Abundance and Distribution of Walleye, Northern Squawfish, and Smallmouth Bass in John Day Reservoir, 1985

ANNUAL PROGRESS REPORT

By

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ABSTRACT

Sampling was conducted from March 24 to September 2 in John Day Reservoir to collect walleye, northern squawfish and smallmouth bass using gill nets, trap nets, boat electrofishers, hook and line and an angler survey. Changes in distributions during sampling were characterized from changes in catch per unit effort (CPUE) in sampling areas. Observed movements of marked and radiotagged fish were examined and used to define discrete populations. Abundances were estimated using a modified Schnabel multiple mark and recapture estimator. Abundance estimates were corrected for angler harvest, size specific vulnerability to gear, recruitment due to growth and tag loss during sampling. Age composition of catch was determined to characterize relative contributions of various year classes to the populations. Ages at which fish were fully recruited to gear were defined by catch curves. Survival of fully recruited year classes was calculated from differences in CPUE's between 1984 and 1985. Mean length at age was estimated and used to determine age specific incremental growth.

A total of 692 walleye, 5,128 northern squawfish and 2,718 smallmouth bass were captured during sampling. Eighty-eight percent of walleye were caught in McNary tailrace or Irrigon-Paterson, whereas 95% of smallmouth bass were caught from Irrigon-Paterson to the John Day forebay. Northern squawfish catches were distributed throughout the reservoir. Walleye and northern squawfish were observed to move throughout the reservoir, whereas movements of smallmouth bass were more localized.

Abundances of walleye and northern squawfish with fork lengths greater than 250 mm and smallmouth bass with fork lengths greater than 200 mm were estimated to be 16,219, 95,407 and 11,259. Anglers harvested an estimated 235 walleye, 2,004 northern squawfish and 4,383 smallmouth bass during the sampling season. Six-year-old walleye, 4-year-old northern squawfish and 3-year-old smallmouth bass were most abundant in catches. Walleye and smallmouth bass were fully recruited to sampling gear by age 3. Age at which northern squawfish were fully recruited was uncertain. Mean survival was 46.1% for walleye and 46.5% for northern squawfish. Mean smallmouth bass survival was 46.5% in the lower and 43.7% in the upper reservoir. Growth of walleye and smallmouth bass has been relatively poor in recent years. Growth of northern squawfish has been stable since 1978.

INTRODUCTION

The goal of this study is to determine the distribution, abundance, and rates of growth and mortality of walleye-(Stizostedion vitreum vitreum), northern squawfish (Ptychocheilus oregonensis and smallmouth bass (Micropterus dolomieui) in John Day Reservoir! This research is part of a cooperative effort with the U.S. Fish and Wildlife Service (USFWS) to estimate the extent of predation on juvenile salmonids. This report summarizes work conducted in 1985, the fourth year of the study. Further background information and a description of the study area can be found in our 1982 (Willis et al. 1985), 1983 (Nigro et al. 1985a) and 1984 (Nigro et al. 1985b) annual reports.

Objectives in 1985 were:

1. Describe distribution and movements of walleye, northern squawfish and smallmouth bass.

2. Estimate abundances of walleye, northern squawfish and smallmouth bass.

   a. Adjust abundance estimates for recruitment because of growth during the time recoveries were made.

   b. Adjust abundance estimates for harvest of marked and unmarked fish by anglers.

3. Determine age composition, growth, survival and year-class strength of walleye, northern squawfish and smallmouth bass.

4. Conceptualize and begin construction of models of the dynamics of walleye, northern squawfish and smallmouth bass populations and the extent of their predation on juvenile salmonids.

Description of modeling efforts requires integration and presentation of results of this study and the USFWS study. As a result, activities addressing objective 4 will be presented in a separate report that will be jointly prepared in 1986 by us (ODFW) and USFWS. The jointly authored report will describe the model in general terms, define state and driving variables for modeling components, identify functional relationships inherent to the model and list sources of data necessary to quantify and evaluate model components. Preliminary estimates of predator abundance and consumption rates will be used to demonstrate how the model will be used to estimate losses of juvenile salmonids to predation.

METHODS AND MATERIALS

Field Sampling

Capture and Handling

Sampling was conducted from March 24 to September 2 (Appendix A, Table A.1) to mark and recapture walleye, northern squawfish and smallmouth bass and describe changes in their relative abundance during sampling. The initial sampling period (Appendix A, Table A.1), however, primarily involved training field crews and the amount of effort and sampling techniques were not similar to subsequent sampling periods. Sampling stations and distribution of effort among stations were unchanged from 1984 in John Day forebay (159) Arlington (156), Irrigon-Paterson (163-151) and McNary tailrace (161) (Nigro et al. 1985b, Figure 1). Additional sampling was conducted in areas between John Day forebay, Arlington and Irrigon-Paterson (Figure 1, Appendix A, Table A.2) to determine whether fish moved freely among areas.

Fish were sampled using gill nets, trap nets, a boat electrofisher and hook and line; methods and gear specifications are described by Willis et al. (1985) and Nigro et al. (1985a,b). Large-mesh (alternating panels of 6.4-cm and 7.6-cm bar mesh) gill nets, used to sample large walleye in 1984, were also used to sample areas of greater velocity and depth in 1985. The anodes used on the electrofishing boat (Nigro et al. 1985a) were replaced in 1985 with two cross-member arrays with four telescoping probes. As in 1984 USFWS provided us with their catch, tagging, recapture and effort data (see Gray et al. 1986 for gear specifications).

Handling and processing of captured fish were unchanged from previous years (Nigro et al. 1985a), except that a right pelvic fin clip was used to recognize fish marked in 1985 that had lost their tags.

Radio Telemetry

Movements of 20 radiotagged walleye (Appendix B, Table B.1) and 23 radiotagged northern squawfish (one transmitter was implanted in a second fish after the first was harvested; Appendix B, Table B.2) were monitored to examine changes in their distributions during sampling and help define areas over which abundance estimates apply. Radio transmitters were surgically implanted in walleye weighing a minimum of 2,800 g and in northern squawfish weighing a minimum of 1,300 g (Nigro et al. 1985b). Transmitters implanted in walleye weighed 51.0 g in air, measured 9.6 cm long by 2.0 cm in diameter, had an expected life of 300 days and transmitted at frequencies ranging from 49.614 to 49.993 MHz. Transmitters implanted in northern squawfish weighed 31.0 g in air, measured 5.7 cm long by 2.0 cm in diameter, had an expected life of 150 days and transmitted at frequencies ranging from 48.184 to 49.799 MHz. Radiotagged fish were located from airplane, boat and shore (Nigro et al. 1985b).

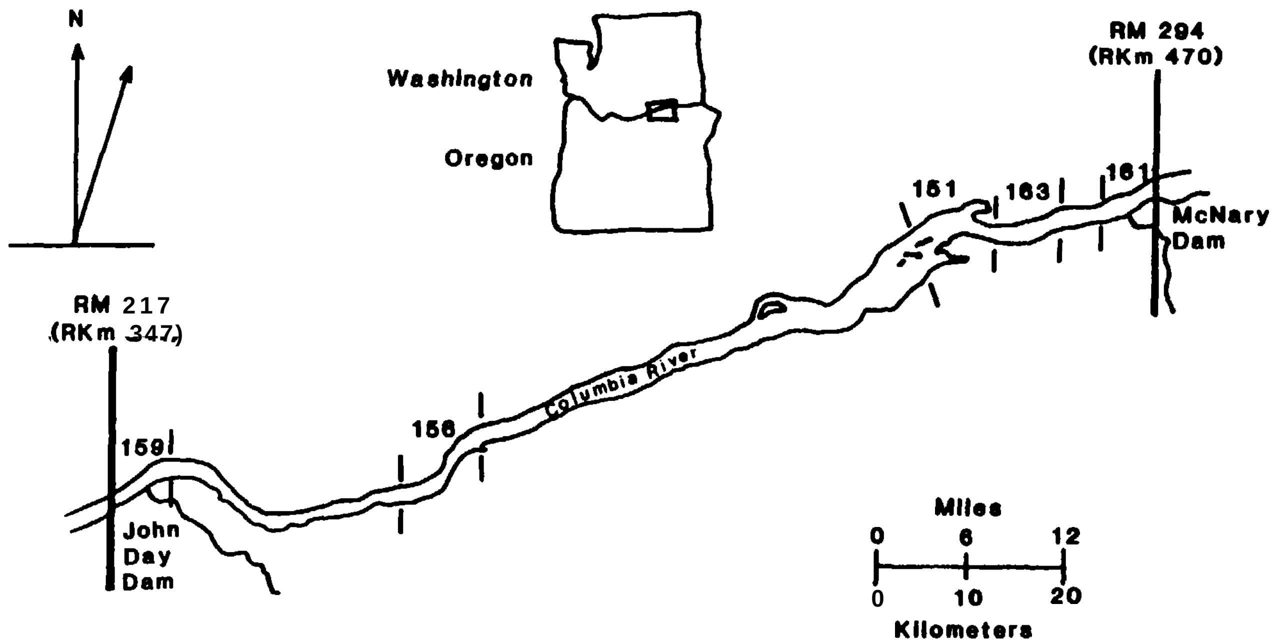

Figure 1. Locations of sampling areas in John Day Reservoir, 1985.

Angler Survey

Anglers were surveyed from April 7 through September 2 between McNary Dam and Paterson, Washington (upper reservoir, Figure 2) and in the John Day forebay and John Day River (lower reservoir, Figure 3) to estimate harvest and recover marked walleye, northern squawfish and smallmouth bass. The John Day forebay and John Day River were included for the first time in 1985 primarily to estimate removals of smallmouth bass from lower reservoir populations.

Anglers were counted on holidays and on two randomly selected weekdays per week (Appendix C, Table C.1). Counts were also made on all weekend days in the upper reservoir and on one randomly selected weekend day per week in the lower reservoir. Anglers fishing the main Columbia River channel in the upper reservoir were counted from the Oregon shore, whereas those fishing in Paterson and Plymouth sloughs were counted from the Washington shore (Figure 2). In the lower reservoir, boat trailers were counted instead of anglers because all anglers could not be observed from shore and access was restricted to a ramp on the John Day River at Lepage Park where complete trailer counts could be made. Counts were made at 2 to 3 hour intervals (Appendix C, Table C.2) beginning randomly at 0600, 0700, 0800 or 0900. Each count was completed in 1/2 to 1-1/2 hours, but was considered instantaneous. Boaters landing at randomly selected ramps and anglers along banks in the vicinity of those ramps were interviewed between counts (Nigro et al. 1985a). Information on species sought, catch and effort (Appendix C, Table C.3) was solicited from anglers.

Laboratory Analysis

Scales collected from walleye, northern squawfish and smallmouth bass from March through June were aged to determine population age structure and age and sex specific growth rates (Nigro et al. 1985b). For each species and population, ten samples per 25-mm fish length interval were randomly selected (when available) to examine population age structure and estimate age specific growth rates. For each sex and length interval, scales were randomly selected (when available) to determine sex specific growth rates. Scales were independently read by two persons using standard techniques (Jearld 1983).

Data Analysis

Distribution and Movements

Catches of walleye, northern squawfish and smallmouth bass were compared among John Day forebay, Arlington, Irrigon-Paterson, McNary tailrace and McNary tailrace boat-restricted zone (BRZ) to determine where each species occurred within the reservoir. Catch per unit effort (CPUE) was compared among sampling periods to discern changes in relative abundance of walleye, northern squawfish and smallmouth bass over time within each sampling area. Comparisons were made by first converting CPUE for each gear to its difference from the mean for all periods divided by the standard deviation over all periods, and then pooling these proportions among gear. Dissimilar effort precluded the use of sampling period 7 in comparing CPUE over time. Areas and time periods for which populations were considered discrete were defined as in 1984 (Nigro et al. 1985b). Movements of individuals within discrete areas and periods were examined by comparing locations where recaptured fish were marked and recaptured, and by observing radiotagged walleye and northern squawfish.

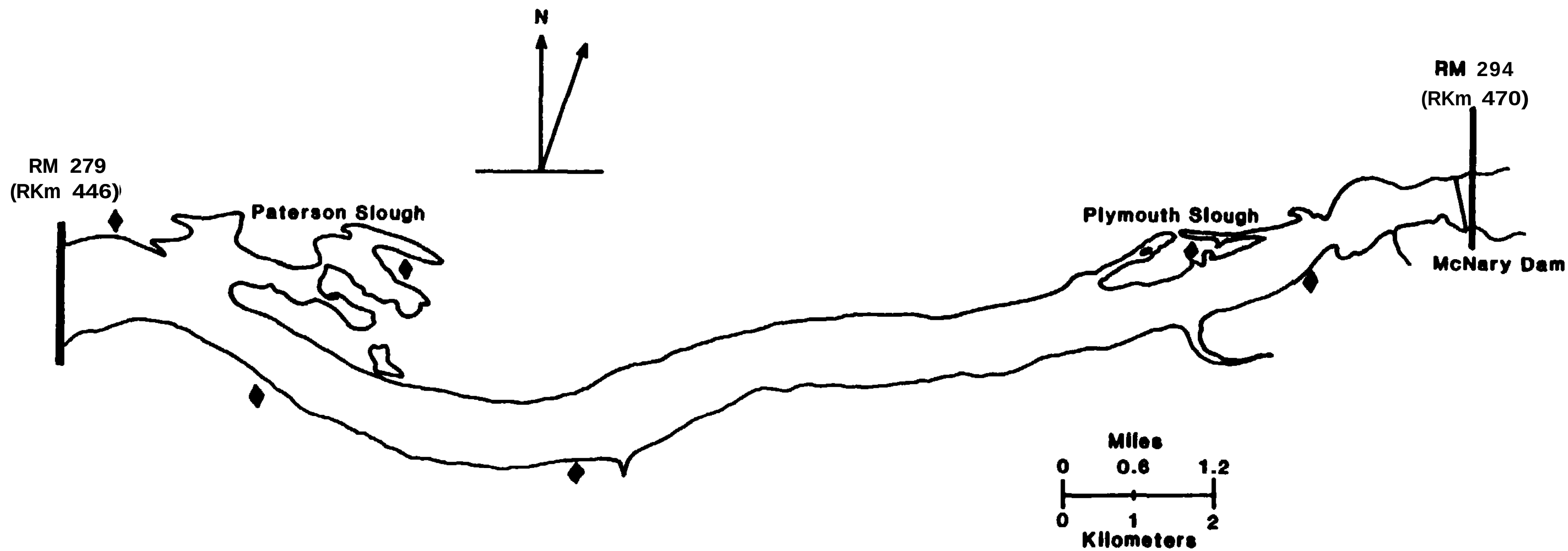

Figure 2. Locations where anglers were interviewed (e) and area where anglers were counted in the upper John Day Reservoir, 1985.

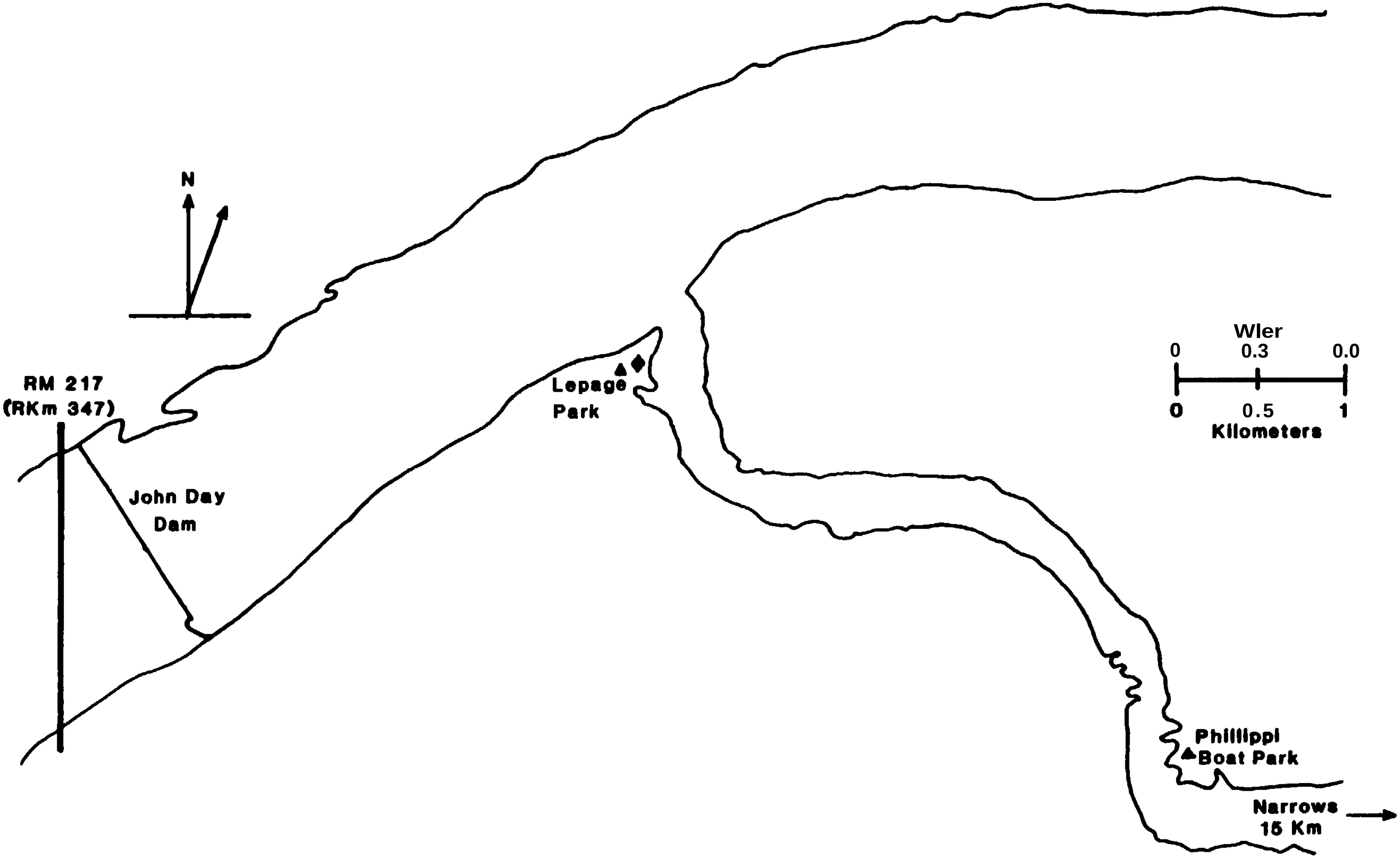

Figure 3. Locations where anglers were interviewed (e) and area where anglers were counted in the lower John Day Reservoir, 1985.

Percent occurrence of radiotagged walleye and northern squawfish in samplable areas (within 50-m of shore) was used to examine biweekly changes in their availability to capture.

Abundance

Abundances of walleye, northern squawfish and smallmouth bass were estimated using a multiple mark and recapture method (Nigro et al. 1985a). Abundance estimates for walleye and northern squawfish were made for the entire reservoir, whereas separate estimates of smallmouth bass abundance were made for the lower (John Day forebay to Willow Creek) and upper (Crow Butte to McNary Dam) reservoir according to observed patterns of movement. Walleye abundance was estimated over the period April 7 through July 6 because catch rates and observed movements indicated that walleye moved out of sampling areas in July. Northern squawfish and smallmouth bass abundances were estimated over the entire sampling season because catch rates and observed movements indicated they remained available to capture throughout the sampling season.

Size specific differences in vulnerability of walleye, northern squawfish and smallmouth bass to our gear were examined by comparing the recapture to at large ratios among size groups. Comparisons were made with a series of Wilcoxon signed-ranks tests (Sokal and Rohlf 1981). Two size groups were compared at a time. Each group contained fish within given length ranges; the first group at or below a given length, the second group above that length. For the initial test, the first group contained fish within 25 mm of the minimum length of fish included in abundance estimates. The second group contained the remainder. For each subsequent test, the length range of the first group was increased by 25 mm, whereas that of the second group was correspondingly decreased. Abundance estimates were made for different size groups when a significant difference between at least one pair of groups was noticed. When significant differences were noted among more than one pair of size groups, separate estimates were made for groups between which the differences were greatest.

Adjustments for recruitment because of growth during sampling were made as in 1983 (Nigro et al. 1985a), except that no adjustments were made for walleye in 1985 because abundance estimates were made over a contracted period. Known removals from populations during sampling were accommodated as in 1983 (Nigro et al. 1985a), except that in 1985 estimates of known removals were also made for the lower reservoir (see Angler Survey). Total angler effort in the lower reservoir was estimated using boat trailer counts (minus the observed number of moored or unoccupied boats) apportioned among user groups (angling or nonangling) based upon proportions observed during interviews.

Tests of the assumption that marked and unmarked fish suffer the same mortality and the apportioning among sampling periods of marked fish recaptured without tags followed approaches used in 1984 (Nigro et al. 1985b).

Age and Growth

Population age composition was estimated as in 1984 (Nigro et al. 1985b). Ages at which walleye, northern squawfish and smallmouth bass were fully recruited to gear were determined by examining catch curves (Ricker 1975). Fork lengths at formation of annuli were backcalculated by sex and year class and were used to estimate mean lengths at various ages (Bagenal and Tesch 1978). Annual variations in age specific growth were examined as percent deviation from the mean (Hile 1941).

Survival and Year-Class Strength

Survival from 1984 to 1985 of fully-recruited year classes of walleye, northern squawfish and smallmouth bass was estimated by comparing catch per unit effort (CPUE) between years (Ricker 1975). Survival of walleye and northern squawfish was estimated from bottom gill-net catches and survival of smallmouth bass from electrofishing catches because those gears comprised the greatest proportion of the catch of each species. Separate estimates of smallmouth bass survival were made for lower and upper reservoir populations. Annual variations in year-class strength were examined as percent deviation from the mean (El-Zarka 1959).

RESULTS

Walleye

Distribution and Movements

Differences in catches among areas indicated that walleye were primarily distributed in the upper reach of John Day Reservoir. Walleye caught in McNary tailrace and Irrigon-Paterson accounted for 88% of those sampled (Figure 4). Distinct seasonal differences in the relative abundance of walleye were observed in Irrigon-Paterson and McNary tailrace but not in Arlington (Figure 5). CPUE peaked in late May in McNary tailrace and early June in Irrigon-Paterson.

Marked walleye released in McNary tailrace and Irrigon-Paterson were often recaptured in areas other than where tagged (Table 1). One half of marked walleye recovered were caught between Irrigon-Paterson and Crow Butte (RKm 420, Table 1, Figure 6).

Distribution of radiotagged walleye released in McNary tailrace changed dramatically during the sampling season. Fish were distributed from McNary tailrace to below Arlington early in the season, but were concentrated between Irrigon-Paterson and Arlington by mid-season (Figure 7). Distances traveled by radiotagged walleye during the sampling season ranged from I4 to II3 km, with a mean of 48.6 km (Table 2). On the average, walleye traveled from 0.4 to 2.5 km/day, but individuals were observed to travel up to 11 km/day. Eighteen of 20 radiotagged walleye entered at least one sampling area from April through August and radiotagged walleye were located more frequently in offshore (>50 m from shore) than nearshore stations as the season progressed (Table 2, Figure 8). Radiotagged walleye were observed near shore less than 45% of the time they were monitored in July and August.

