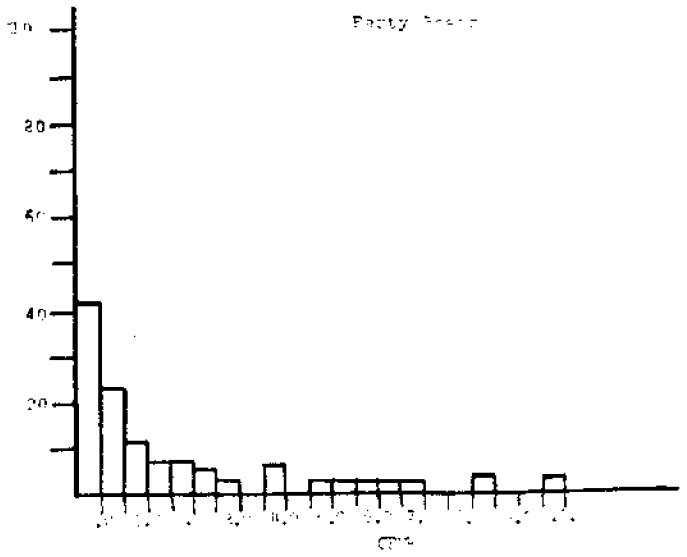
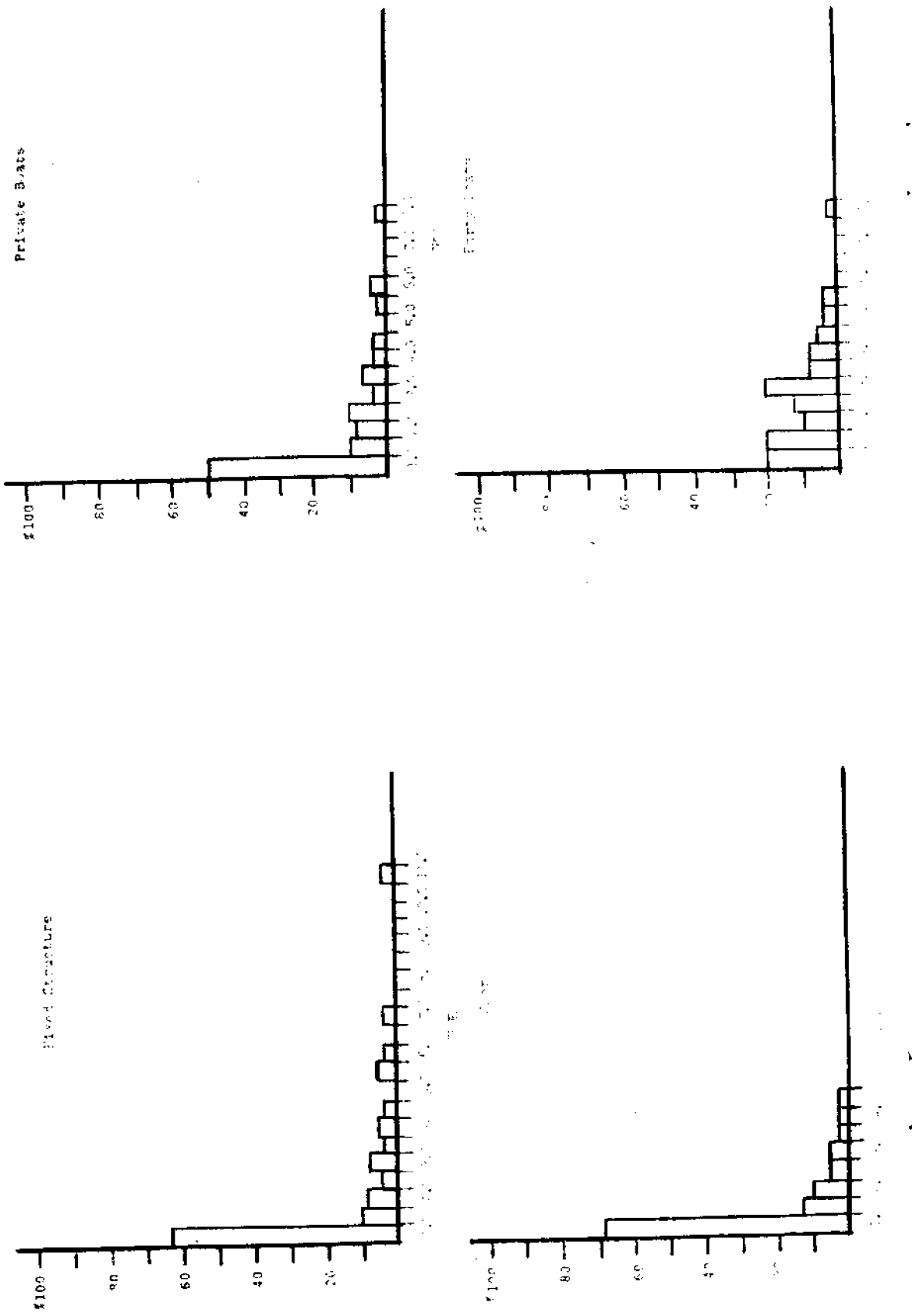