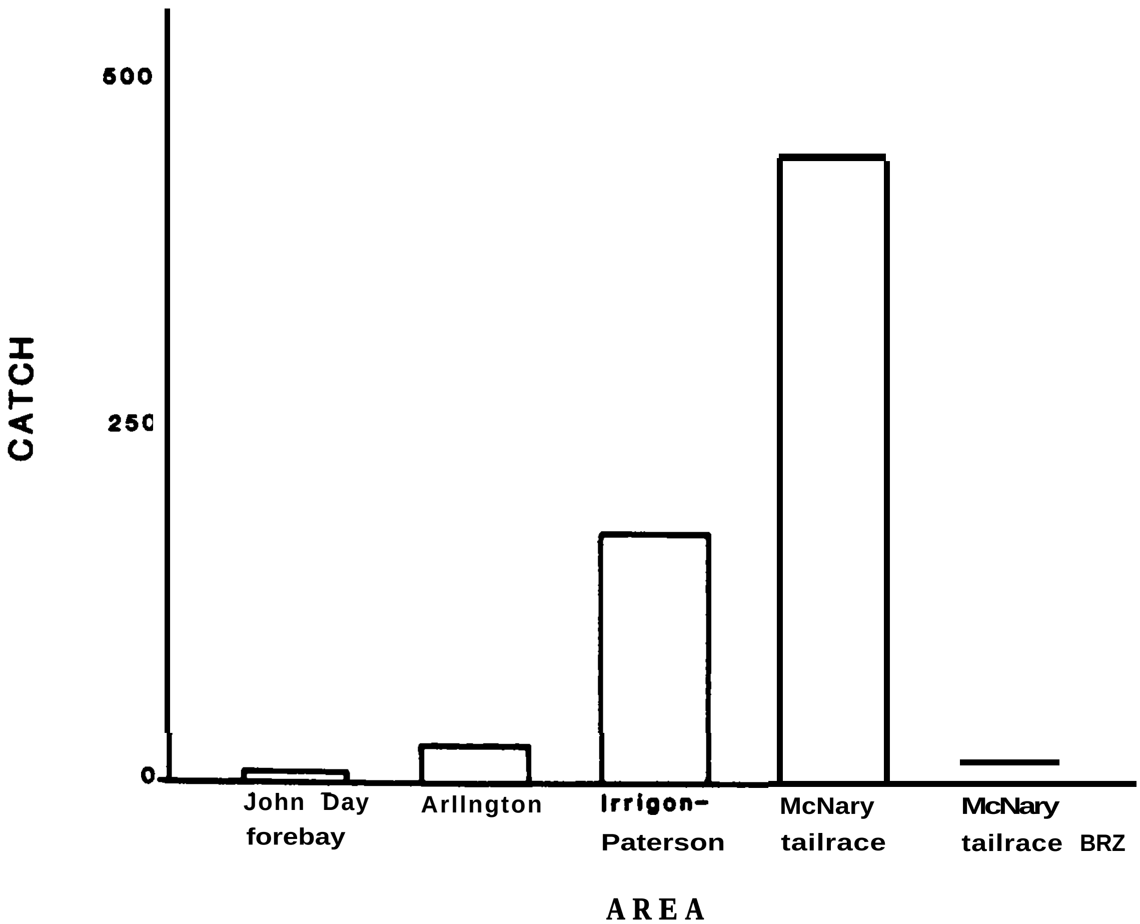

Figure 4. Total catch of walleye by area, all gear combined, John Day Reservoir, March 24-September 2, 1985. BRZ is the boat restricted zone.

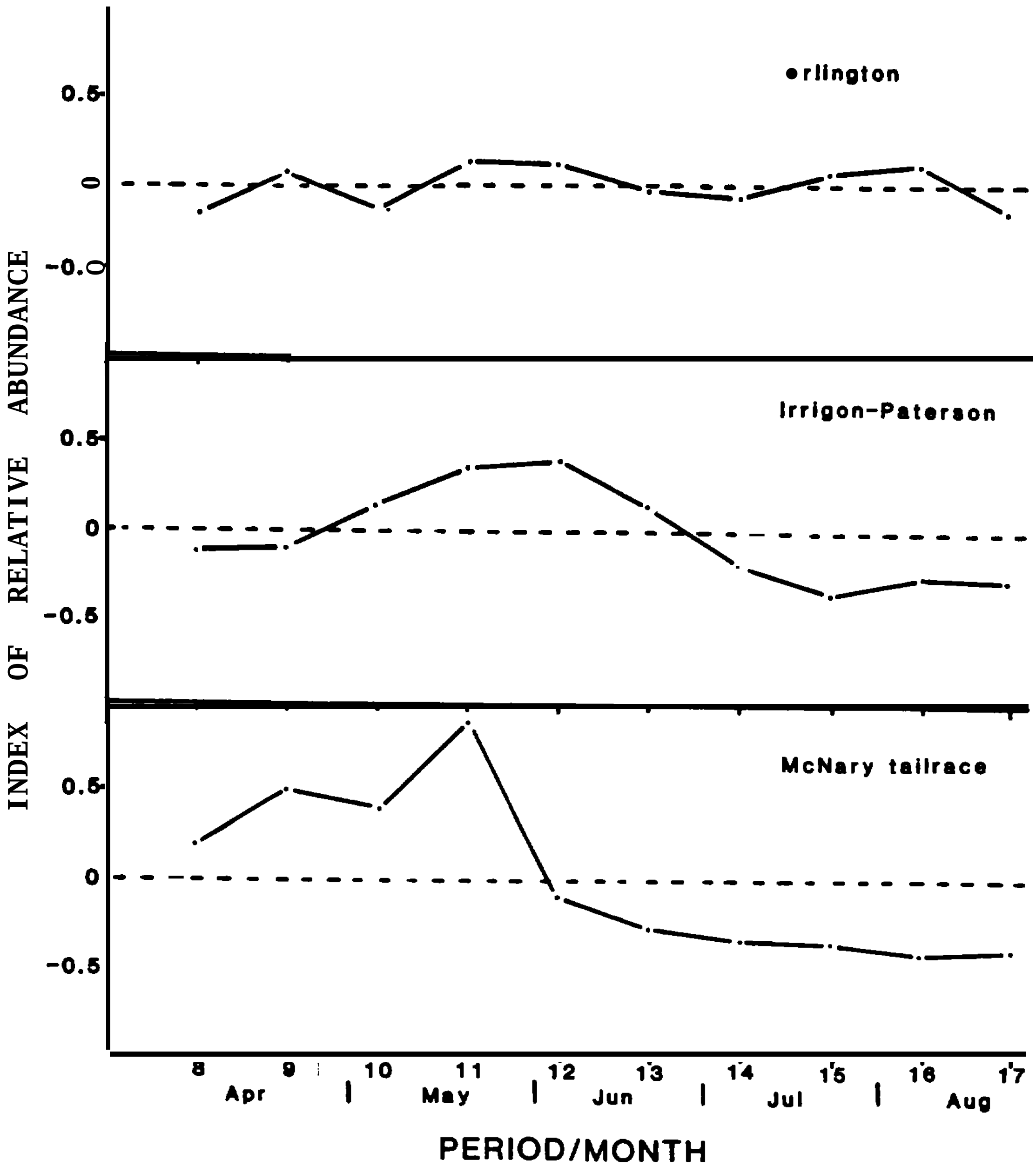

Figure 5. Index of relative abundance of walleye by area, John Day Reservoir, April 7-September 2, 1985. Index is the number of standard deviations from the mean catch per unit effort (CPUE) and is based on the combined CPUE from gill nets, trap nets, and electrofishing.

Table 1. Numbers of marked walleye released and recaptured by area, John Day Reservoir, March 24-September 2, 1985. Numbers in parenthesis are fish recaptured in the same station where released.

Area released	Number released	Area recaptured						
		A	B	C	D	E	F	G
A. John Day forebay	3	0	--	--	--	--	--	--
B. Forebay to Arlington	0	--	0	--	--	--	--	--
C. Arlington	14	--	--	0	--	--	--	--
D. Arlington to Paterson	3	--	--	--	0			--
E. Paterson to Irrigon	125	--	--	--	3	4(3)	1	--
F. McNary tailrace	389	--	--	--	7	--	7(3)	--
G. McNary tailrace BRZ[a]	14	--	--	--	--	--	--	0

[a]Boat restricted zone.

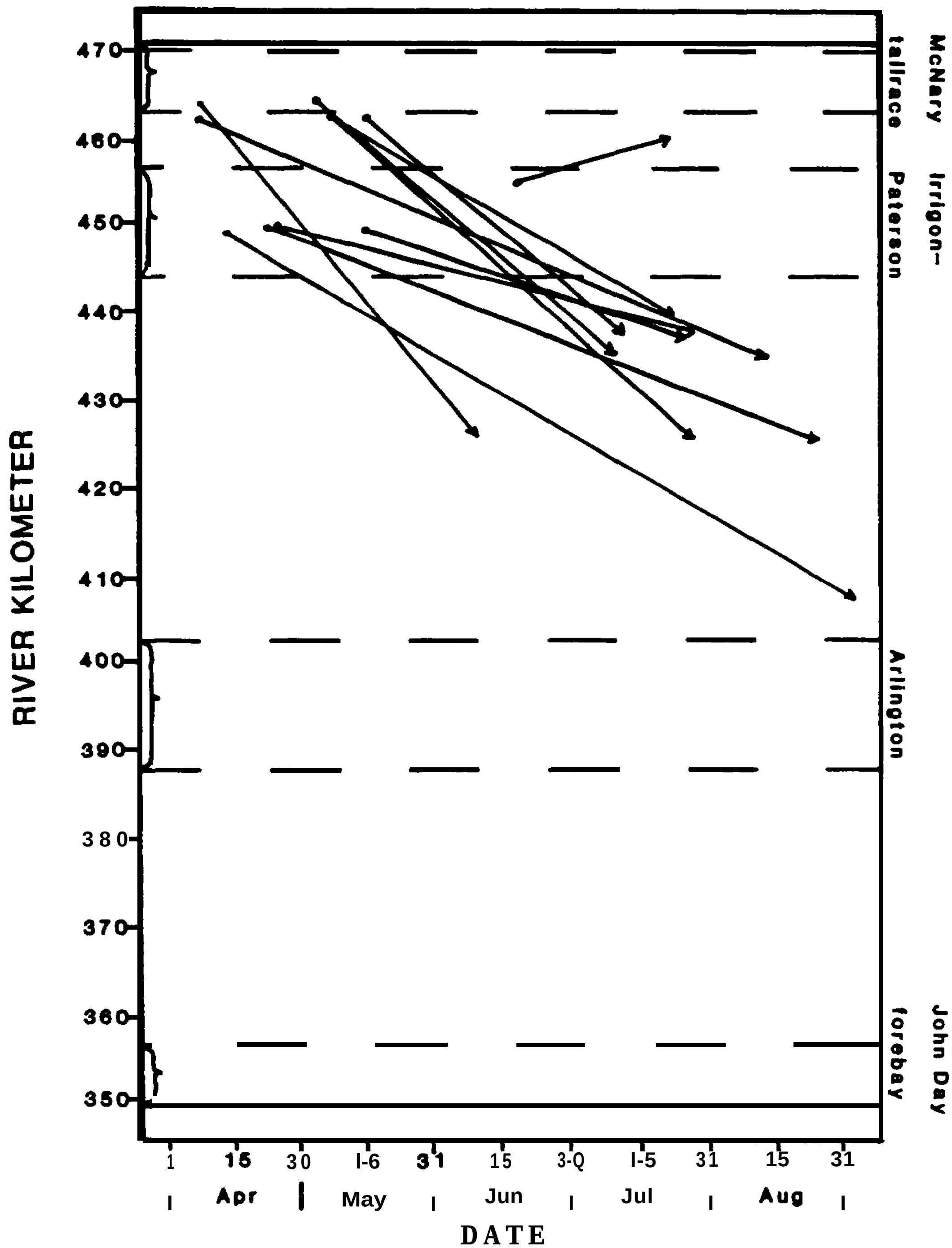

Figure 6. Locations and dates of releases and recoveries of marked walleye recaptured in areas other than where marked, John Day Reservoir, 1985. Areas sampled are indicated by brackets.

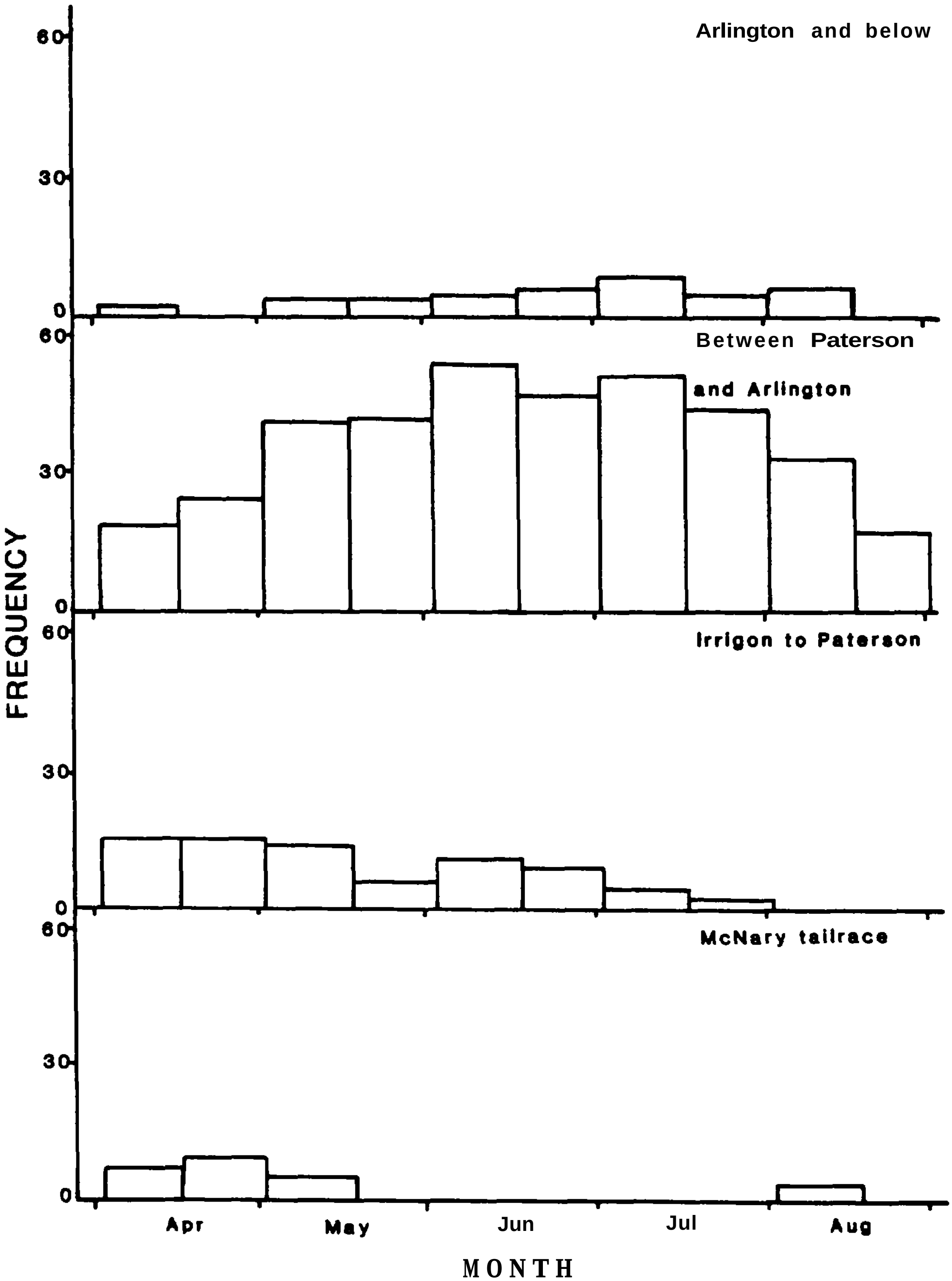

Figure 7. Frequency of observations by area of radiotagged walleye released in McNary tailrace. April 7-September 2. 1985.

Table 2. Movements of twenty radiotagged walleye released in McNary tailrace, John Day Reservoir, April 7-September 2, 1985.

Transmitter frequency (MHz)	Number of observations	Movements per day (km)		Range boundaries (Rkm)		Sampling areas entered
		Mean	Maximum	Lower	Upper	
49.614	13	2.5	6.9	345.3	458.6	3
49.634	27	0.9	8.8	421.1	459.9	1
49.652	35	0.8	3.5	424.5	454.0	1
49.673	33	0.6	3.1	422.5	465.0	2
49.682	24	0.8	3.4	363.6	441.2	1
49.714	5	0.8	2.5	424.8	438.9	0
49.731	28	1.3	7.8	364.9	450.4	2
49.801	34	0.6	6.8	379.7	452.6	2
49.813	10	2.8	9.6	379.2	467.4	3
49.822	22	1.7	6.4	363.9	438.9	1
49.832	27	1.0	11.0	425.7	464.4	2
49.843	29	1.2	5.4	405.5	454.7	1
49.853	32	0.4	2.8	424.8	447.8	1
49.902	27	0.9	9.7	423.0	463.4	2
49.914	14	0.5	1.4	426.4	440.9	0
49.944	34	1.1	7.6	430.4	463.2	2
49.954	16	1.2	4.8	423.5	460.7	1
49.974	36	0.8	5.2	433.6	469.7	2
49.982	34	l:o	4.3	420.3	467.1	2
49.993	34	0.5	4.7	431.9	448.1	1

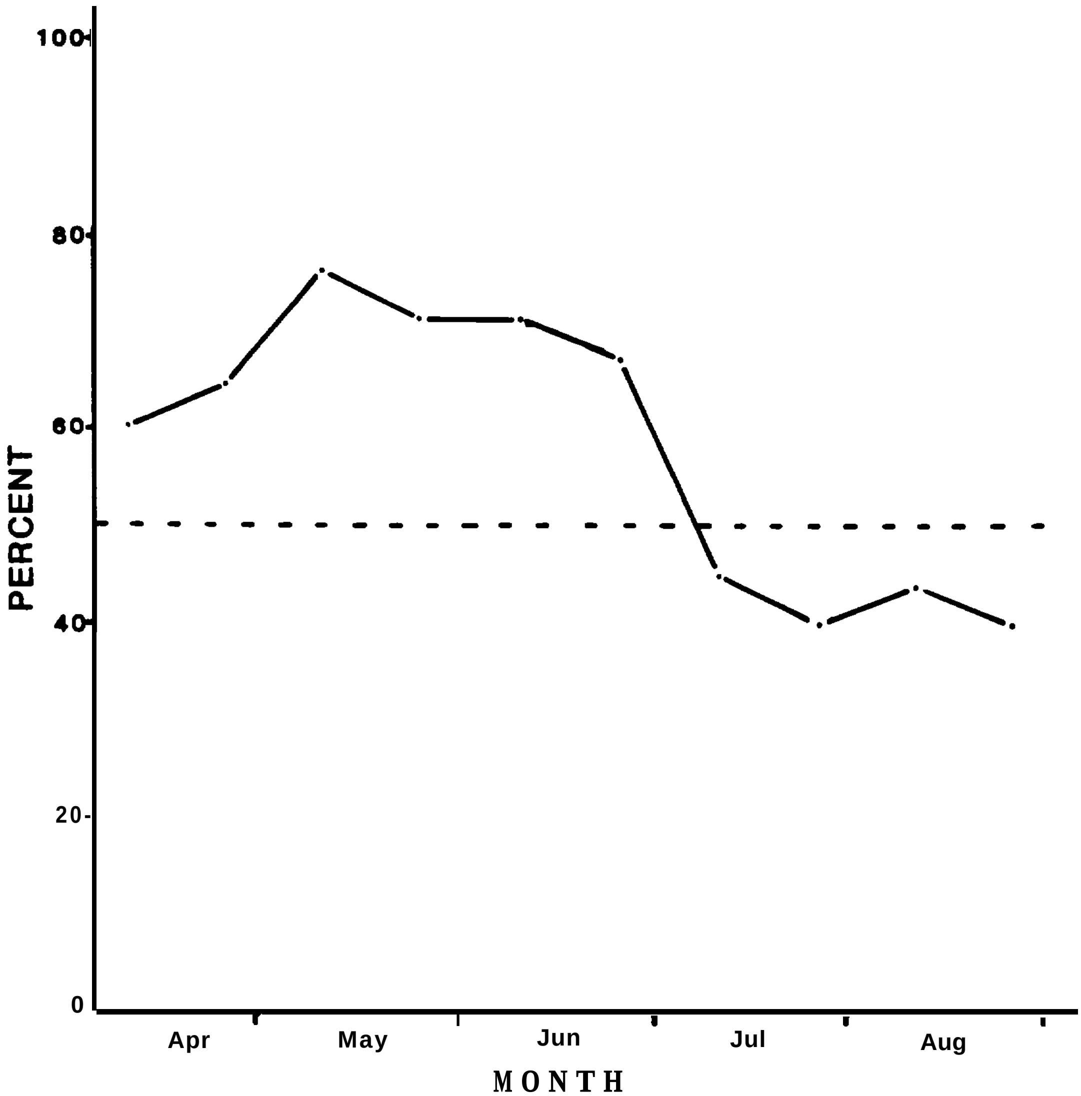

Figure 8. Percent observations of radiotagged walleye in nearshore areas (<50 m from shore), John Day Reservoir, April 7-September 2, 1985.

Abundance

Low numbers of recaptured walleye precluded statistical testing for size specific differences in vulnerability to capture by our gear (ratios of recaptures to marks at large; Figure 9). Most walleye captured had fork lengths greater than 500 mm (Figure 10).

Walleye abundance in the John Day Reservoir was estimated as 16,219 fish with 95% confidence limits of 7,279 and 40,094. Female walleye comprised 37% of sexed fish with fork lengths greater than or equal to 250 mm (n=70). Anglers harvested an estimated 235 walleye from April 7 through September 2 (Table 3), most of which had fork lengths greater than 500 mn (Figure 11). Observed harvest of marked walleye was 1.6 times that of estimated harvest (Table 3).

Survival of marked and unmarked walleye related to capture and handling was not significantly ($p<0.05$) different ($X^2=0.3, df=1, p=0.61$). Three of fourteen walleye recaptured during sampling had lost their tags.

Age and Growth

Most walleye sampled were age 6, but ages ranged from 1 to 12 years (Figure 12). Walleye were fully recruited to sampling gears by age 3 (Figure 13). Mean fork lengths of female walleye were greater than those of males of the same age (Figure 14). Growth of walleye aged greater than 1 was relatively poor in 1981, but has since improved (Figure 15).

Survival and Year-Class Strength

Age specific survival of walleye from 1984 to 1985 averaged 46.1% (Table 4). Walleye year-class strength was greatest in 1979, but has since been much less (Figure 16).

Northern Squawfish

Distribution and Movements

Comparisons of catches among areas indicated that northern squawfish were distributed throughout John Day Reservoir (Figure 17). Seasonal differences in relative abundance of northern squawfish were observed in Irrigon-Paterson, McNary tailrace and McNary tailrace BRZ, but not in John Day forebay or Arlington (Figure 18). CPUE was below average in Irrigon-Paterson and McNary tailrace in late July and August and was below average in McNary tailrace BRZ in April. Thirty-two percent of marked northern squawfish recaptured were taken in areas other than where tagged (Table 5, Figure 19).

Radiotagged northern squawfish released in McNary tailrace and John Day forebay ranged throughout the reservoir during the sampling season (Figure 20). Maximum distances traveled by radiotagged northern squawfish ranged from 0.5 to 122.9 km, with means of 35.1 km in the upper reservoir and 17.6 km in the lower reservoir (Table 6). Mean distance traveled per day was as great as 1.9 km, but individuals were observed to travel over 13 km/day. All radiotagged northern squawfish entered at least one sampling area from April

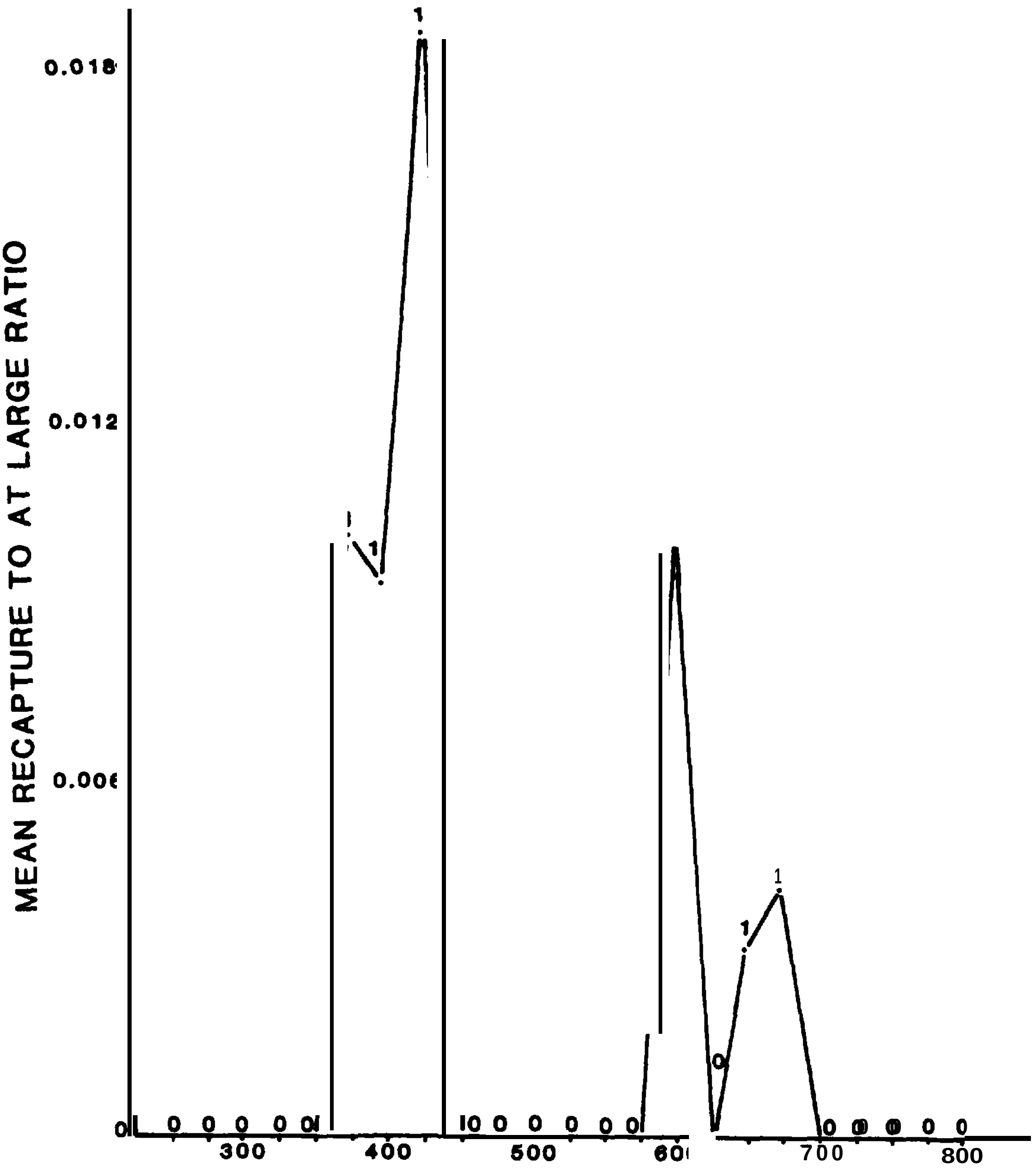

Figure 9. Ratios of recaptures to marks at large (vulnerability) for walleye by length interval, John Day Reservoir, April 7-July 6, 1985. Number of recaptures within a length interval is above each point.