FIGURE 2. October - November



III. Characteristics of Anglers

Weighted means of characteristics of Rhode Island anglers suggest that the typical fisherman in Rhode Island is the same in each of the three sample periods (Table 7). The representative angler has fished about 20 of his 40 years and has a family income of about $17,000. On a typical trip, the angler can expect to catch 1.38 fish per hour in August-September and 1.11 fish per hour in October-November. The cost figures indicate that anglers are less willing to spend on fishing as colder weather arrives.

The number of out-of-state anglers is substantial in Rhode Island (Figure 3). In general, slightly less than one-half of the anglers interviewed in Rhode Island were from out of state. Because of the large number of out-of-state anglers, it is of interest to examine the differences between Rhode Island resident and non-resident anglers. Tables 8, 9 and 10 give characteristics of Rhode Island anglers and of out-of-state anglers by mode for August-September and October-November and December-January.

TABLE 7

Characteristics of Rhode Island Anglers in Rhode Island Marine Waters

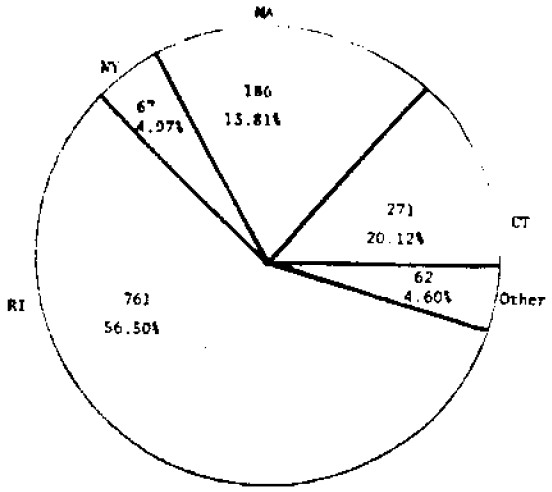
	August-September	October-November	December-January
One Way Distance Travelled per Trip (in miles)	14.75 (.61)[a]	13.9 (.67)	17.6 (3.66)
Age	39.2 (.76)	42.7 (1.02)	42.1 (6.75)
Cost per Trip	$5.22 (.45)	$3.98 (.29)	$ .83 (.46)
Years Fished	19.8 (.74)	21.8 (.94)	19.5 (7.9)
Fish Caught per Hour	1.38 (.21)	1.11 (.14)	b
Family Income	$17,990 (495)	$17,900 (702)	b

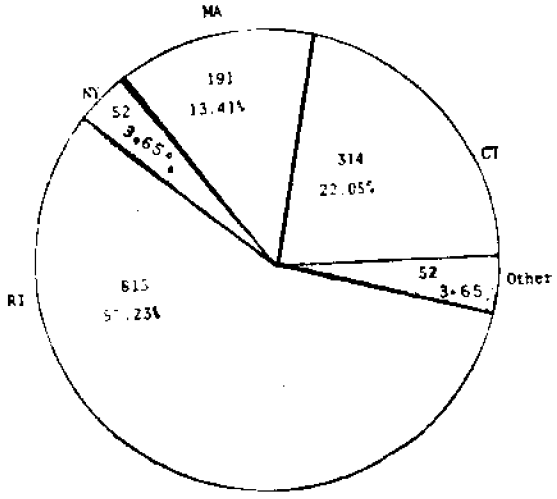
[a]Standard errors in parentheses.

[b]Not estimated.