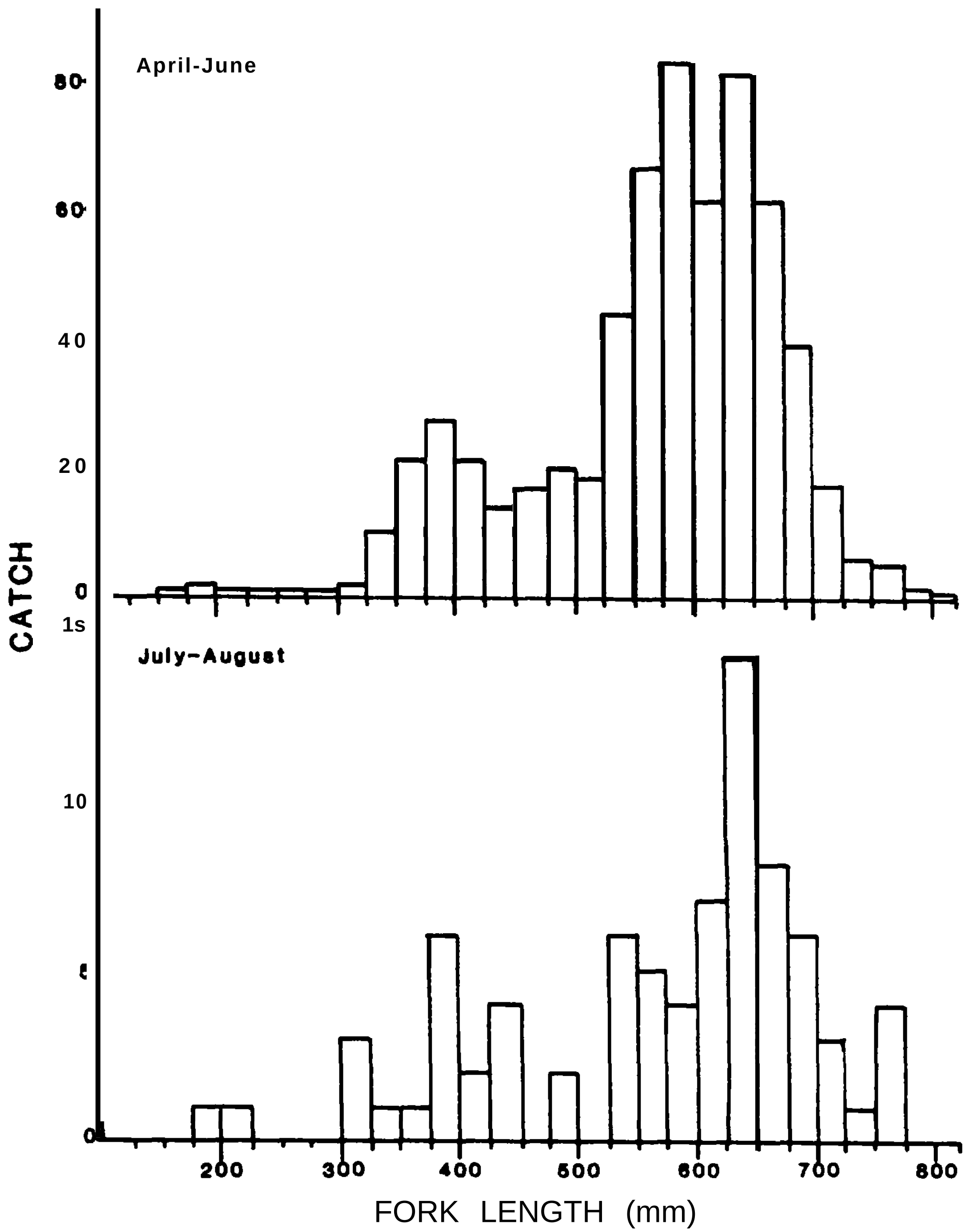

Figure 10. Length-frequency distributions of walleye collected in John Day Reservoir, 1985.

Table 3. Estimated and observed numbers[a] of unmarked and marked walleye harvested by anglers, John Day Reservoir, April 7-September 2, 1985.

Area Status	Period 8	9	10	11	12	13	14	15	16	17	Sum
Lower reservoir											
Unmarked											
Estimated	0	0	0	0	0	0	0	0	0	0	0
Observed	0	0	0	0	0	0	0	0	0	0	0
Marked											
Estimated	0	0	0	0	0	0	0	0	0	0	0
Observed	0	0	0	0	0	0	0	0	0	0	0
Upper reservoir											
Unmarked											
Estimated	28	0	0	18	0	9	51	22	7	92	227
Observed, interviews	5	0	0	2	0	1	10	4	5	16	43
Observed, voluntary[b,c]	0	0	0	0	0	2	2	3	0	4	11
Marked											
Estimated	0	0	0	0	0	0	0	0	2	6	8
Observed, interviews	0	0	0	0	0	0	0	0	1	1	2
Observed, voluntary[b]	0	0	0	0	1	0	3	4	1	2	11

[a] Includes fish >250 mm fork length.
[b] Includes areas outside those in which anglers surveyed.
[c] Recaptures of fish tagged in previous years.

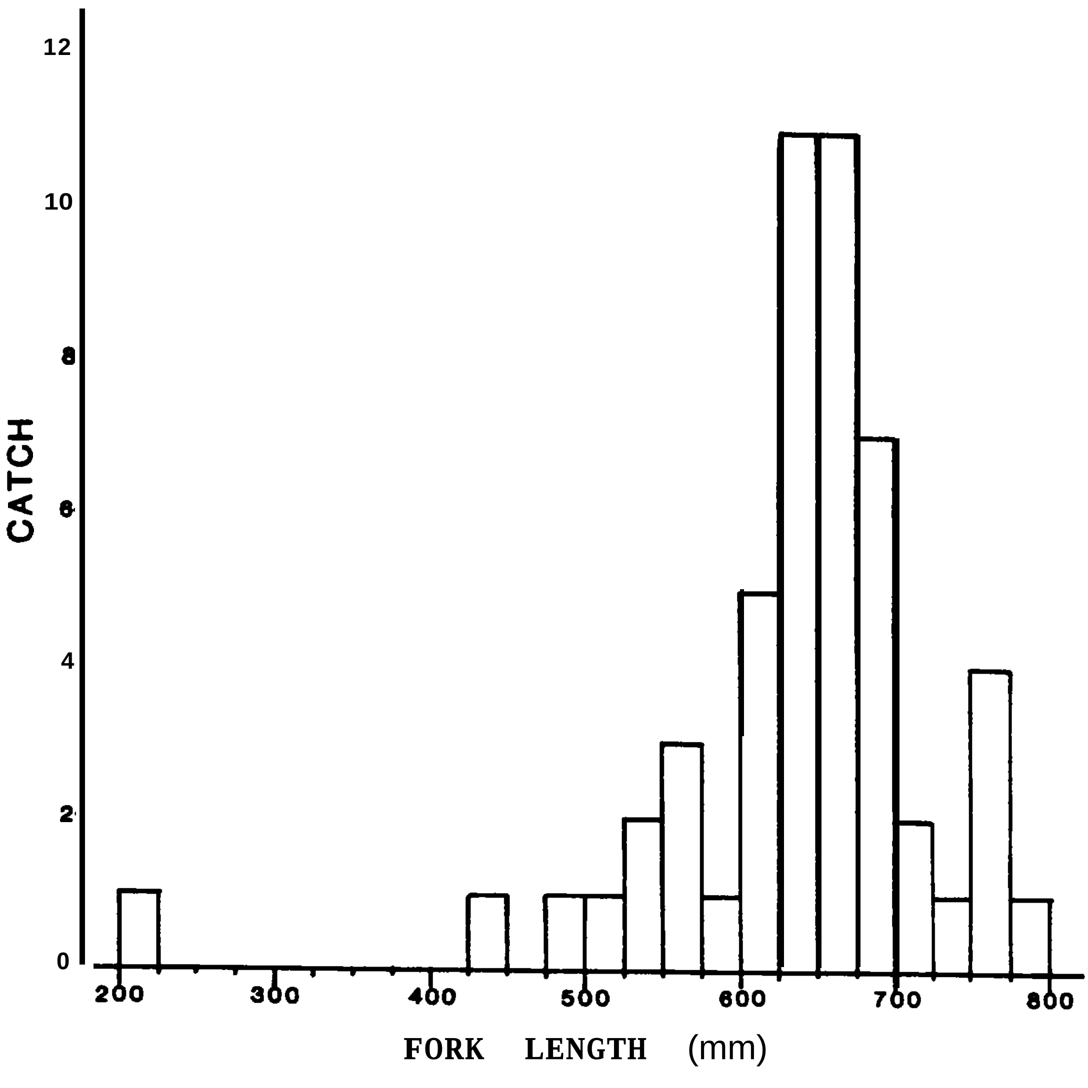

Figure 11. Length-frequency distribution of walleye harvested by anglers, upper John Day Reservoir, April 7-September 2, 1985.

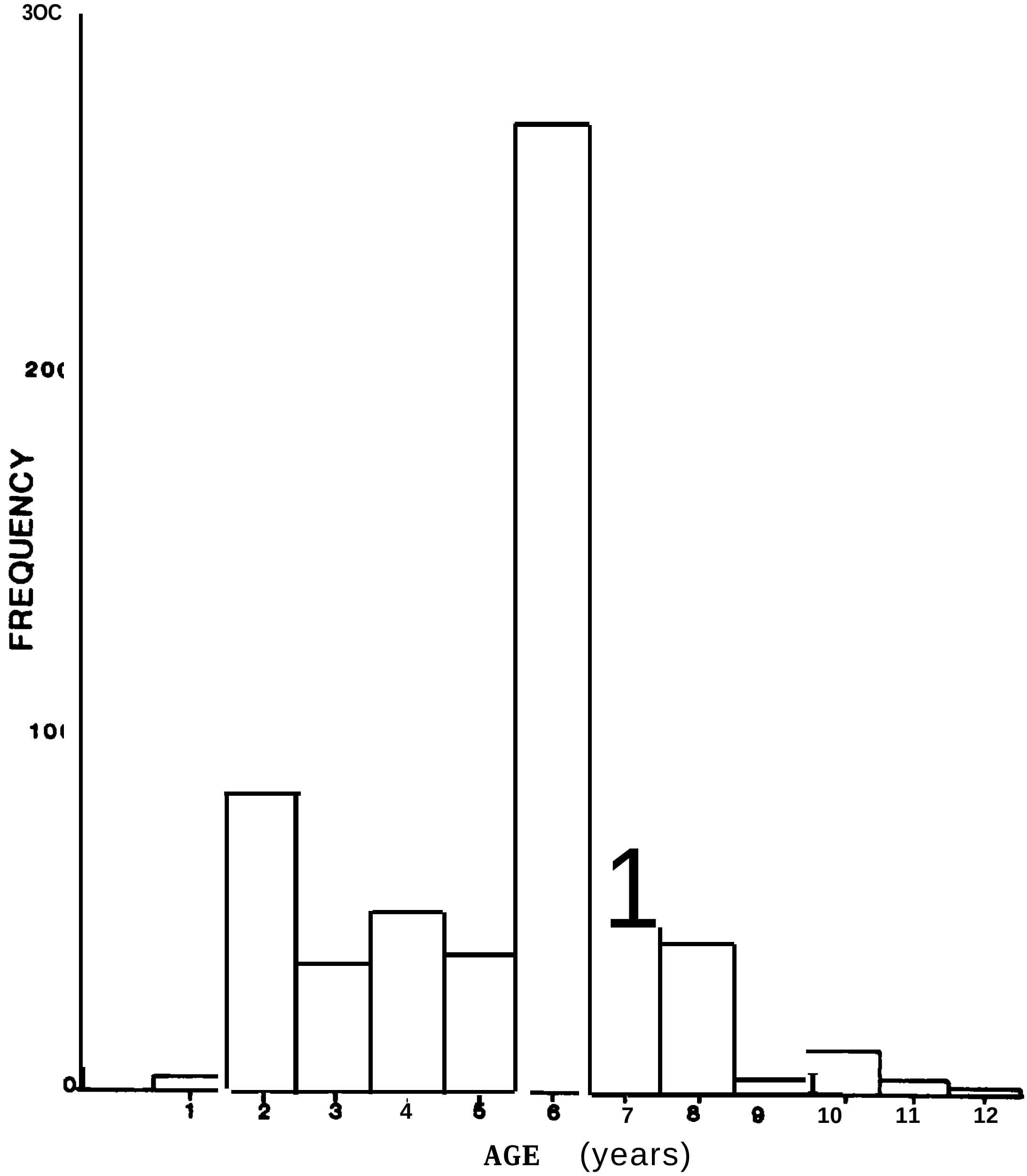

Figure 12. Estimated age-frequency distribution of walleye, John Day Reservoir, March 24-June 30, 1985.

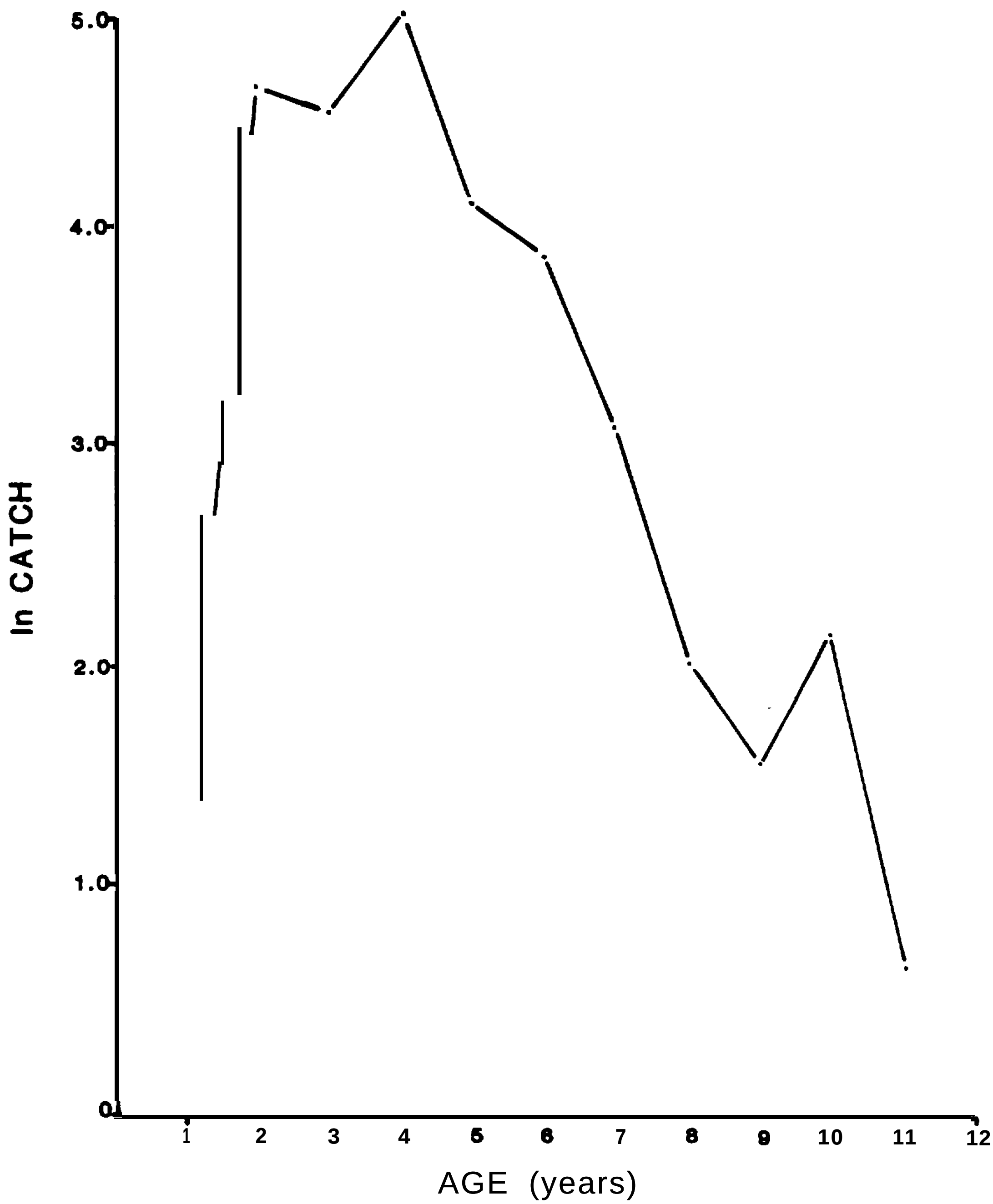

Figure 13. Catch curve for walleye caught by bottom gill nets, John Day Reservoir, March-June 1983-1985.

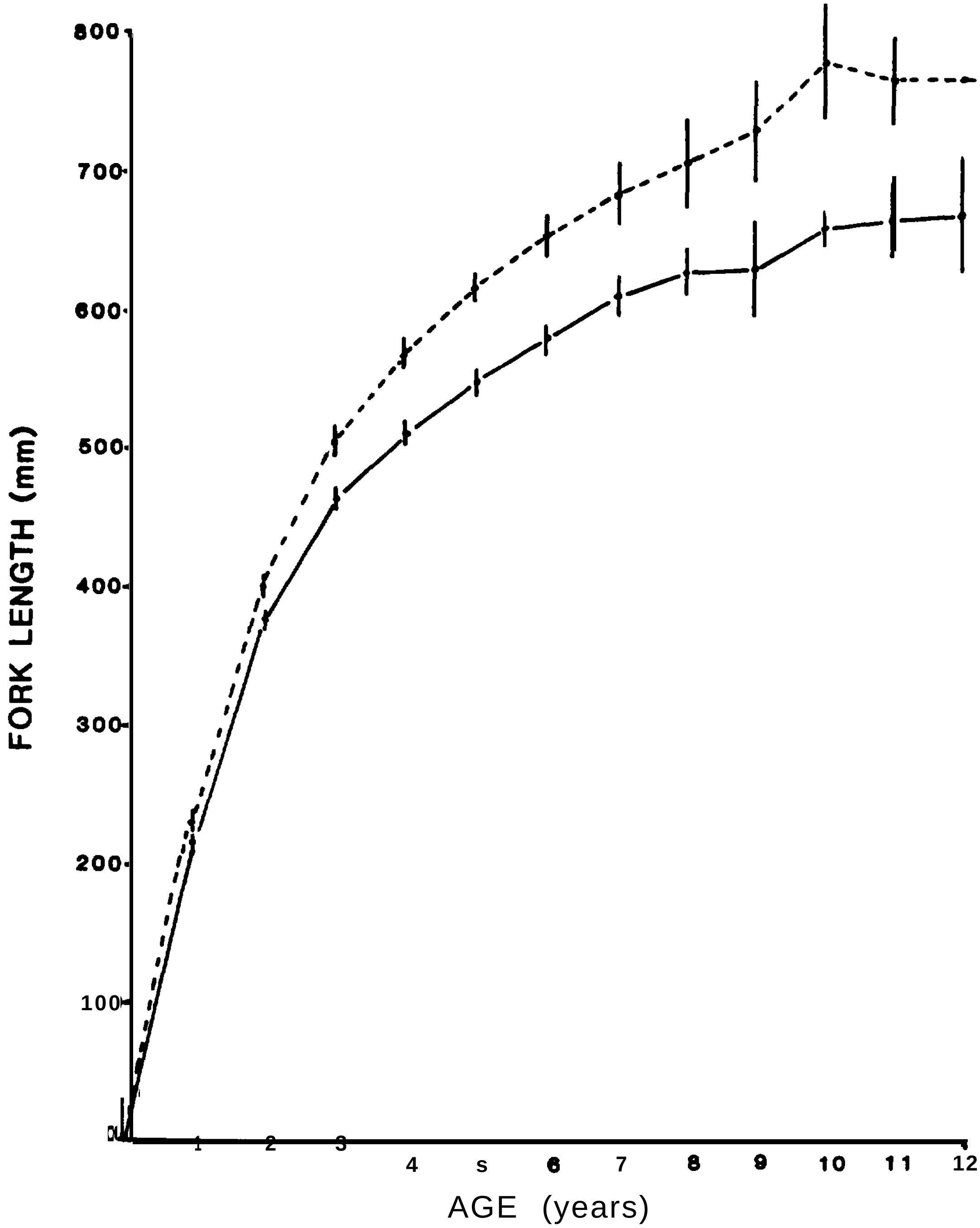

Figure 14. Mean backcalculated fork lengths and 95% confidence intervals (vertical bars) for male (—) and female (--) walleye, John Day Reservoir, 1983-1985.

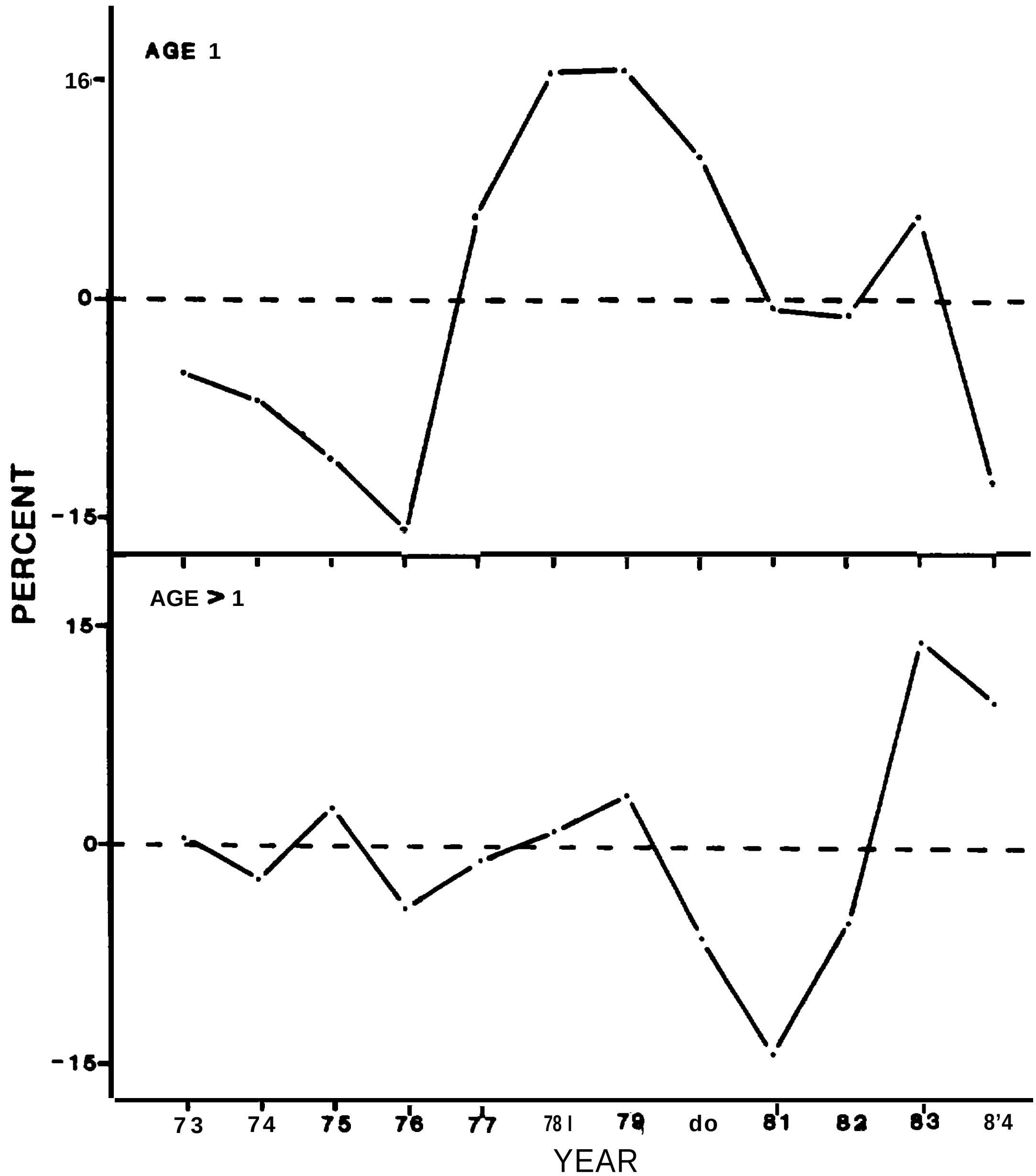

Figure 15. Relative growth (percent deviation from mean) of walleye by age group, John Day Reservoir, 1973-1984. Age >1 includes age groups 2-12.

Table 4. Estimates of walleye survival (S) from catch per unit effort differences (bottom gill-net catches only) between 1984 and 1985, John Day Reservoir.

Year class	Age	S
1982	2-3	0.543
1981	3-4	0.425
1980	4-5	0.185
1979	5-6	0.519
1978	6-7	0.596
1977	7-8	0.333
1976	8-9	0.000
1975	9-10	1.000
1974	10-11	0.000
Geometric mean		0.461

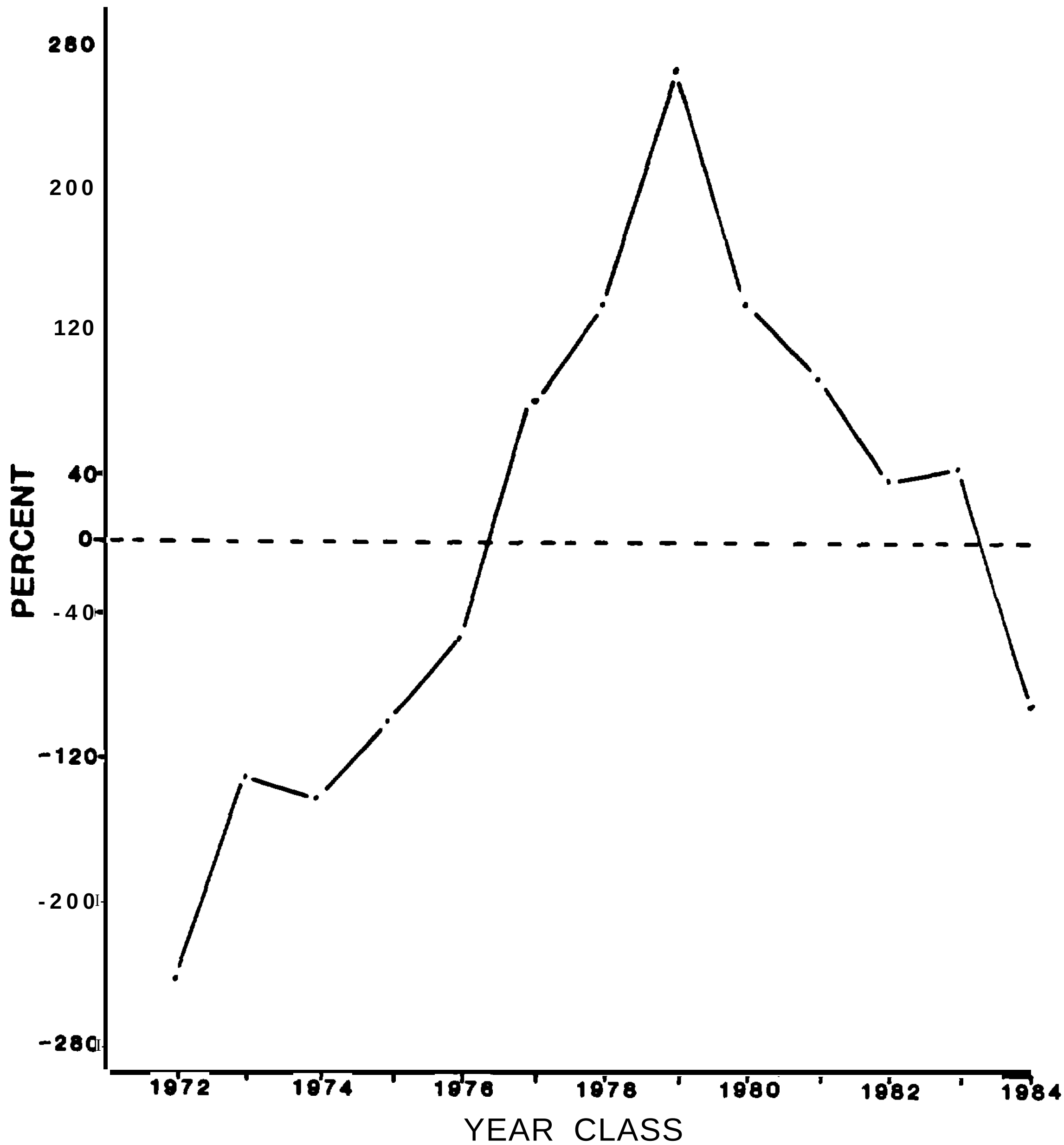

Figure 16. Relative year-class strength (percent deviation from mean) of walleye, John Day Reservoir, 1972-1984.

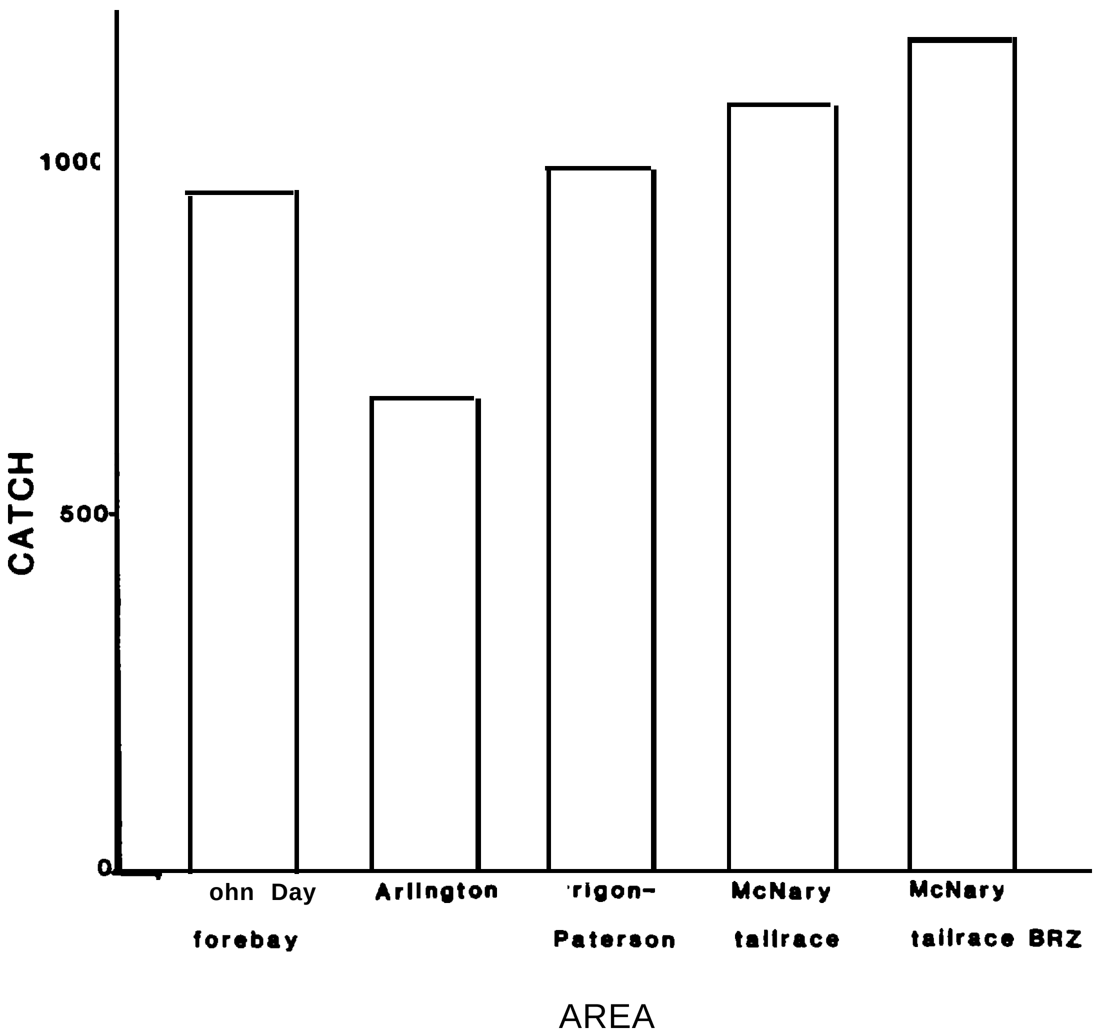

Figure 17. Total catch of northern squawfish by area, all gear combined, John Day Reservoir, March 24-September 2, 1985. BRZ is the boat restricted zone.

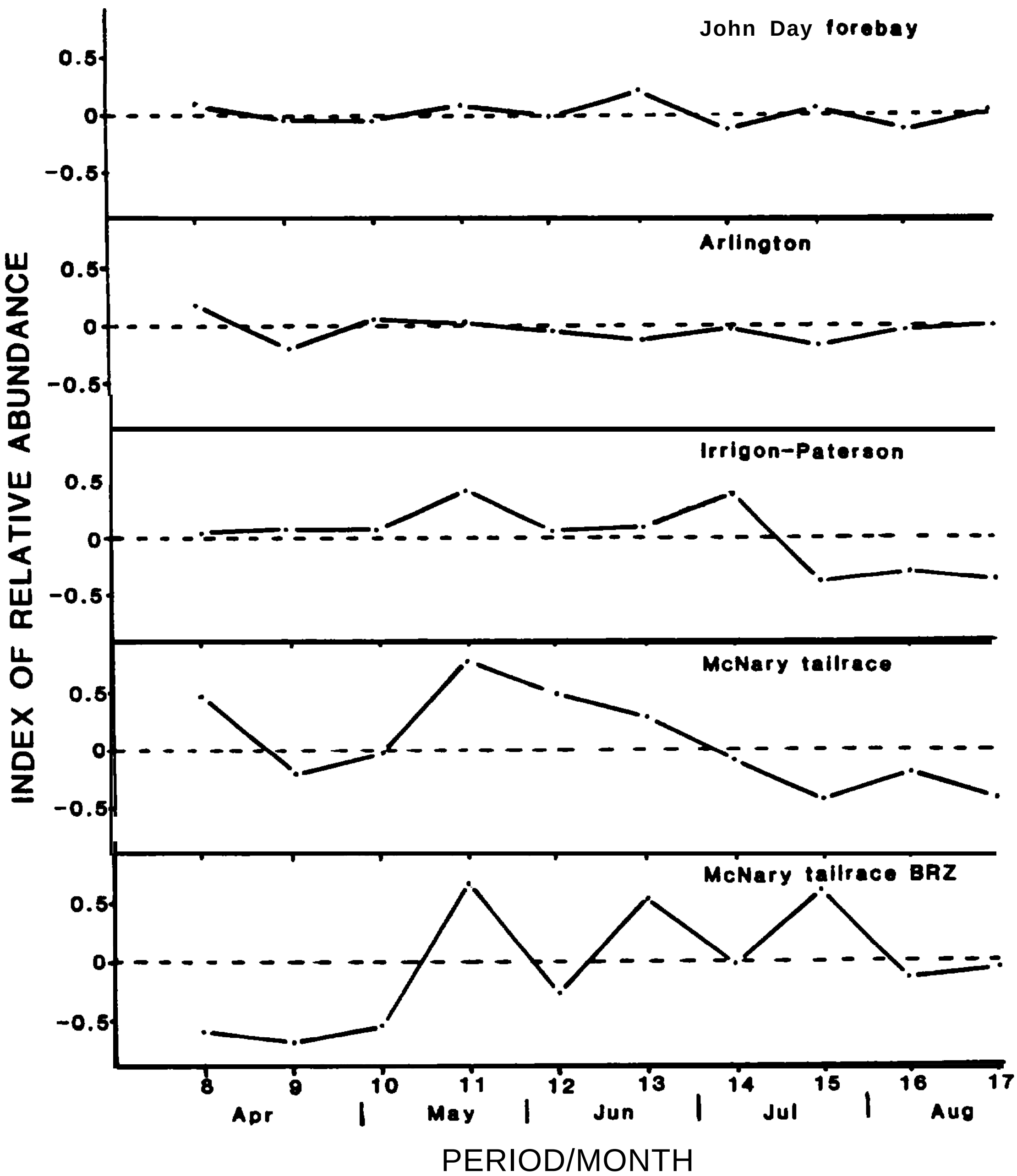

Figure 18. Index of relative abundance of northern squawfish by area, John Day Reservoir, April 7-September 2, 1985. Index is the number of standard deviations from the mean catch per unit effort (CPUE) and is based on the combined CPUE from gill nets, trap nets, electrofishing, and dam angling. BRZ is the boat restricted zone.

Table 5. Numbers of marked northern squawfish released and recaptured by area, John Day Reservoir, March 24-September 2, 1985. Numbers in parentheses are fish recaptured in the same station released.

Area released	Number released	Area recaptured						
		A	B	C	D	E	F	G
A. John Day forebay	554	16(4)	--	2	--	--	--	--
B. Forebay to Arlington	0	--	0	--	--	--	--	--
C. Arlington	346	4	1	8(1)	--	1	--	--
D. Arlington to Paterson	6	--	--	--	0	--	--	--
E. Paterson to Irrigon	478	1	--	--	1	8	--	2
F. McNary tailrace	592	--	--	--	--	4	11(2)	4
G. McNary tailrace BRZ[a]	586	--	--	1	--	--	7	17(16)

[a]Boat restricted zone.

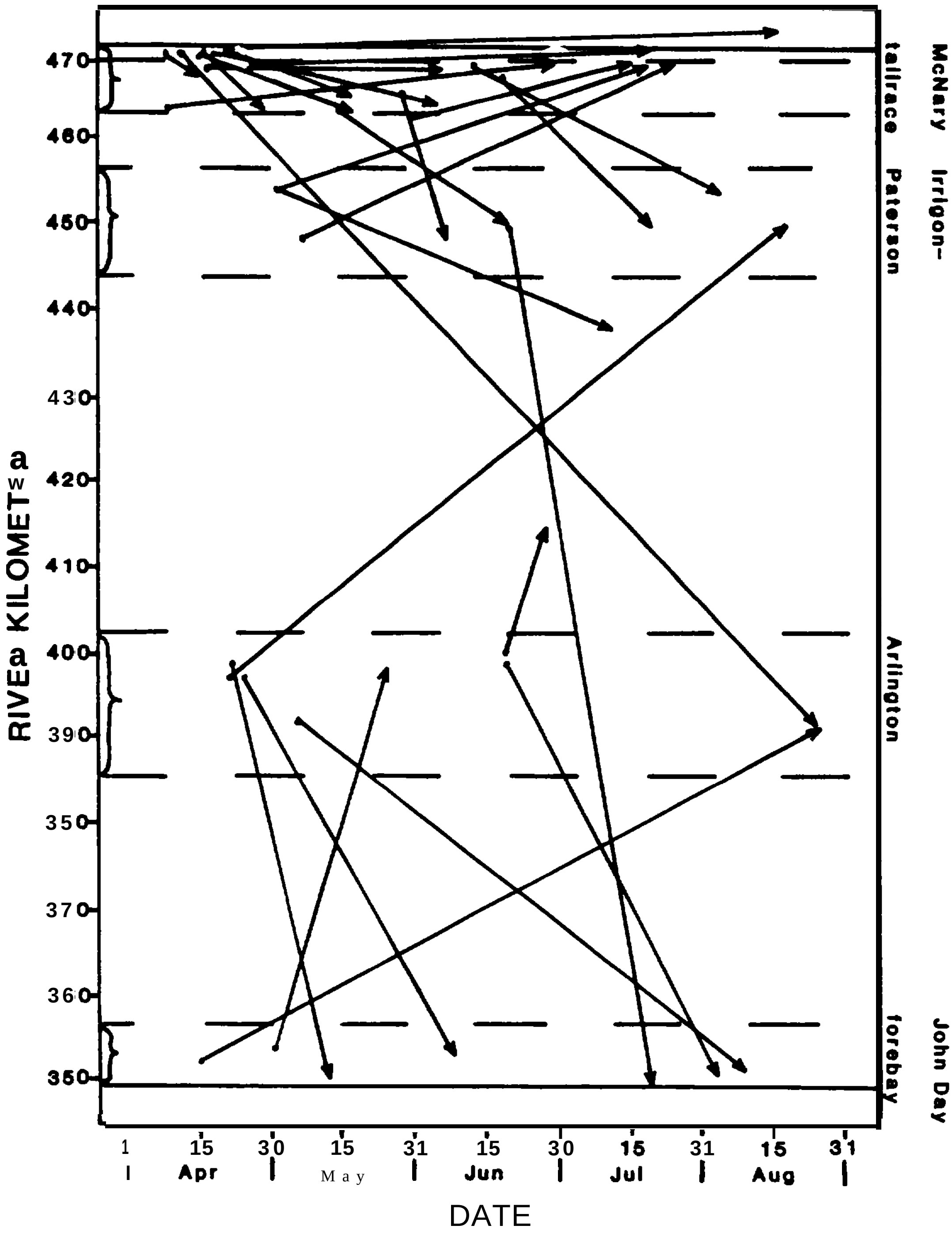

Figure 19. Locations and dates of releases and recoveries of marked northern squawfish recaptured in areas other than where marked, John Day Reservoir, 1985. Areas sampled are indicated by brackets.

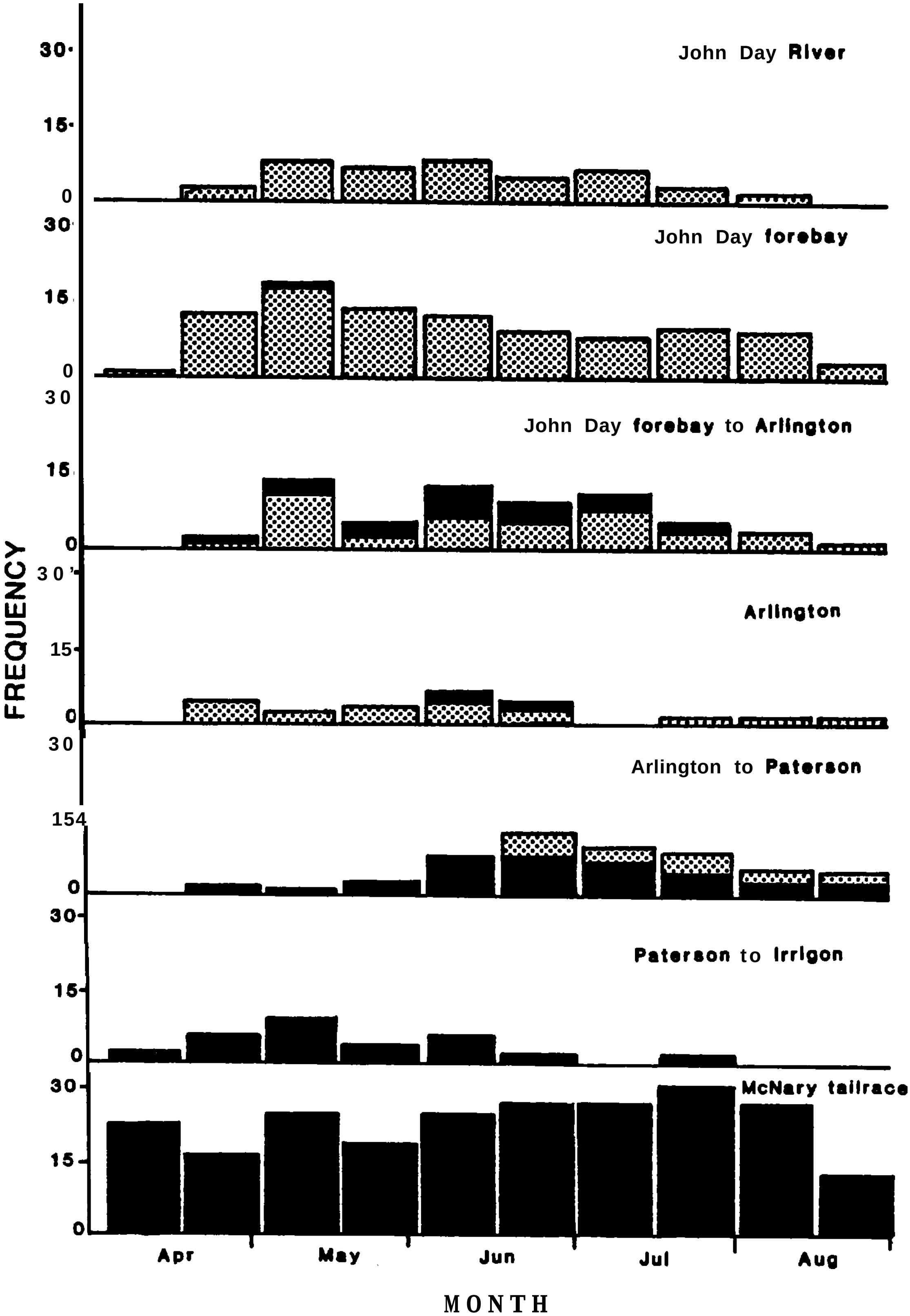

Figure 20. Frequency of observations by area of radiotagged northern squawfish released in McNary tailrace (■) and John Day forebay (⚄), April 7-September 2, 1985.

Table 6. Movements of twenty-three radiotagged northern squawfish, John Day Reservoir April 7-September 2, 1985.

Area released	Transmitter f rectuency (MHz)	Number of observations	Movements per day (km)		Ranoe boundaries (Rkm)		Sampling areas entered
			Mean	Maximum	Lower	Upper	
Jonn Day forebay	48.714	2	0.7	0.7	355.4	363.1	1
	48.064	7	1.0	2.9	347.5	373.3	1
	48.993	13	0.1	0.9	346.7		1
	49.048	26	0.0	0:1	347.5	350.0	1
	49.093	17	0.4	3.1	347.7	354.3	1
	49.301	23	0.6	4.0	347.9	368.6	1
	49.317	10	1.2	4.7	350.8	423.0	2
	49.382	18	0.2	1.0	347.5	350.8	1
Arlington	49.152	15	0.5	2.1	379.7	390.0	1
	49.328	25	1.3	13.1	350.8	440.4	2
McNary tailrace	48.184	29	0.1	1.4	458.7	469.7	1
	48.209	19	1.2	7.1	418.5	468.5	2
	48.210	5	0.5	0.2	467.7		1
	48.333	33		5.1	436.0	469.7	2
	48.373	34	0.7	4.7	446.8		2
	48.414	31	1.5	9.8	370.7	469.8	3
	48.492	34	1.2	7.6	425.1	469.8	2
	48.553	30	1.9	9.2	346.9	469.8	4
	48.638	34	0.7	6.9	432.0	469.8	2
	46.658	17	0.1	0.6	467.6	469.8	1
	48.679	28	0.0	0.2	468.9		1
	49.598	21	0.1	0.5	467.7	469.8	1
	49.779	21	0.6	4.8	433.6	469.7	2

through August. Radiotagged fish in the lower reservoir remained near shore throughout the season, while those in the upper reservoir occurred offshore nearly half the time they were monitored late in the season (Figure 21).

Abundance

Size specific differences in vulnerability to capture (ratios of recaptures to marks at large) were statistically significant (<0.05) between northern squawfish less than or equal to 375 mm and greater than 375 mm (Ts=0, n=9, $p<0.01$; Figure 22). Length frequencies of northern squawfish captured during the sampling season were bimodal (Figure 23).

An estimated 95,407 northern squawfish inhabited John Day Reservoir (Table 7). Female northern squawfish comprised 47% of sexed fish with fork lengths less than or equal to 375 mm (n=939) and 95% of sexed fish over 375 mm in length (n=991). Anglers harvested an estimated 2,004 northern squawfish from April 7 through September 2 (Table 8). Fork length of fish harvested ranged from 175 to 475 mm (Figure 24). Observed harvest of marked northern squawfish was 1.4 times that of estimated harvest (Table 8).

Survival of marked and unmarked northern squawfish captured during field sampling was not significantly ($p<0.05$) different (X2=1.6, df=l,p=0.21). Eight of 90 northern squawfish recaptured during sampling had lost their tags.

Age and Growth

Four-year-old northern squawfish were most abundant in samples, although ages ranged from 1 to 17 years (Figure 25). Age at which northern squawfish were fully recruited to sampling gears may have ranged from 4 to 11 years (Figure 26). Mean fork lengths of female northern squawfish aged 7 and older were greater than those of males of corresponding ages (Figure 27). Growth of northern squawfish aged greater than 1 was similar from 1978 through 1983 but improved in 1984 (Figure 28). Growth of 1 year olds in 1984 was greater than in any previous year.