DISTRIBUTION OF RESIDENCY OF MARINE RECREATIONAL ANGLERS FISHING IN RHODE ISLAND WATERS

AUGUST-SEPTEMBER





OCTOBER-NOVEMBER

DECEMBER-JANUARY

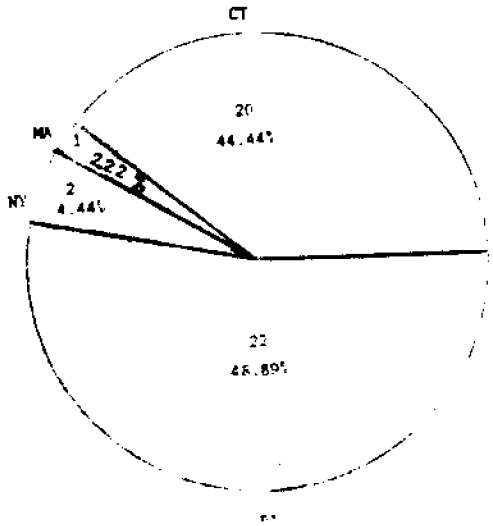


TABLE 8

Anglers' Characteristics: Means by Mode, August-September

Characteristics	Mode: Fixed Structure	Shore	Private Boats	Party Boats
	Rhode Island Anglers			
One-way Distance Travelled, Miles	15.8 (.91)	11.9 (.79)	15.9 (1.23)	35.30 (2.29)
Age	36.8 (1.16)	37.9 (1.15)	40.8 (1.23)	37.3 (2.80)
Cost per Trip	$ 1.93 (.20)	$ 1.69 (.15)	$ 7.93 (.94)	$ 24.74 (2.75)
Years Fished	16.4 (1.1)	18.2 (1.0)	21.9 (1.3)	19.4 (2.7)
Household Income	$ 16,810 (743)	$ 16,530 (620)	$ 19,310 (892)	$ 22,020 (1,744)
Fish Caught per Hour	2.63 (.53)	1.05 (.25)	1.44 (.37)	.92 (.34)
	Out-of-State Anglers			
One Way Distance Travelled, Miles	23.3 (2.65)	34.8 (3.05)	47.3 (4.76)	85.9 (6.3)
Age	39.7 (1.31)	39.9 (1.16)	42.6 (1.5)	39.7 (1.55)
Cost per Trip	$ 1.70 (.16)	$ 3.62 (.45)	$ 6.74 (.83)	$ 29.49 (1.61)
Years Fished	17.4 (1.2)	16.8 (1.0)	19.7 (1.5)	12.5 (1.3)
Household Income	$ 21,320 (912)	$ 18,490 (824)	$ 20,840 (1,409)	$ 21,620 (1,142)
Fish Caught per Hour	1.55 (.29)	.72 (.17)	1.40 (.26)	1.15 (.18)

TABLE 9

Anglers' Characteristics: Means by Mode, October-November

Characteristics	Mode: Fixed Structure	Shore	Private Boats	Party Boats
	Rhode Island Anglers			
One-way Distance Travelled, Miles	14.9 (.91)	12.7 (.68)	13.8 (1.32)	28.4 (2.66)
Age	41.6 (1.36)	44.2 (1.21)	42.7 (1.97)	29.2 (2.88)
Cost per Trip	$ 1.93 (.24)	$ 2.49 (.16)	$ 5.14 (.62)	$ 25.68 (.61)
Years Fished	21.8 (1.4)	21.7 (1.1)	22.2 (1.8)	13.4 (3.6)
Household Income	$ 15,870 (874)	$ 15,240 (592)	$ 20,540 (1,419)	$ 23,150 (3,919)
Fish Caught per Hour	1.22 (.19)	.69 (.09)	1.36 (.29)	1.20 (.26)
	Out-of-State Anglers			
One-way Distance Travelled, Miles	48.2 (4.95)	54.6 (3.6)	77.8 (9.7)	102.2 (7.69)
Age	41.5 (1.48)	42.9 (1.09)	44.6 (2.30)	45.1 (1.83)
Cost per Trip	$ 3.55 (.58)	$ 5.91 (1.00)	$ 9.00 (1.65)	$ 36.34 (3.50)
Years Fished	17.2 (1.4)	17.7 (1.0)	21.4 (2.2)	18.3 (1.7)
Household Income	$ 18,430 (871)	$ 19,350 (857)	$ 19,460 (1,336)	$ 21,250 (1,628)
Fish Caught per Hour	1.42 (.28)	.41 (.06)	.97 (.17)	1.44 (.13)

TABLE 10

Anglers' Characteristics: Means by Mode, December-January[a]