Survival and Year-Class Strength

Age specific survival of northern squawfish from 1984 to 1985 averaged 46.5% (Table 9). Year-class strengths of northern squawfish have varied and appear to be cyclic (Figure 29).

Smallmouth Bass

Distribution and Movements

Differences in catch among areas indicated that smallmouth bass were not abundant in McNary tailrace or McNary tailrace BRZ. Only 5% of smallmouth bass sampled were caught in those areas (Figure 30). Relative abundance of smallmouth bass varied among sampling periods in all areas, but no seasonal trends were apparent (Figure 31). Marked smallmouth bass were most likely to be recaptured where released (Table 10); although some fish were recaptured in other areas (Figure 32).

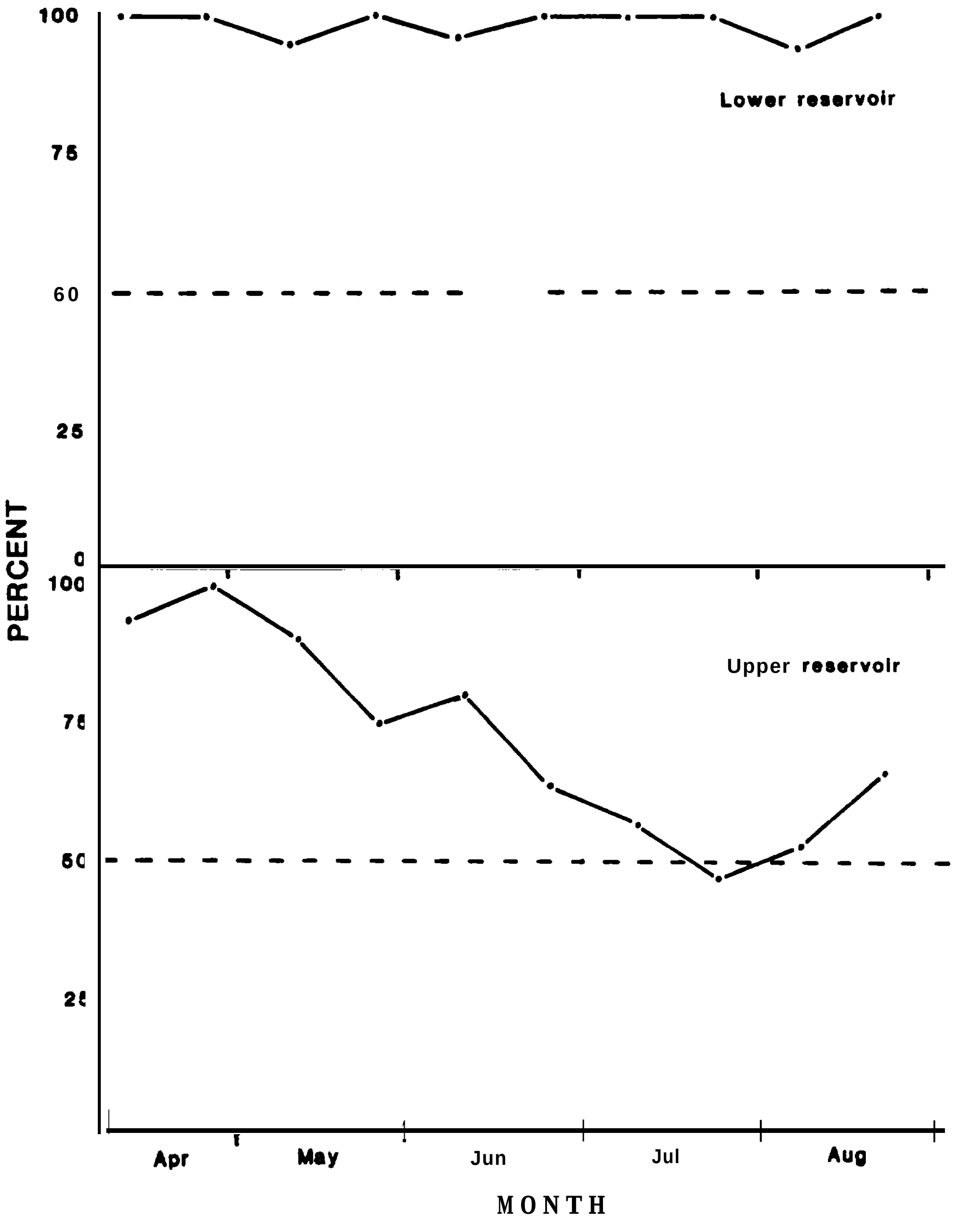

Figure 21. Percent observations of radiotagged northern squawfish in nearshore areas (<50 m from shore), John Day Reservoir, April 7-September 2, 1985.

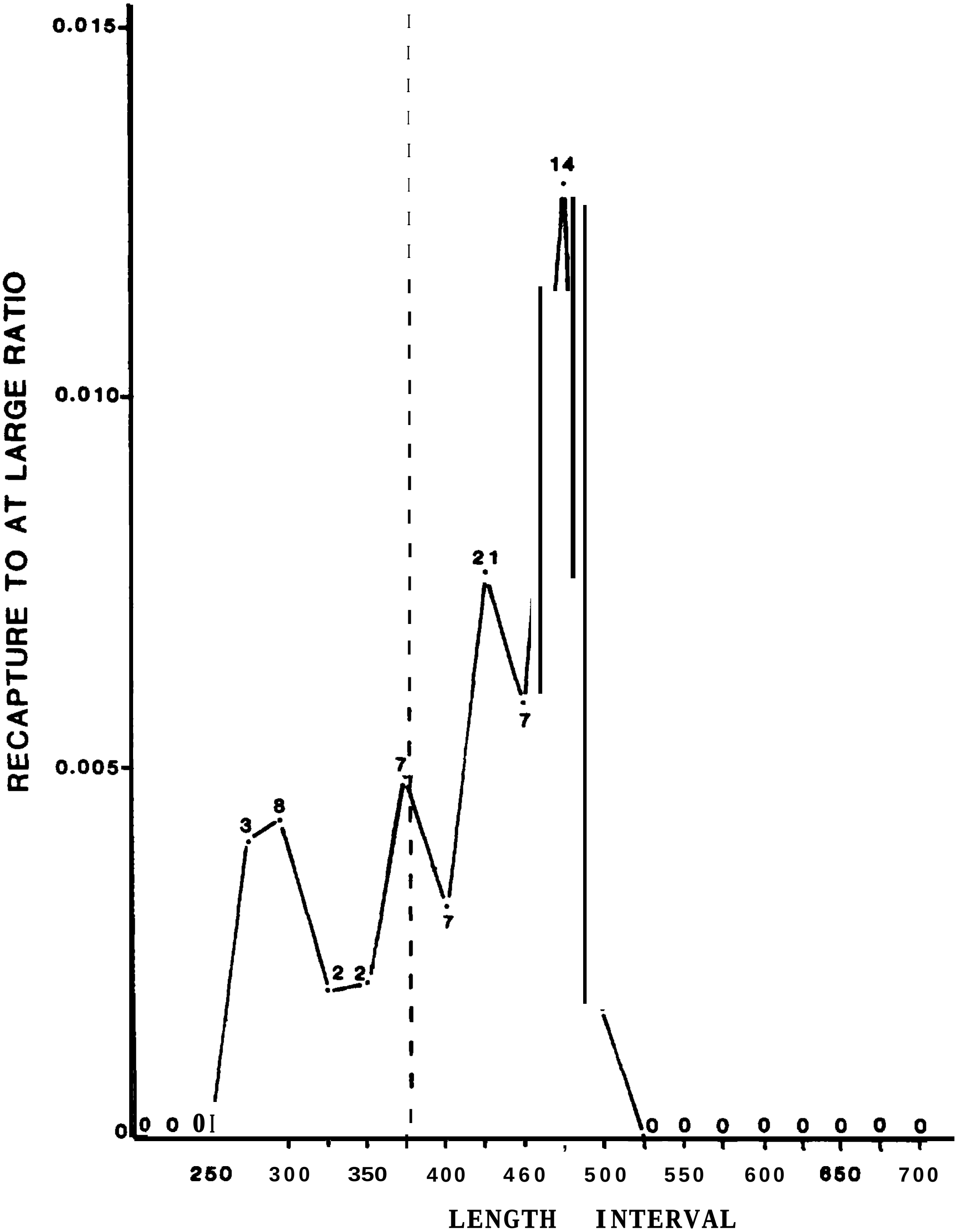

Figure 22. Ratios of recaptures to marks at large (vulnerability) for northern squawfish by length interval, John Day Reservoir, March 24-September 2, 1985. Number of recaptures within a length interval is above each point. Dashed line indicates length at which vulnerability to capture is significantly ($P<0.05$) different.

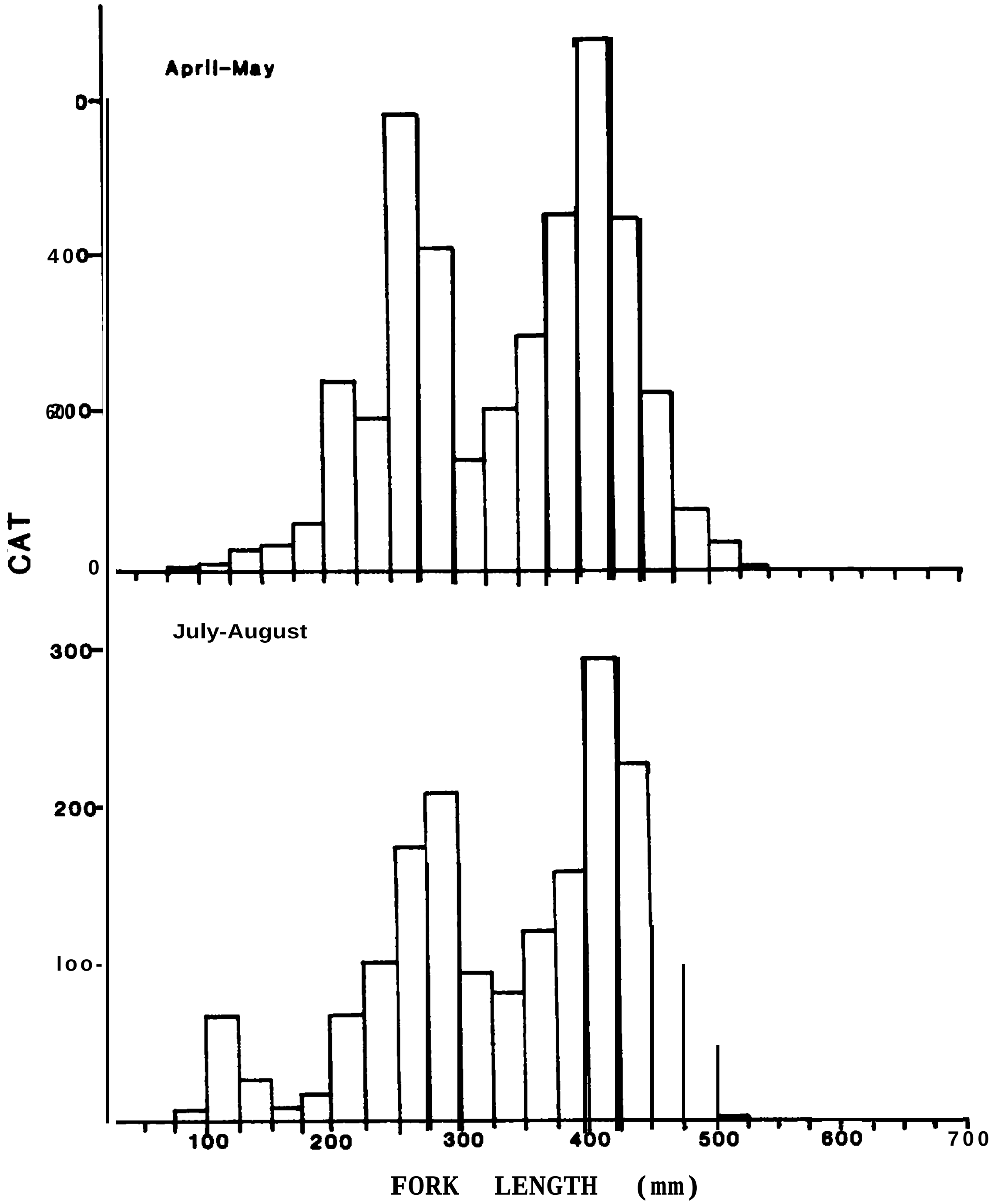

Figure 23. Length-frequency distributions of northern squawfish collected in John Day Reservoir, 1985.

Table 7. Estimated abundance of northern squawfish based on multiple mark and recapture surveys and Overton's (1965) estimator, John Day Reservoir, 1985.

Length interval (mm)	Estimate	95% confidence limits	
		Lower	Upper'
250-375	53,178	34,320	84,272
>375	42,229	42,229	56,819

Table 8. Estimated and observed numbers[a] of unmarked and marked northern squawfish harvested by anglers, John Day Reservoir, April 7-September 2, 1985.

Area Status	8	9	10	11	12	13	14	15	16	17	Sum
	Period										
Lower reservoir											
Unmarked											
Estimated	60	49	481	292	100	163	94	161	37	198	1,635
Observed, interviews	22	15	174	47	9	23	11	20	2	31	354
Observed, voluntary[b,c]	0	0	0	2	1	2	1	0	0	0	6
Marked											
Estimated	0	0	0	0	0	7	0	0	0	0	7
Observed, interviews	0	0	0	0	0	1	0	0	0	0	1
Observed, voluntary[b]	0	0	0	0	1	1	1	0	1	0	4
Upper reservoir											
Unmarked											
Estimated	23	23	13	24	176	0	38	9	11	45	362
Observed, interviews	4	4	2	3	23	1	4	3	6	4	54
Observed, voluntary[b,c]	0	3	0	1	0	0	1	0	0	0	5
Marked											
Estimated	0	0	0	0	0	0	0	0	0	0	0
Observed, interviews	0	0	0	0	0						0
Observed, voluntary[b]	0	0	1	0	0	0 1	0 2	0 0	0 1	0 0	5

[a]Includes fish >250 mm fork length.
[b]Includes areas-outside those in which anglers surveyed.
[c]Recaptures of fish tagged in previous years.

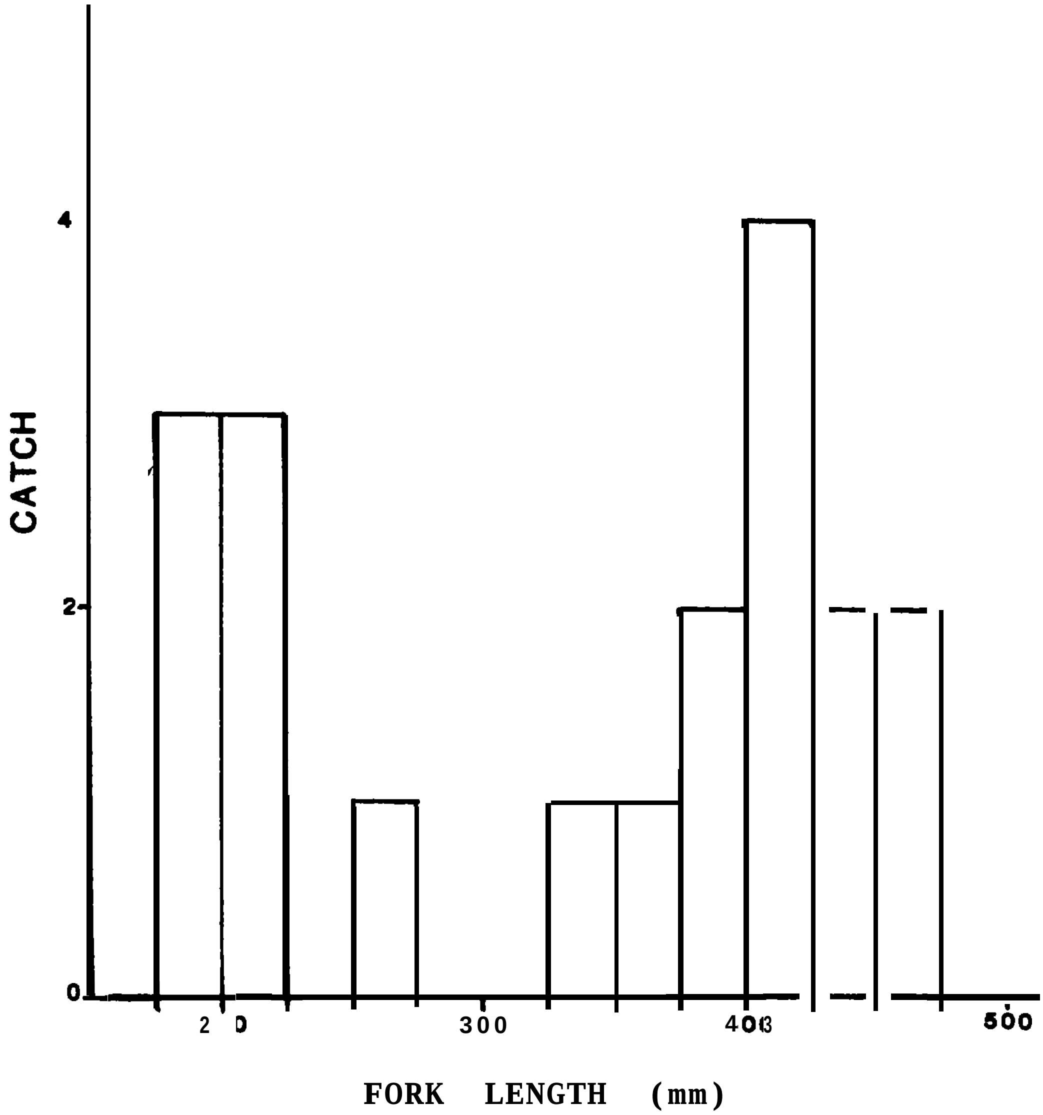

Figure 24. Length-frequency distribution of northern squawfish harvested by anglers, John Day Reservoir, April 7-September 2, 1985.

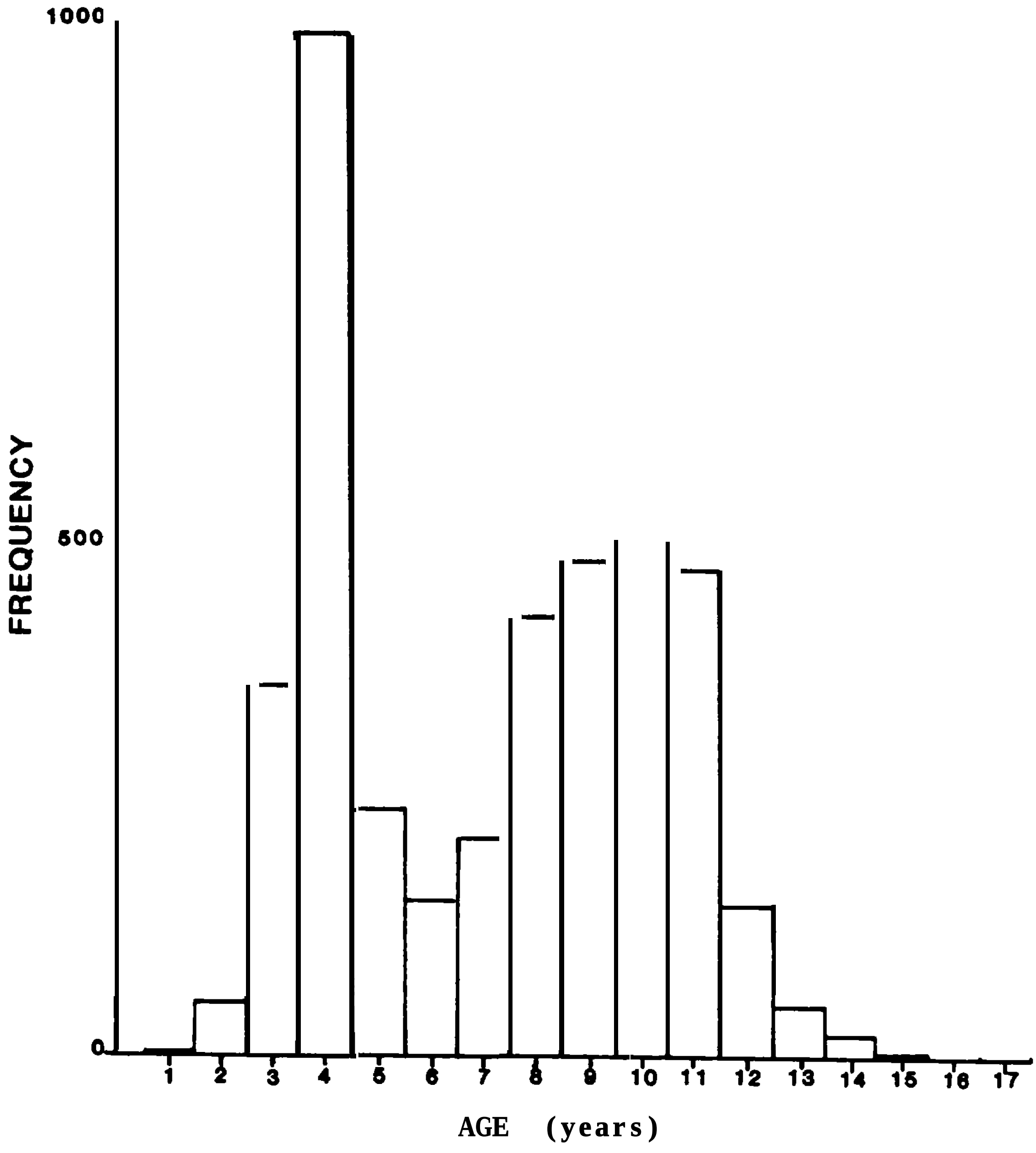

Figure 25. Estimated age-frequency distribution of northern squawfish, John Day Reservoir, March 24-June 30, 1985.

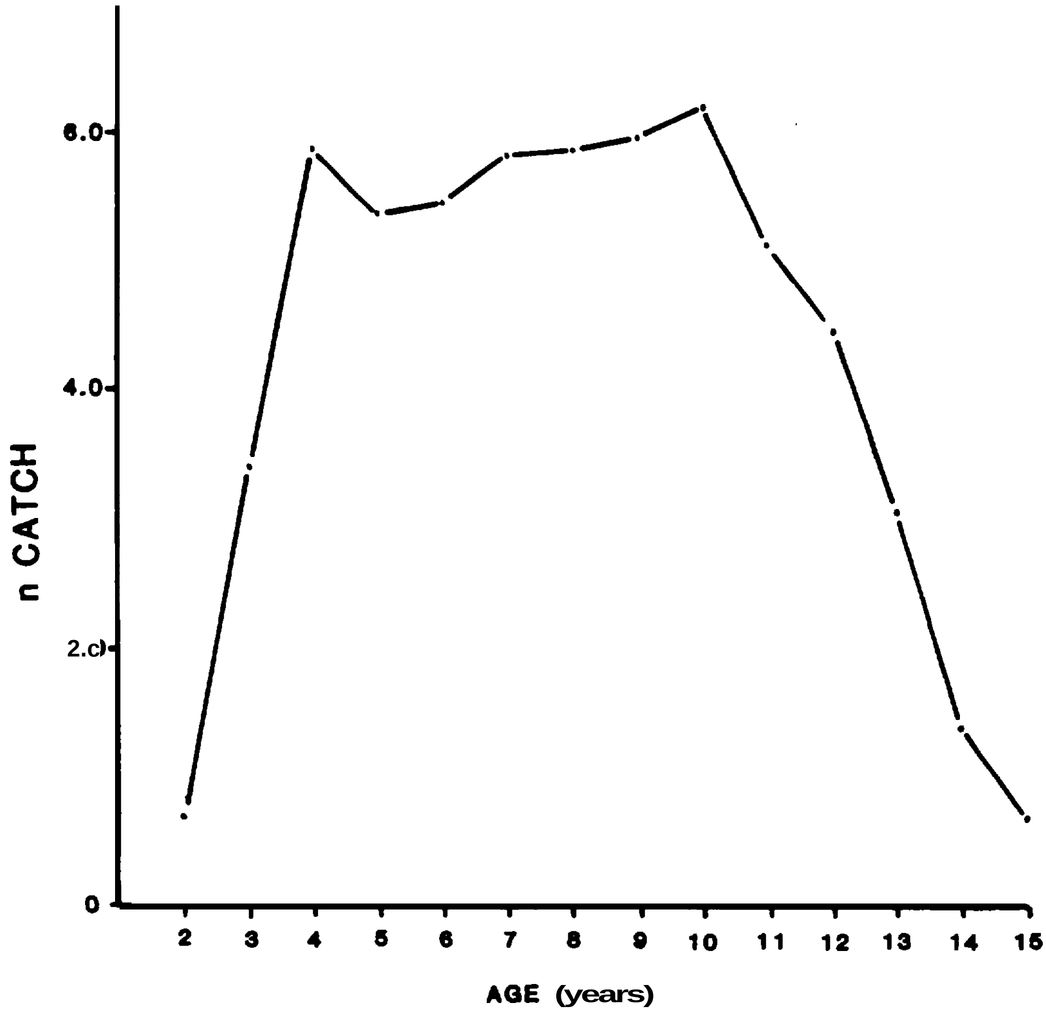

Figure 26. Catch curve for northern squawfish caught by bottom gill nets, John Day Reservoir, March-June 1983-1985.

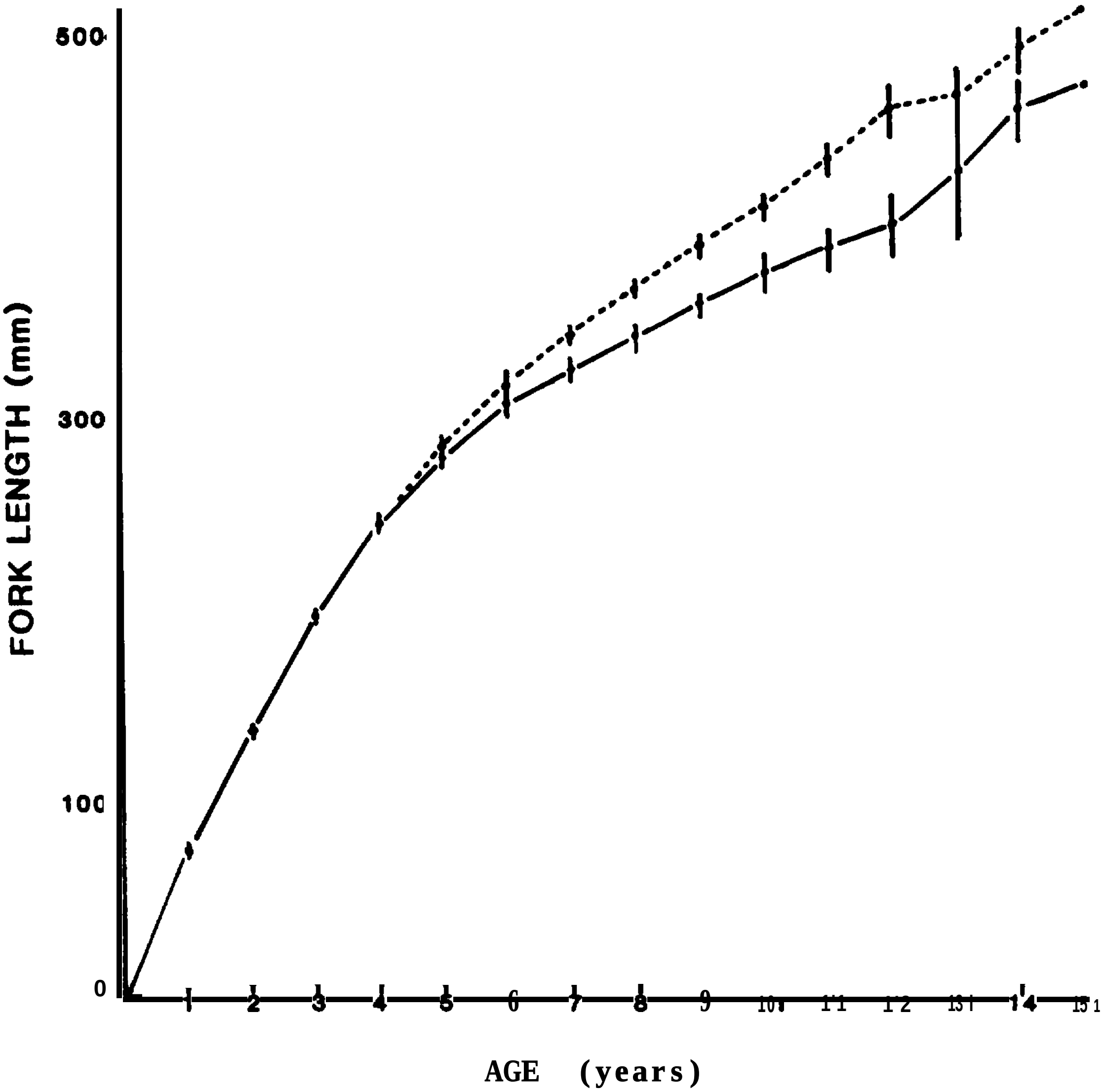

Figure 27. Mean backcalculated fork length and 95% confidence intervals (vertical bars) for male (—) and female (--) northern squawfish, John Day Reservoir, 1983-1985.

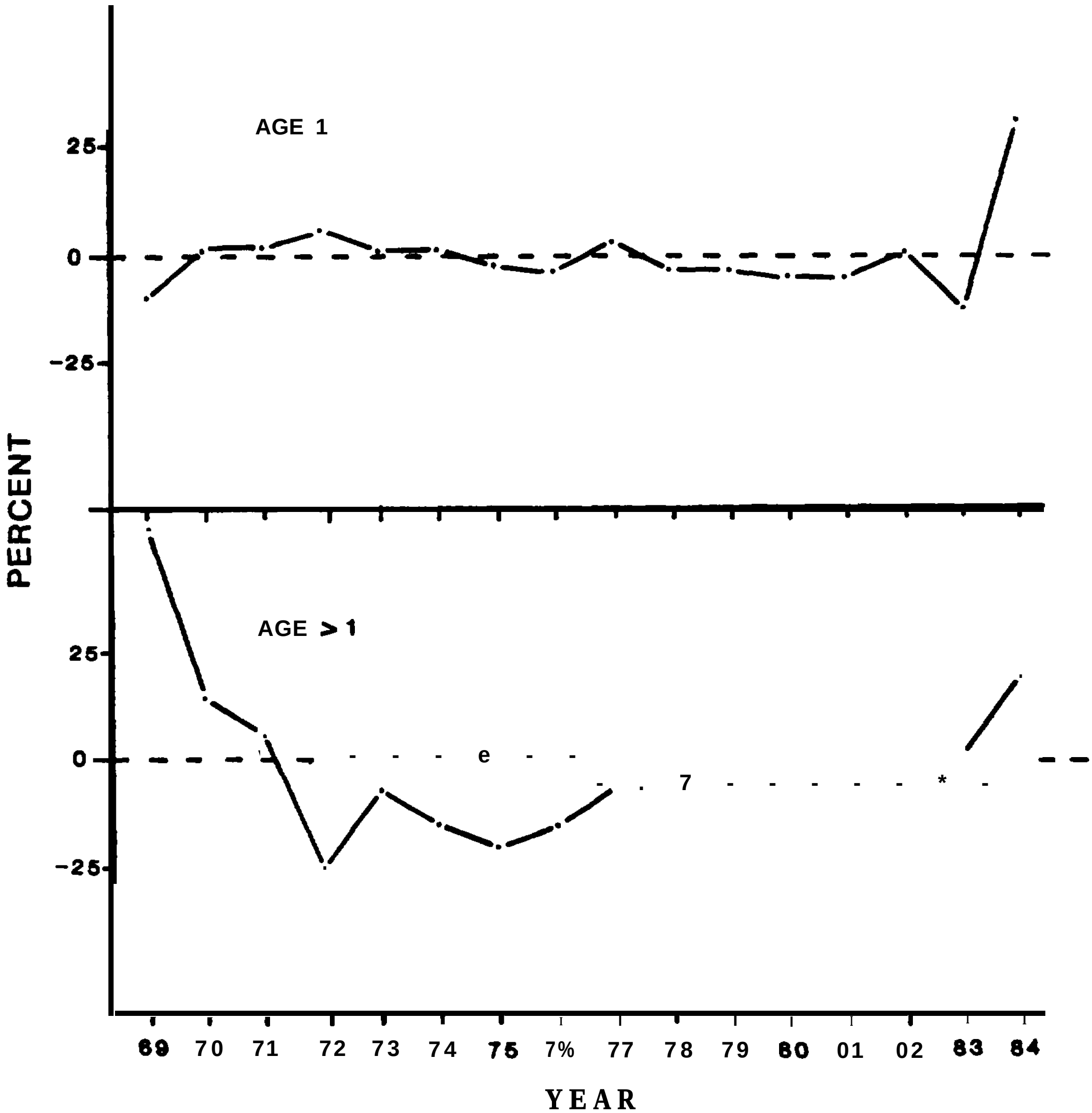

Figure 28. Relative growth (percent deviation from mean) of northern squawfish by age group, John Day Reservoir, 1970-1984. Age >1 includes age groups 2-17.

Table 9. Estimates of northern squawfish survival (S) from catch per unit effort differences (bottom gill-net catches only) between 1984 and 1985, John Day Reservoir.

Year class	Age	S
1979	5-6	0.609
1978	6-7	0.899
1977	7-8	1.109
1976	8-9	1.112
1975	9-10	0.990
1974	10-11	0.475
1973	11-12	0.336
1972	12-13	0.112
1971	13-14	0.093
Geometric mean		0.465

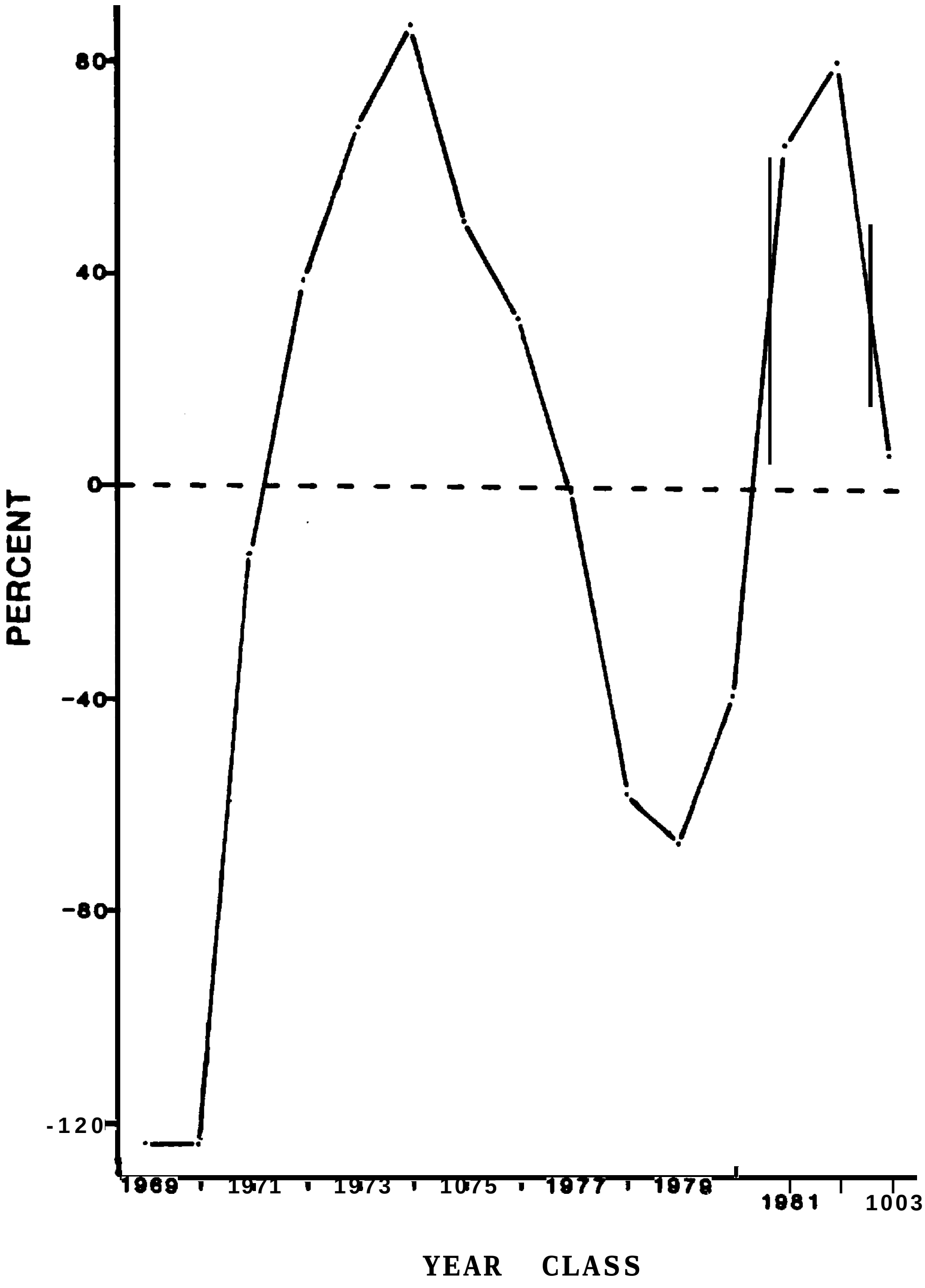

Figure 29. Relative year-class strength (percent deviation from mean) of northern squawfish, John Day Reservoir, 1969-1983.

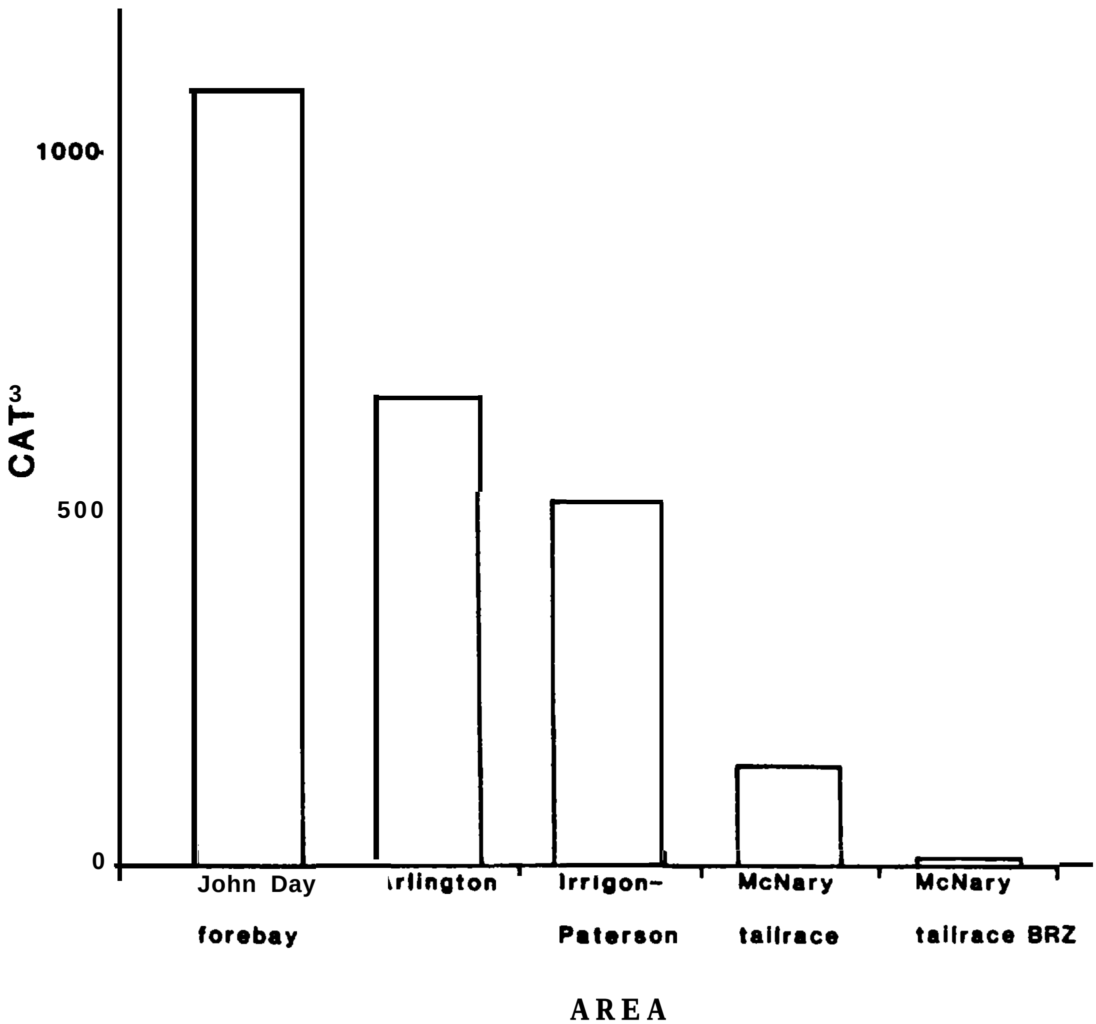

Figure 30. Total catch of smallmouth bass by area, all gear combined, John Day Reservoir, March 24-September 2, 1985. BRZ is the boat restricted zone.

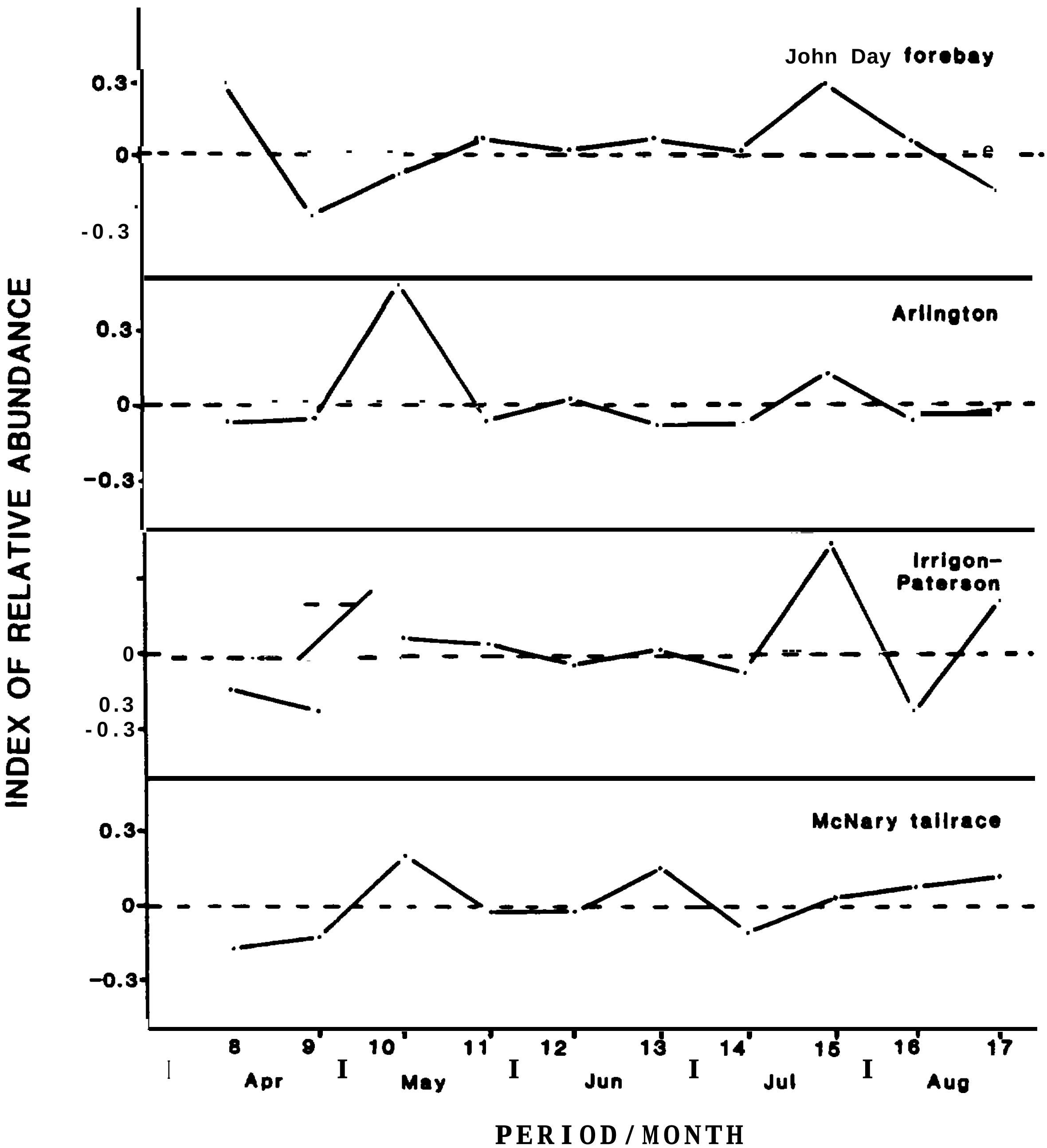

Figure 31. Index of relative abundance of smallmouth bass by area, John Day Reservoir, April 7-September 2, 1985. Index is the number of standard deviations from the mean catch per unit effort (CPUE) and is based on the combined CPUE from gill nets, trap nets, and electrofishing.

Table 10. Numbers of marked smallmouth bass released and recaptured by area, John Day Reservoir, March 24-September 2, 1985. Numbers in parentheses are fish recaptured in the same Station where released.

Area released	Number released	Area recaptured						
		A	8	C	D	E	F	G
A. John Day forebay	458	138 101)	--	1	--	--	--	--
8. Forebay to Arlington	1	6	2	--	--	--	--	--
C. Arlington	434	--	--	ſ1(52)	2	--	--	--
D. Arlington to Paterson	152			--	8(1)	--	--	--
E. Paterson to Irrigon	338	--	--		--	31(26)	1	--
F. McNary tailrace	92	--	--	--	--	2	5(4)	--
G. McNary tailrace BRZ[a]	4	--	--	--	--	--	--	0

[a]Boat restricted zone.

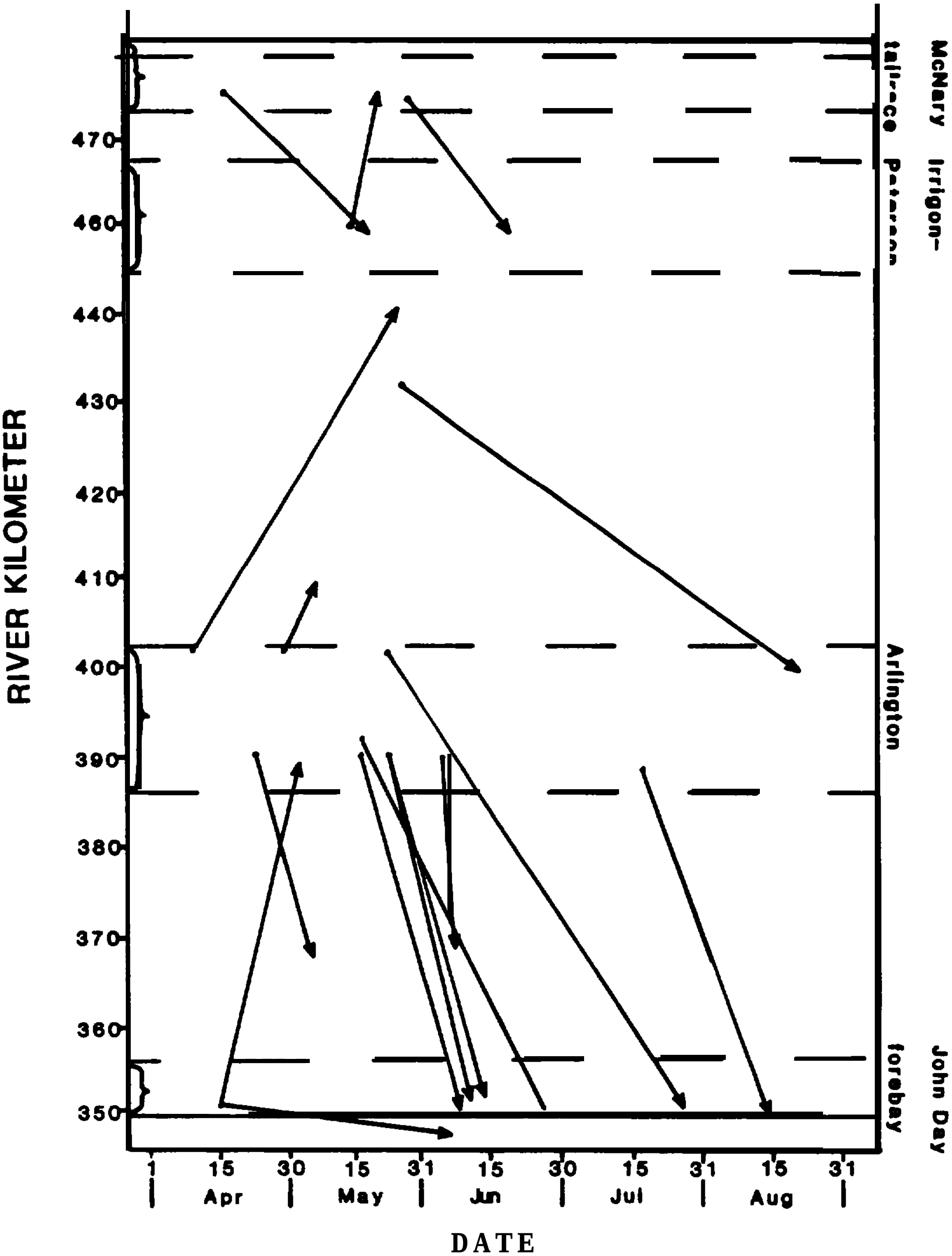

Figure 32. Locations and dates of releases and recoveries of marked smallmouth bass recaptured in areas other than where marked, John Day Reservoir, 1985. Areas sampled are indicated by brackets.