Characteristics	Mode			
	Structure	Shore	Private Boats	Party Boats
Rhode Island Anglers				
One-way Distance Travelled, Miles	24.0 (6.6)	9.0 (3.79)	16.0 (5.4)	15.2 (4.4)
Age	57.5 (12.5)	b	50.0 (14.0)	37.0 (4.4)
Cost per Trip	$ .75 (.24)	$ 1.33 (1.33)	b	$ 18.4 (4.3)
Years Fished	30.0 (15.0)	3.5 (1.5)	20.0 (15.0)	18.3 (4.4)
Household Income	b	b	b	$ 21,500 (2,500)
Fish Caught per Hour	0 -	0 -	0 -	.74 (.16)
Out-of-State Anglers				
One-way Distance Travelled, Miles	- -	- -	- -	107 (10.7)
Age	- -	- -	- -	41.8 (3.03)
Cost per Trip	- -	- -	- -	$ 31.55 (2.30)
Years Fished	- -	- -	- -	26.1 (6.9)
Household Income	- -	- -	- -	$ 23,000 (5,000)
Fish Caught per Hour	- -	- -	- -	1.1 (.15)

[a]Estimates are given for party boat fishing only for out-of-state anglers. All other modes have two or fewer observations in the field sample.

[b]Not estimated ($n \leq 2$).

IV. Conclusion

This report has presented catch and effort estimates for marine recreational fishing in Rhode Island during three two-month periods: August-September and October-November 1978 and December 1978-January 1979. It will be followed by an annual report which will provide further analysis of Rhode Island's marine sportfishing as well as an in-depth economic analysis of recreational fishing in the state.

Acknowledgements

We are indebted both to the hundreds of cooperative anglers, from Rhode Island and from other states, who took the time and effort to answer our questions, and to our excellent interviewers who collected that information. The telephone survey was performed under contract by Human Sciences Research, Inc., McLean, VA (NOAA 047-158-44088). Special thanks to Ken Hansen and Bob Noorigian for their valuable assistance throughout this work.

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[a]Available from: Marine Advisory Service, University of Rhode Island, Narragansett, RI 02882.

APPENDIX A

Estimation of Seasonal Variables

1. Estimates Computed from Telephone Survey Only

Definition of sample measures:

n_1 = number of households contacted by phone.

n_2 = number of households having at least one member who took at least one saltwater finfishing trip in previous two months. (See Table 1 for values of n_1 and n_2 for the three periods of this report.)

t_{ij} = trips to the i^{th} fishing mode by the j^{th} family contacted in the phone survey.

Definition:

p = participation: the proportion of Rhode Island households having at least one finfishing trip in the previous two months.

(1) Estimate of p:

$$\hat{p} = n_2/n_1$$

(2) Estimate of variance of $\hat{p}$:

$$V(\hat{p}) = \hat{p}(1-\hat{p})/n_1$$

where V(.) denotes variance.

Definition:

t_i = mean number of trips in i^{th} mode by participating households.

(3) Estimate of t_i:

$$\hat{t}_i = \sum_{j=1}^{n_1} t_{ij} / n_2$$

(4) Estimate of variance of $\hat{t}_i$:

$$V(\hat{t}_i) = \sum_{j=1}^{n_2} (t_{ij} - \hat{t}_i)^2 / n_2(n_2-1)$$

Definition:

t = mean trips on all modes per participating household.

(5) Estimate of t:

$$\hat{t} = \sum_{i=1}^{m} \sum_{j=1}^{n_1} t_{ij} / n_2 = \sum_{i=1}^{m} \hat{t}_i$$

where m is the number of modes.

(6) Estimate of the variance of $\hat{t}$:

$$V(\hat{t}) = \sum_{j=1}^{n_2} (\sum_{i=1}^{m} t_{ij} - \hat{t})^2 / n_2(n_2 - 1)$$

Definition:

P = total number of participating households in Rhode Island population.

(7) Estimate of P:

$$\hat{P} = \hat{p}H$$

where H is the number of households in Rhode Island as given by the U.S. Bureau of the Census.

(8) Estimate of the variance of P:

$$V(\hat{P}) = V(H\hat{p}) = H^2 V(\hat{p})$$

where $V(\hat{p})$ is given in (2).

Definition:

T_i = total finfishing trips on i^{th} mode by Rhode Island population.