Abundance

Vulnerability of smallmouth bass to capture varied with size in the lower, but not in the upper John Day Reservoir. Although smallmouth bass were fully recruited to our gear by 200 mm (minimum tagging size), statistically significant ($p<0.05$) differences in vulnerability were observed in the lower reservoir between fish with fork lengths less than or equal to 225 mm and fish greater than 225 mm (Ts=0, n=9, $p<0.01$; Figure 33). Most smallmouth bass captured during the sampling season had fork lengths less than 300 nn (Figure 34).

An estimated 11,359 smallmouth bass were present in John Day Reservoir (Table 11). In the lower reservoir, smallmouth bass over 225 mm in fork length were 5.2 times more abundant than those between 200 and 225 mm. Smallmouth bass abundances in the lower and upper reservoir were comparable. Female smallmouth bass comprised 49% of sexed fish in the lower reservoir (n=228) and 50% of sexed fish in the upper reservoir (n=50). Anglers harvested an estimated 4,154 smallmouth bass from the lower reservoir and 229 from the upper reservoir from April 7 through September 2 (Table 12). Observed harvest of marked smallmouth bass was less than estimated harvest in the lower reservoir, but was greater than estimated harvest in the upper reservoir. Harvested fish had fork lengths greater than 200 mm (Figure 35).

Survival of marked and unmarked smallmouth bass captured during field sampling was not significantly ($p<0.05$) different ($X2=1.6$, df=l, $p=0.21$). Ten of 222 smallmouth bass recaptured during sampling had lost their tags.

Aqe and Growth

Ages of smallmouth bass in samples ranged from 1 to 10 years, but the most abundant age group in the lower and upper reservoir was 3 years (Figure 36). Smallmouth bass were fully recruited to sampling gear by age 3 (Figure 37). Mean fork lengths of smallmouth bass in the lower reservoir were less than those of the same age in the upper reservoir (Figure 38). Growth of smallmouth bass aged greater than 1 in the lower reservoir was poor in 1982 but improved in subsequent years (Figure 39). In the upper reservoir, growth of smallmouth bass aged greater than 1 was poor in 1980 and 1981, but improved in 1982 and 1983.

Survival and Year-Class Strenqth

Age specific survival of smallmouth bass from 1984 to 1985 averaged 46.5% in the lower reservoir and 43.7% in the upper reservoir (Table 13). Smallmouth bass year-class strength was highly variable in the lower and upper reservoir (Figure 40).

DISCUSSION

Sampling conducted between John Day forebay and Arlington and between Arlington and Irrigon-Paterson indicated that few marked smallmouth bass released elsewhere in the reservoir moved into these areas (Table 11). Similar movement patterns were displayed by smallmouth bass throughout the

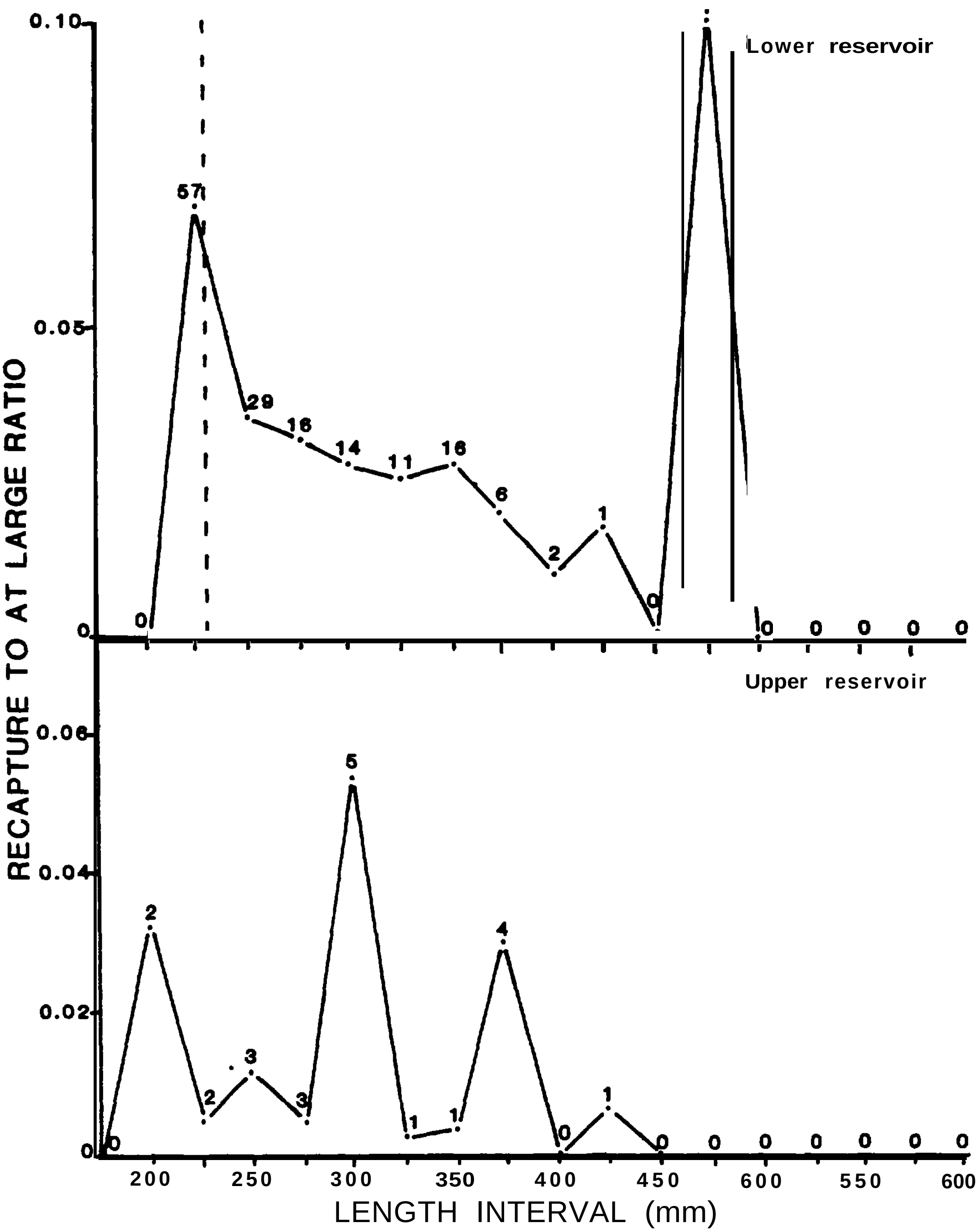

Figure 33. Ratios of recaptures to marks at large (vulnerability) for smallmouth bass by length interval, John Day Reservoir, April 7-September 2, 1985. Total recaptures within a length interval is above each point. Dashed line indicates length at which vulnerability to capture is significantly ($P<0.05$) different.

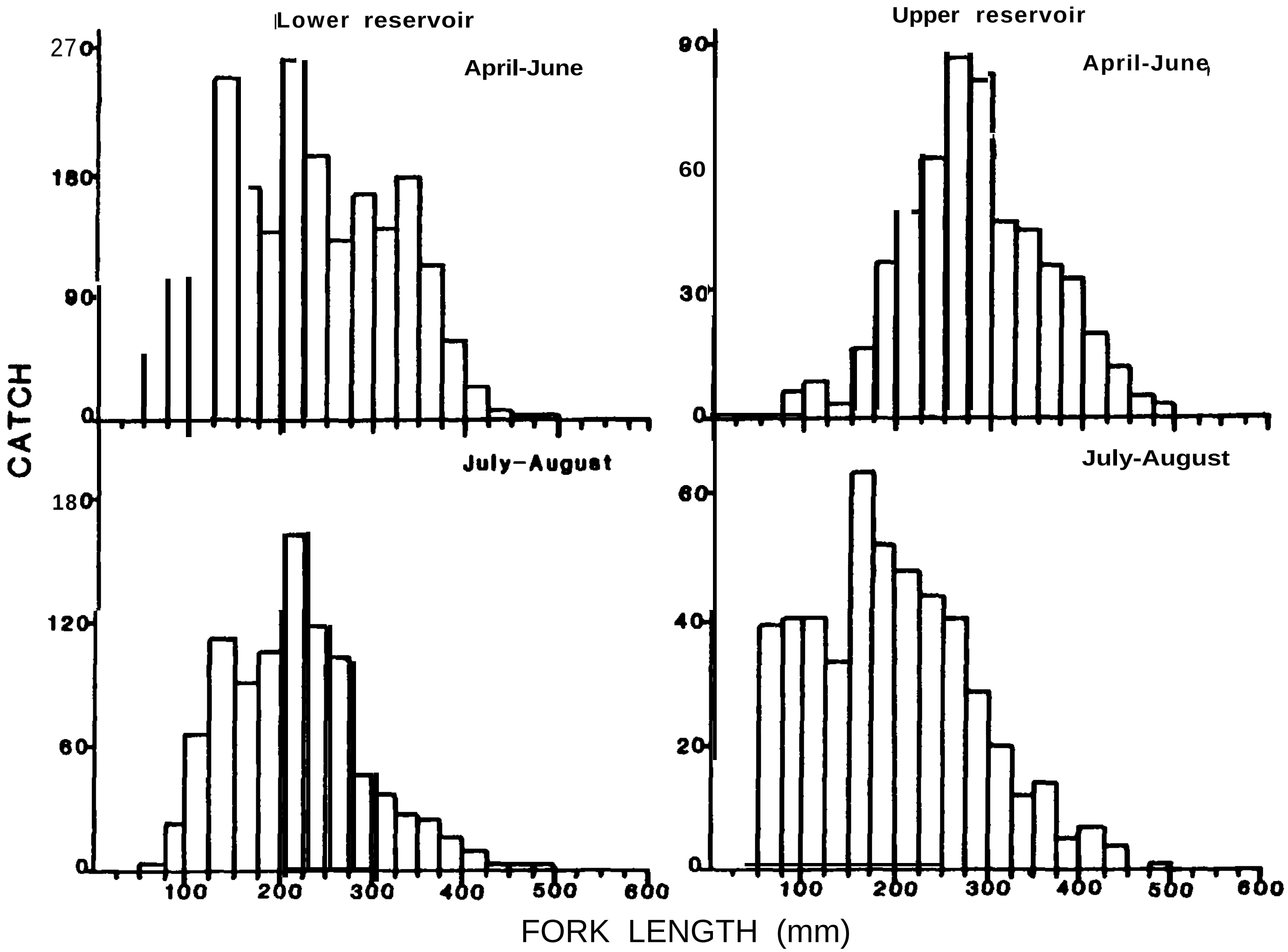

Figure 34. Length-frequency distributions of smallmouth bass collected in John Day Reservoir, 1985.

Table 11. Estimated abundance of smallmouth bass based on multiple mark and recapture survey and Overton's (1965) estimator, John Day Reservoir, 1985.

Area	Length interval (mm)	Estimate	95% confidence limits	
			Lower	Upper
Lower reservoir	200-225	860	667	1,131
	>225	4,500	3,709	5,578
Upper reservoir	>200	5,999	3,910	9,401

Table 12. Estimated and observed numbers[a] of unmarked and marked smallmouth bass harvested by anglers, John Day Reservoir, April 7-September 2, 1985.

Area / Status	Period 8	9	10	11	12	13	14	15	16	17	Sum
Lower reservoir											
Unmarked											
Estimated	11	155	590	215	369	451	181	687	495	849	4,003
Observed, interviews	4	49	210	35	43	61	22	92	27	133	676
Observed, voluntary[b,c]	1	2	6	3	5	1	1	2	2	0	23
Marked											
Estimated	0	3	25	12	36	7		860	0	0	151
Observed, interviews	0	1	9	2	4	1	1	8	0	0	26
Observed, voluntary[b]	0	7	5	6	10	7	3	9	2	7	56
Upper reservoir											
Unmarked											
Estimated	11	22	117	72	0	63	9	0	0	0	294
Observed, interviews	2	4	18	12	0	15	2	0	0	0	53
Observed, voluntary[b,c]	2	2	2	3	3	1	0	0	1	0	14
Marked											
Estimated	0	0	0	0	0	4	0	0	0	0	4
Observed, interviews	0	0	0	0	0	1	0	0	0	0	1
Observed, voluntary[c]	0	0	2	5	1	4	2	1	0	1	16

[a] Includes fish >200 mm fork length.
[b] Includes areas-outside those in which anglers surveyed.
[c] Recaptures of fish tagged in previous years.

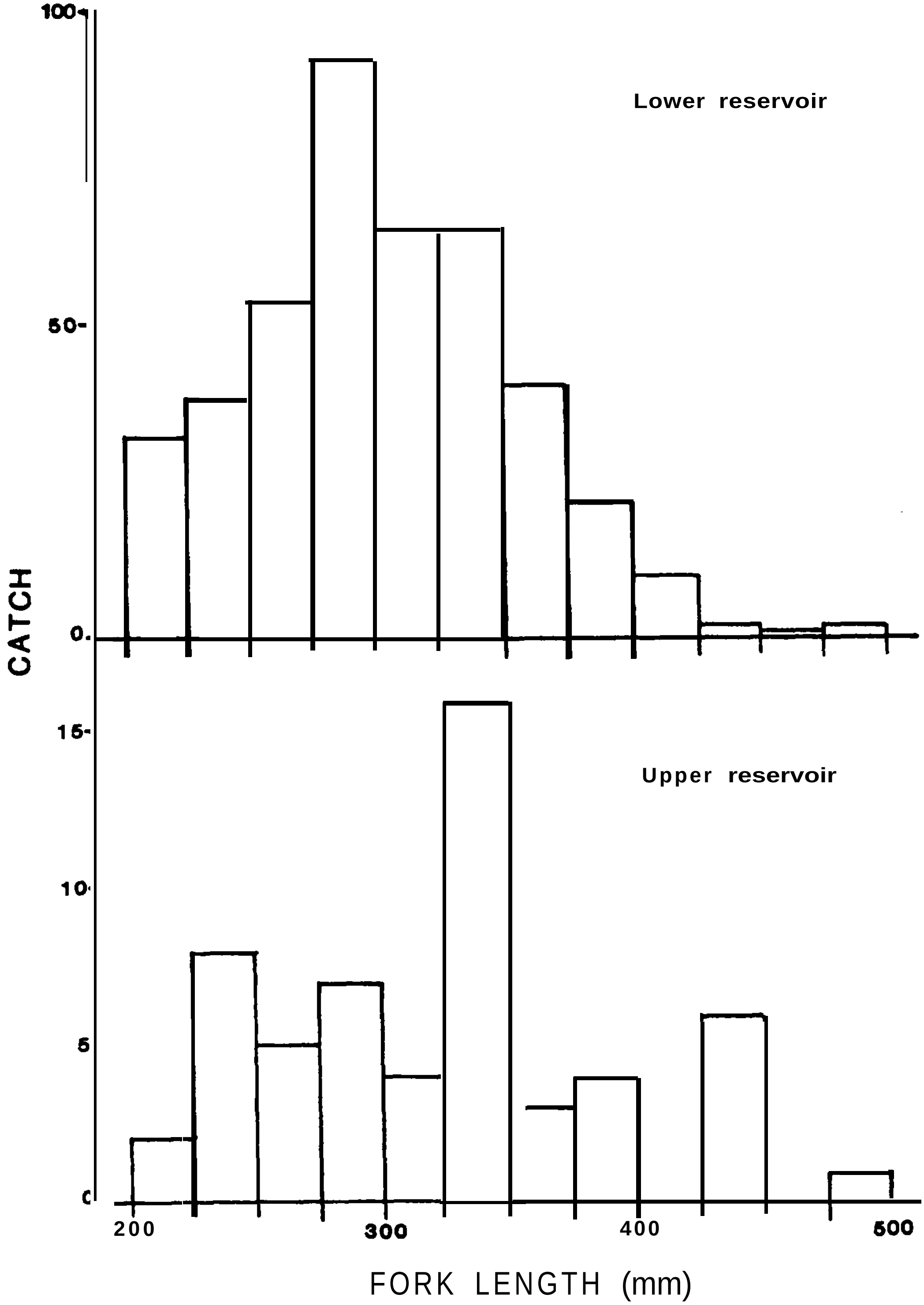

Figure 35. Length-frequency distributions of smallmouth bass harvested by anglers, John Day Reservoir, April 7-September 2, 1985.

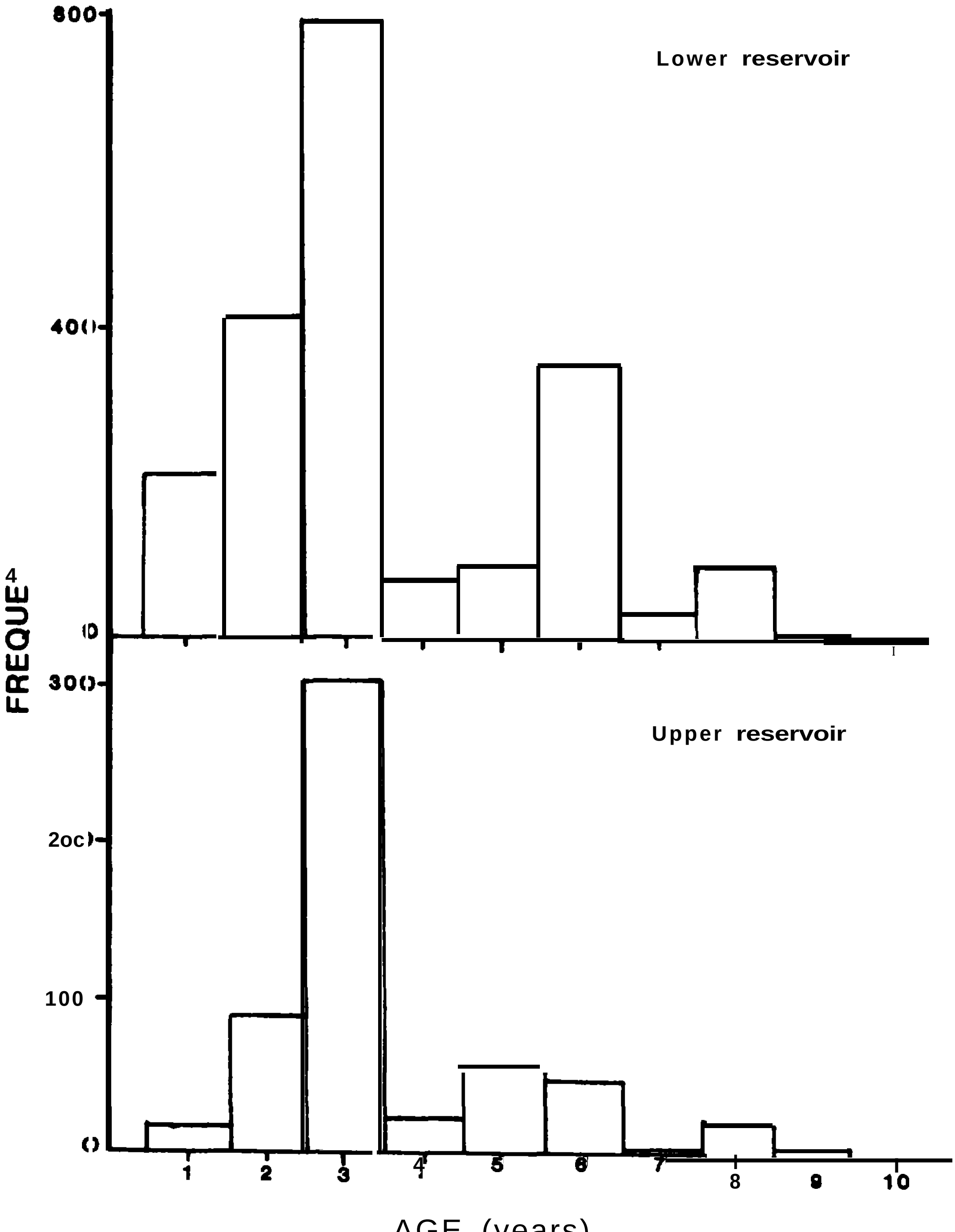

Figure 36. Estimated age-frequency distributions of smallmouth bass, John Day Reservoir, March 24-June 30, 1985.

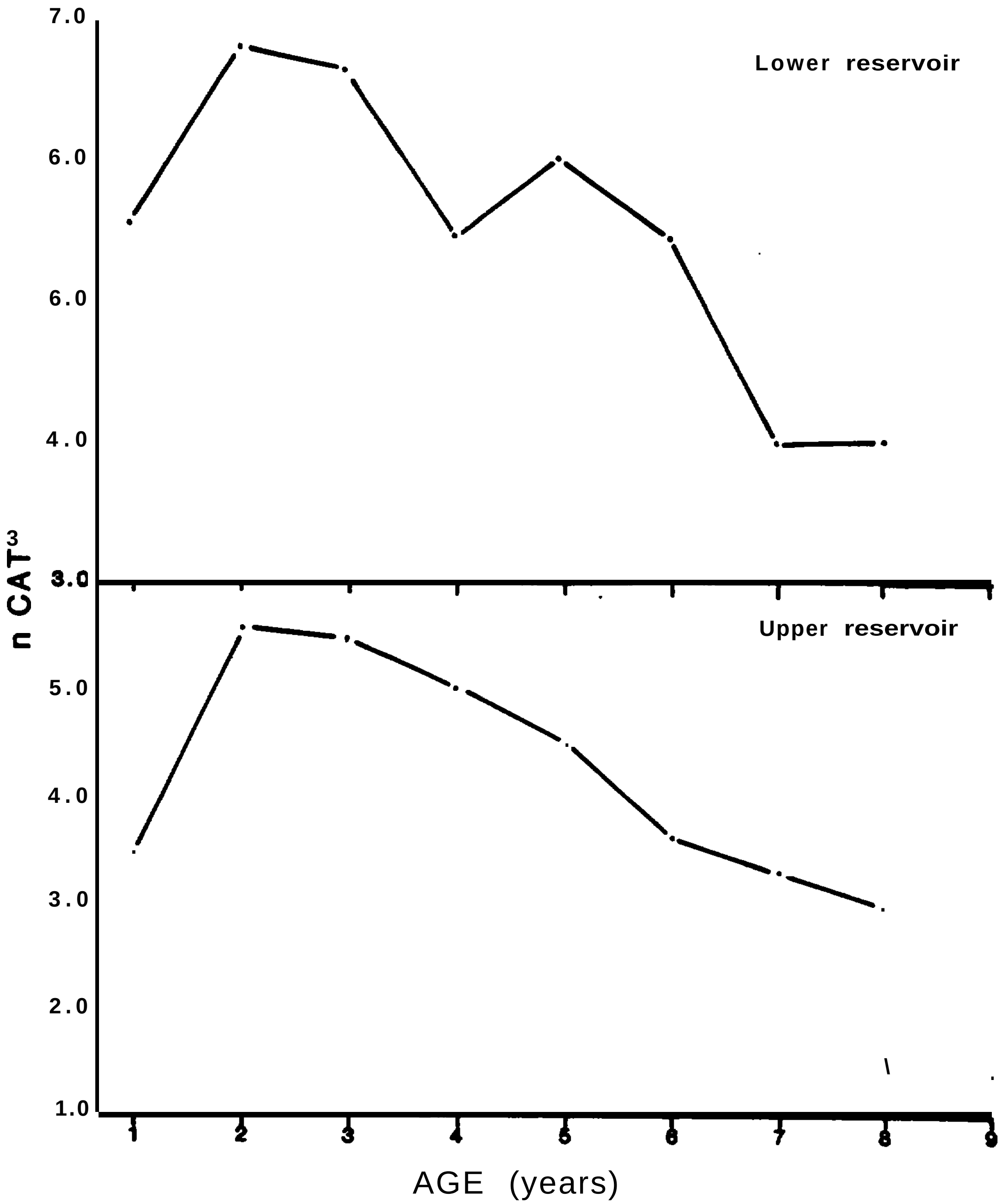

Figure 37. Catch curves for smallmouth bass caught by electrofishing, John Day Reservoir, March-June 1984-1985.