(9) Estimate of T_i:

$$\hat{T}_i = H\hat{p}t_i = H\frac{n_2}{n_1}\sum_{j=1}^{n_2} t_{ij}/n_2 = H \cdot \sum_{j=1}^{n_1} t_{ij}/n_1 = H\hat{t}_{ai}$$

where $\hat{t}_{ai} = \sum_{j=1}^{n_1} t_{ij}/n_1$ is the estimate of mean trips per i^{th} mode for all households (participants and non-participants).

(10) Estimate of the variance of T_i:

$$V(\hat{T}_i) = V(H\hat{t}_{ai}) = H^2V(\hat{t}_{ai})$$

where $V(\hat{t}_{ai})$ denotes the variance of mean trips per i^{th} mode by all households:

$$V(\hat{t}_{ai}) = \sum_{j=1}^{n_1}(t_{ij} - \hat{t}_{ai})^2/n_1(n_1 - 1)$$

Note that the difference between $V(\hat{t}_i)$ in equation 4 and $V(\hat{t}_{ai})$ in equation (10) is that for all households the summation is taken across n_1 rather than n_2.

Definition:

T = total finfishing trips on all modes in Rhode Island by the Rhode Island population.

(11) Estimate of T:

$$\hat{T} = H\hat{p}\hat{t} = (Hn_2/n_1) \cdot \sum_{j=1}^{n_1} \sum_{i=1}^{m} t_{ij}/n_2 = H \sum_{j=1}^{n_1} \sum_{i=1}^{m} t_{ij}/n_1 = H\hat{t}_a$$

where $\hat{t}_a = \sum_{j=1}^{n_1} \sum_{i=1}^{m} t_{ij}/n_1$

(12) Estimate of variance of $\hat{T}$:

$$V(\hat{T}) = V(H\hat{t}_a) = H^2 V(\hat{t}_a)$$

where $V(\hat{t}_a) = \sum_{j=1}^{n_1} (\sum_{i=1}^{m} t_{ij} - \hat{t}_a)^2/n_1(n_1 - 1)$ is the variance of mean trips by all households.

As in (9) and (10), the estimates in (11) and (12) sum over all sampled households, including those who do not participate in marine angling.

II. Variables Estimated from Field Survey Only

Definitions of sample measures:

k_i = number of anglers intercepted on the i^{th} mode during sample period. (See Table 1 for the total values of $(\sum_{i=1}^{m} k_i)$ for the three seasons studied in this report.)

c_{ij}^k = characteristic j on angler k on mode i.

x_{ij}^k = number of fish of species j landed by the k^{th} angler interviewed on the i^{th} mode.

Definition:

x_{ij} = mean number of fish of species j caught per trip on mode i.

(13) Estimate of x_{ij}:

$$\hat{x}_{ij} = \sum_{k=1}^{k_i} x_{ij}^k / k_i$$

(14) Variance of $\hat{x}_{ij}$:

$$V(\hat{x}_{ij}) = \sum_{k=1}^{k_i} (x_{ij}^k - \hat{x}_{ij})^2 / k_i(k_i-1)$$

Definition:

c_{ij} = mean value of j^{th} characteristic for anglers fishing on i^{th} mode.

(15) Estimate of c_{ij}:

$$\hat{c}_{ij} = \sum_{k=1}^{k_i} c_{ij}^k / k_i$$

(16) Variance of c_{ij}:

$$V(\hat{c}_{ij}) = \sum_{k=1}^{k_i} (c_{ij}^k - \hat{c}_{ij})^2 / k_i(k_i - 1)$$

III. Estimates Combining Results of Field and Telephone Surveys

Definition:

X_{ij} = total catch of j^{th} species on i^{th} mode by Rhode Island anglers.

(17) Estimate of X_{ij}:

$$\hat{X}_{ij} = \hat{T}_i \hat{x}_{ij}$$

where $\hat{T}_i$ is given in (9) and $\hat{x}_{ij}$ is given in (13).

(18) Estimate of variance of $\hat{X}_{ij}$:

$$V(\hat{X}_{ij}) = \hat{T}_i^2 V(x_{ij}) + x_{ij}^2 V(\hat{T}_i) - V(x_{ij})V(T_i)$$

This estimator assumes that $\hat{x}_{ij}$ and $\hat{T}_i$ are distributed independently. In the sample sense this is true as the two are estimated from independent surveys. $V(\hat{x}_{ij})$ is found in (14) and $V(\hat{T}_i)$ is found in (10). For a derivation of the sample variance of a product, see Goodman (1960).

Definition:

X_j = total catch of j^{th} species by Rhode Island anglers.

(19) Estimate of X_j:

$$\hat{X}_j = \sum_{i=1}^{m} \hat{X}_{ij} = \sum_{i=1}^{m} \hat{x}_{ij} \hat{T}_i$$

(20) Variance of $\hat{X}_j$:

$$V(\hat{X}_j) = V\left(\sum_{i=1}^{m} \hat{x}_{ij} \hat{T}_i\right) = \sum_{i=1}^{m} V(\hat{x}_{ij} \hat{T}_i) + \sum_{\substack{k=1 \\ k \neq i}}^{m} \sum_{i=1}^{m} C(\hat{x}_{kj} \hat{T}_k, \hat{x}_{ij} \hat{T}_i)$$

$$= \sum_{i=1}^{m} [\hat{x}_{ij} V(\hat{T}_i) + \hat{T}_i^2 V(\hat{x}_{ij}) - V(\hat{T}_i) V(\hat{x}_{ij})] + \sum_{\substack{k=1 \\ k \neq i}}^{m} \sum_{i=1}^{m} \hat{x}_{kj} \hat{x}_{ij} C(\hat{T}_k, \hat{T}_i)$$

where C(.,.) is the covariance of two variables, assuming:

(a) $\hat{x}_{kj}$ and $\hat{x}_{ij}$ to be distributed independently; i.e., the sample mean of the catch rate of the j^{th} species on the i^{th} mode distributed independently of the sample mean of the j^{th} species on the k^{th} mode.

(b) $\hat{T}_i$ and $\hat{x}_{ij}$ to be distributed independently; i.e., the sample estimate of the total trips in the i^{th} mode is distributed independently of the estimate of the catch rate of the j^{th} species in the i^{th} mode.

A close approximation of $V(\hat{X}_j) = V(\sum_{i=1}^{m} \hat{x}_{ij} \hat{T}_i)$ is $\sum_{i=1}^{m} V(\hat{x}_{ij} \hat{T}_i)$, because the covariance terms, $C(\hat{x}_{kj} \hat{T}_k, \hat{x}_{ij} \hat{T}_i)$ are smaller than the variance terms by several orders of magnitude in absolute value.

Definition:

X = total catch of all species in all modes by Rhode Island anglers.

(21) Estimate of X:

$$\hat{X} = \sum_{j=1}^{s} \sum_{i=1}^{m} \hat{X}_{ij} = \sum_{j=1}^{s} \hat{X}_j$$

where s is the number of species landed and $\hat{X}_j$ is from (19).

(22) Estimate of the variance of $\hat{X}$:

$$V(\hat{X}) = V(\sum_{j=1}^{s} \hat{X}_j) = \sum_{j=1}^{s} V(\hat{X}_j)$$

assuming the estimates of the catch by species, $\hat{X}_j$, are independent.

Definition:

c_j = the j^{th} characteristic of Rhode Island anglers (age, years fished, etc.).

(23) Estimate of c_j:

$$\hat{c}_j = \sum_{t=1}^{m} \hat{w}_i \hat{c}_{ij}$$

where the estimator of c_{ij} is given in (15) and w_i is given below.

Definition:

w_i = the proportion of all trips taken on the i^{th} mode by Rhode Island households.

(24) Estimate of w_i:

$$\hat{w}_i = \hat{T}_i / \sum_{j=1}^{m} \hat{T}_j$$

where $\hat{T}(.)$ is defined in (9).

The w_i are distributed multinomially. Consequently $V(\hat{w}_i) = \hat{w}_i(1-\hat{w}_i)/n_2$ and $C(\hat{w}_i,\hat{w}_j) = -\hat{w}_i/\hat{w}_j/n_2$.

(25) Estimate of the variance of $\hat{c}_j$:

$$V(\hat{c}_j) = \sum_{i=1}^{m} [\hat{w}_i^2 V(\hat{c}_{ij}) + \hat{c}_{ij}^2 V(\hat{w}_i) - V(\hat{c}_{ij}) V(\hat{w}_i)]$$

$$+ \sum_{\substack{i=1 \\ i \neq k}}^{m} \sum_{k=1}^{m} \hat{c}_{ij} \hat{c}_{kj} C(\hat{w}_i,\hat{w}_k).$$

The estimator $V(\hat{c}_{ij})$ is given by (16).