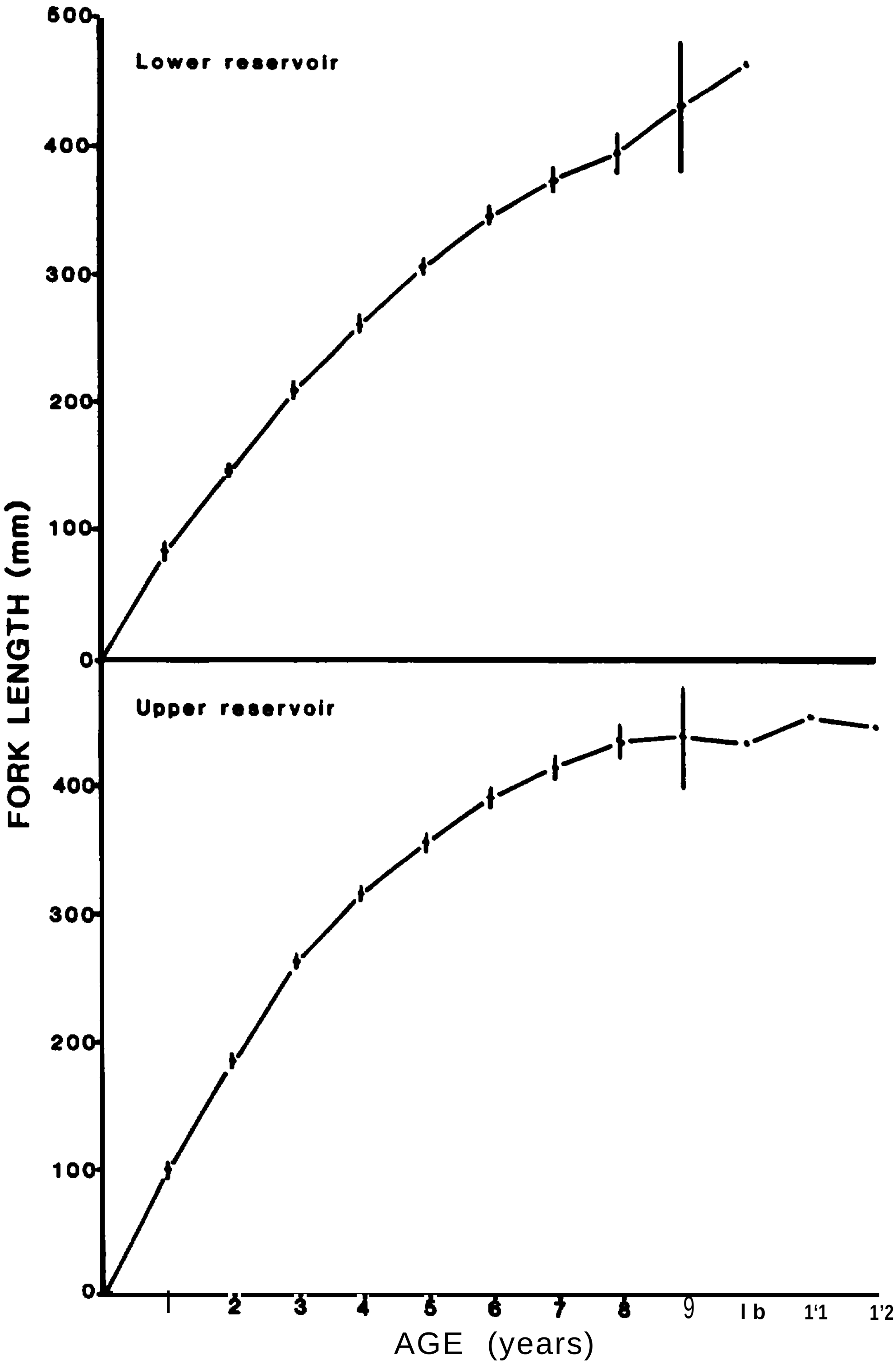

Figure 38. Mean backcalculated fork lengths and 95% confidence intervals (vertical bars) for smallmouth bass, sexes combined, John Day Reservoir, 1983-1985.

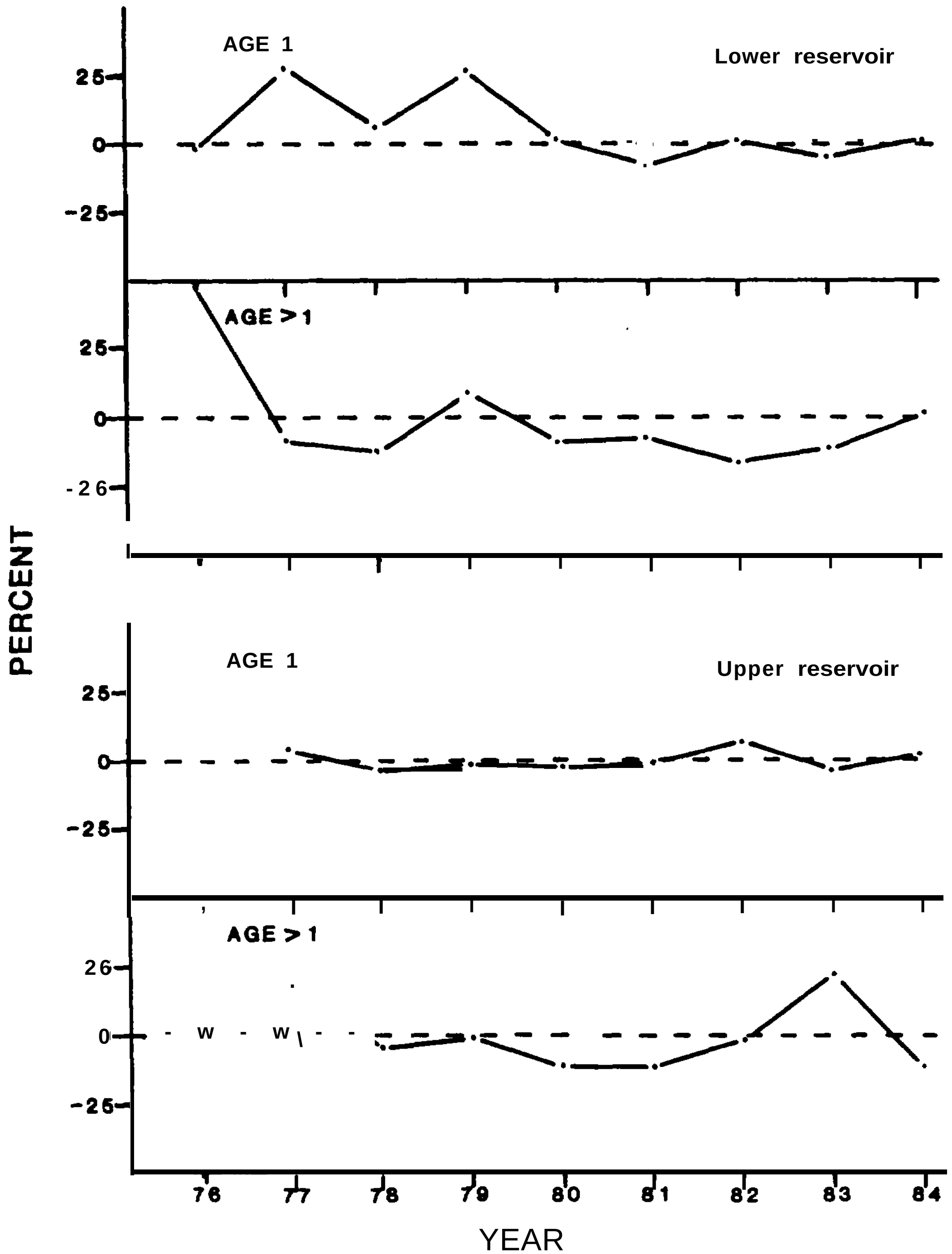

Figure 39. Relative growth (percent deviation from mean) of smallmouth bass, John Day Reservoir, 1976-1984. Age >1 includes age groups 2-11.

Table 13. Estimates of smallmouth bass survival (S) from catch per unit effort differences (electrofishing catches only) between 1984 and 1985, John Day Reservoir.

Year class	Age	Lower reservoir	Upper reservoir
1983	1-2		--
1982	2-3	1.033	0.910
1981	3-4	0.389	0.205
1980	4-5	0.156	0.227
1979	5-6	0.398	0.567
1978	6-7	0.294	0.167
1977	7-8	1.381	1.143
1976	8-9	--	0.667
Geometric mean		0.465	0.437

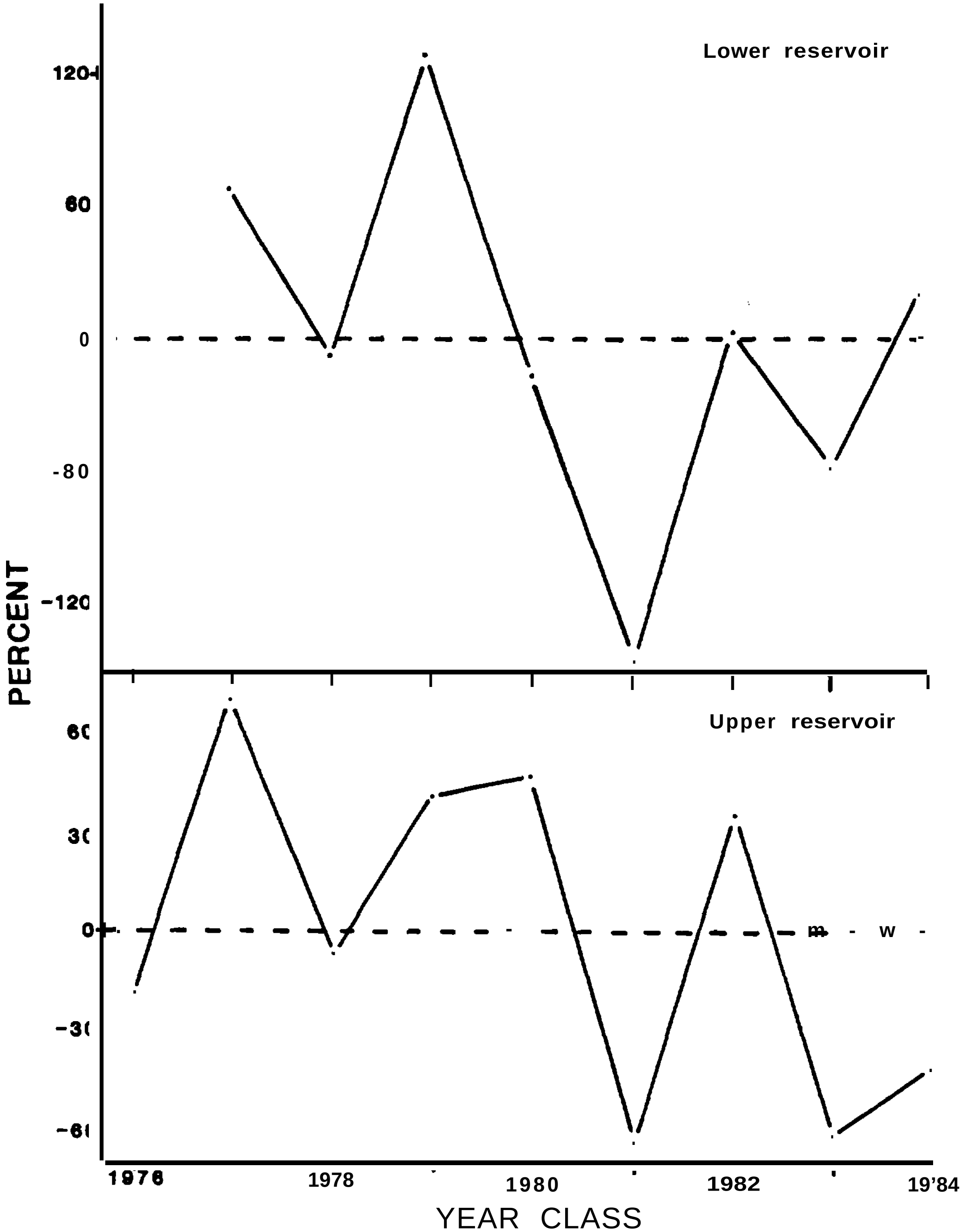

Figure 40. Relative year class strength (percent deviation from mean) of smallmouth bass, John Day Reservoir, 1976-1984.

reservoir. Only 5% of the marked fish were recaptured outside sampling areas where originally released, and those were recaptured in adjacent sampling areas. Limited movements indicate that smallmouth bass are not very mobile and may incompletely mix in John Day Reservoir. Incomplete mixing of marked fish violates an assumption of the abundance estimator resulting in under-estimation of smallmouth bass abundance.

Because movements of smallmouth bass appear limited, an alternate method for estimating smallmouth bass abundance is being considered. Estimates would be made for each sampling area and the density of fish in that area calculated. Abundances in areas not sampled would be estimated as the product of their area and an estimate of smallmouth bass density based on densities observed in sampling areas. Estimates of smallmouth bass calculated in this manner would assume that smallmouth bass are distributed throughout the reservoir and would likely overestimate their true abundance.

Walleye and northern squawfish appear very mobile and marked fish probably mix well with unmarked fish. Fifty percent of marked walleye (Table 1) and 31% of marked northern squawfish (Table 6) were recaptured in sampling areas other than where released. All radiotagged northern squawfish (Table 7) and 90% of radiotagged walleye (Table 2) entered at least one sampling area during the sampling season. By their patterns of movement it appears that a homogeneous population of northern squawfish resides in John Day Reservoir. However, if radiotagged walleye behave as do unmarked members of the population, 10% of walleye never entered our sampling areas during sampling; therefore, 1,622 (95% confidence intervals 728-4,009) more walleye may be present in John Day Reservoir than were estimated.

Sampling between regular sampling areas will again be conducted in 1986, focusing efforts on smallmouth bass to further investigate the magnitude of their movements.

Size specific estimates of walleye and northern squawfish abundance in 1984 (Nigro et al. 1985b) were based on comparisons among size groups of recaptures to at large ratios (vulnerability indices) calculated as the sum of recaptures over the season divided by the number of marks at large at the end of the season. This method was incorrect. Comparisons should have been made based on sampling period specific recapture to at large ratios (Youngs and Robson 1978). However, size specific comparisons using chi-square tests based on period specific counts of recaptures and marks at large were precluded by insufficient sample sizes when recaptures were stratified by period.

The vulnerability of different size groups to capture in 1984 was recalculated using Wilcoxon signed-rank tests based on period specific recapture to at large ratios. Results of Wilcoxon tests indicated that size specific vulnerabilities of northern squawfish and smallmouth bass were the same as those calculated in 1984 (Nigro et al. 1985b). However, for walleye results of Wilcoxon tests indicated that in 1984 vulnerability to capture changed significantly (T_s=0, n=6, p=0.03) after walleye exceeded lengths of 500 mm, not 475 mm.

The estimate of walleye abundance in 1984 was recalculated based on results of Wilcoxon tests. The abundance of walleye with fork lengths between 250 and 500 mm was estimated as 1,542 fish (95% confidence intervals 820-3,053), whereas the estimate of walleye with fork lengths greater than 500 mm was 13,956 fish (95% confidence intervals 6,908-30,285).

Estimates of smallmouth bass abundance in 1983, 1984 and 1985 and walleye and northern squawfish abundance in 1984 and 1985 were compared by a test for differences between Schnabel abundance estimates (Chapman and Overton 1966). A test using Schnabel estimates will accurately identify significant differences in abundance if size-specific differences in vulnerability and numbers of fish removed from the populations are similar among years. Estimates of walleye and northern squawfish abundance in 1983 were not included in comparisons because of differences in areas over which abundance estimates applied. Comparisons of smallmouth bass abundance estimates among years do not include a lower reservoir estimate for 1983 because none was made.

Abundance estimates in 1984 and 1985 were not significantly ($p<0.05$) different for walleye ($Z=0.8, p=0.42$) or northern squawfish ($Z=0.Z, p=0.82$ for fish between 250 mm and 375 mm and $Z=1.3$, $p=0.18$ for fish greater than 375 mm). However, smallmouth bass abundance estimates in 1984 were significantly ($P<0,05$) less than in 1985 in the upper ($Z=5.5, p<0.01$) and lower ($Z=2.5, p=0.01$) reservoir. Upper reservoir estimates of smallmouth bass abundance in 1983 and 1985 were not significantly different ($Z=1.8, p=0.07$).

Statistical differences between 1984 and 1985 in smallmouth bass abundance estimates are probably results of changes in sampling approaches. The estimate of smallmouth bass abundance in the upper reservoir in 1984 was significantly less than estimates in 1985 and 1983 (Nigro et al. 1985b) because a local concentration of fish in Irrigon-Paterson was intensely sampled in 1984 and contributed a disproportionately high number of recaptures to catches. The result was an underestimate of smallmouth bass abundance in the upper reservoir in 1984. The estimate of smallmouth bass abundance in the lower reservoir in 1984 was significantly less than in 1985. Anglers were not surveyed in the lower reservoir in 1984 and the estimate was not adjusted for removals by anglers. The angler survey in 1985 suggested a substantial harvest of smallmouth bass by anglers in the John Day forebay and John Day River. Failure to account for a harvest of similar magnitude in 1984 would result in an underestimate of abundance (Seber 1982).

Smaller diameter tags used in 1985 did not reduce tag loss over 1984. While it appears that loss of tags during sampling is inherent with externally applied tags, the present method of tagging appears to be superior to T-anchor type tags.

A single year class dominated the walleye catch, whereas several year classes contributed significantly to northern squawfish and smallmouth bass catches. The 1979 year class has comprised the majority of walleye caught in John Day Reservoir since 1980 (Nigro et al. 1985b). The relative strength of the 1979 year class of walleye is nearly twice that of the next strongest year class (Figure 16). The 1981 and 1982 year classes dominated northern squawfish catches and are the strongest year classes since 1975 (Figure 29). Since these year classes were not fully recruited to our gear (Figure 26), their large contribution to the catch may not reflect their true abundance relative to fully recruited year classes. Year-class composition of smallmouth bass catches was similar to that of 1984 (Nigro et al. 1985b). The 1982 year class was again dominant in both the lower and upper reservoir. The 1980 year class was much less prevalent in the upper reservoir, indicating low survival between 1984 and 1985 (Table 13).

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REFERENCES

Bagenal, T.B. and F.W. Tesch. 1978. Age and growth. Pages 101-136 in T. Bagenal, editor. Methods for assessment of fish production in fresh waters. International Biological Programne Publications Committee Handbook Number 3. Blackwell Scientific Publications, Oxford, England.

El-Zarka, S.E. 1959. Fluctuations in the population of yellow perch, Perca flavescens (Mitchill) in Saginaw Bay, Lake Huron. USFWS Fishery Bulletin 151.

Gray, G.A., G.M. Sonnevil, H.C. Hansel, C.W. Huntington, and D.E. Palmer. 1986. Feeding activity, rate of consumption, daily ration, and prey selection of major predators in the John Day Pool. Annual Report to Bonneville Power Administration by U.S. Fish and Wildlife Service, Contract Number DI-AI79-82BP34796, Portland OR, USA.

Hile, R. 1941. Age and growth of the rock bass, Ambloplites rupestris (Rafinesque), in Nebish Lake, Wisconsin. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. 33:189-337.

Jearld, W.E. 1983. Age determination. Pages 301-324 in L.A. Nielsen and D.L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda MD, USA.

Nigro, A.A., C.F. Willis, R.C. Beamesderfer, J.C. Elliott, and B.L. Uremovich. 1985. Abundance and distribution of walleye, northern squawfish and smallmouth bass in John Day Reservoir and tailrace, 1983. Annual Report to Bonneville Power Administration by Oregon Department of Fish and Wildlife, Contract Number DE-A179-82BP35097, Portland OR, USA.

Nigro, A.A., C.F. Willis, R.C. Beamesderfer, J.C. Elliott, M.P. Faler, L. M. Miller, and B.L. Uremovich. 1985. Abundance and distribution of walleye, northern squawfish and smallmouth bass in John Day Reservoir 1984. Annual Report to Bonneville Power Administration by Oregon Department of Fish and Wildlife, Contract Number DE-AI79-82BP3097, Portland OR, USA.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, Number 191.

Seber, G.A.F. 1982. The estimation of animal abundance and related paramaters. Second edition. MacMillan Publishing Co., Inc. New York NY, USA.

Sokal, R.R. and F.J. Rohlf. 1981. Biometry. Second edition. W.F. Freeman and Co. San Francisco CA, USA.

Willis, C.F., A.A. Nigro, B.L. Uremovich, J.C. Elliott, and W.J. Knox. 1985. Abundance and distribution of northern squawfish and walleye in John Day Reservoir and tailrace, 1982. Annual Report to Bonneville Power Administration by Oregon Department of Fish and Wildlife, Contract Number DE-AI79-82BP35097, Portland OR, USA.

Youngs, W.D. and D.S. Robson. 1978. Estimation of population number and mortality rates. Pages 137-164 in T. Bagenal, editor. Methods for assessment of fish production in fresh water. International Biological Programme Publications Committee Handbook Number 3. Blackwell Scientific Publications, Oxford, England.

APPENDIX A

Sanpling Periods, Sampling Effort, Catch, Catch Per Unit Effort and Gear Specific Length-Frequency Distributions

Table A.l. **Dates corresponding to sampling periods, March 24-September 2, 1985.**

Sampling period	Beginning date	Ending date
7	Mar 24	Apr 6
8	Apr 7	Apr 20
9	Apr 21	May 4
10	May 5	May 18
11	May 19	Jun 1
12	Jun 2	Jun 15
13	Jun 16	Jul 6[a]
14	Jul 7	Jul 20
15	Jul 21	Aug 3
16	Aug 4	Aug 17
17	Aug 18	Sep 2

[a]Includes 1 week break.

Table A.2. Distribution of sampling effort (in hours) by area, gear and period, John Day Reservoir, March 24-September 2, 1985.

Area Gear	Period											
	7	8	9	10	11	12	13	14	15	16	17	Sum
John Day forebay												
Bottom gill net	2	39	38	24	24	21	21	23	24	27	18	271
USFWS[a] gill net	0	0	25	0	0	0	0	0	0	0	0	25
Vertical gill net	0	0	0	0	0	0	23	0	0	70	0	93
Trap net	6	144	183	141	142	139	184	148	183	140	143	1553
Trap net lead	0	145	184	142	143	139	185	149	183	140	144	1554
ODFW[b] electrofisher	1	2	0	5	1	6	0	0	0	6	0	21
USFWS electrofisher	0	0	18	0	15	4	18	14	2	0	15	86
Forebay to Arlington												
USFWS electrofisher	0	0	0	0	0	0	0	0	16	0	0	16
Arlington												
Bottom gill net	3	24	25	24	32	25	22	26	27	18	24	250
USFWS gill net	0	0	22	0	16	0	36	0	0	0	53	127
Trap net	0	281	279	253	281	209	277	323	280	283	275	2741
Trap net lead	0	282	280	254	282	210	277	296	282	284	276	2723
ODFW electrofisher	0	5	0	5	0	3	0	0	0	0	0	13
USFWS electrofisher	0	0	30	0	36	0	36	0	4	0	20	126
Arlington to Paterson												
Bottom gill net	0	0	0	0	192	0	193	0	0	0	0	385
Surface gill net	0	0	0	0	31	0	0	0	0	0	0	31
USFWS gill net	0	0	0	0	0	0	0	27	0	0	0	27
ODFW electrofisher	0	0	0	0	2	0	1	0	12	0	2	17
USFWS electrofisher	0	0	0	0	0	0	0	0	3	0	0	3
Irrigon-Paterson												
Bottom gill net	2	16	24	24	22	19	22	22	22	22	22	217
USFWS gill net	0	53	0	84	3	66	1	0	0	73	0	280
Trap net	0	183	181	276	277	280	279	276	276	255	277	2560
Trap net lead	0	185	184	278	279	281	280	278	277	279	278	2599
ODFW electrofisher	0	0	7	0	4	0	6	6	0	2	6	31
USFWS electrofisher	0	19	0	21	0	21	0	0	0	18	0	79
McNary tailrace												
Bottom gill net	4	21	23	22	17	20	22	21	25	19	22	216
USFWS gill net	0	50	0	52	3	34	1	0	0	33	0	173
Trap net	0	212	281	213	216	208	273	204	274	209	206	2296
Trap net lead	0	215	282	215	217	209	275	206	276	210	207	2312
ODFW electrofisher	0	0	5	0	5	0	6	5	0	0	6	27
USFWS electrofisher	1	9	0	10	0	15	0	0	4	9	0	48
USFWS trawl	0	6	0	5	0	7	0	0	0	2	0	20
McNary tailrace BRZ[c]												
Bottom gill net	0	2	1	0	0	0	0	1	0	3	1	8
USFWS gill net	0	12	0	6	0	26	0	0	0	17	0	61
ODFW electrofisher	0	0	1	0	1	0	0	1	0	0	2	5
USFWS electrofisher	0	6	0	3	0	4	0	2	1	2	0	18
Angling	0	8	12	9	10	14	20	13	30	12	8	136
All												
Bottom gill net	21	102	111	94	287	85	280	93	98	89	87	1347
Surface gill net	0	0	0	0	31	0	0	0	0	0	0	31
USFWS gill net	0	115	47	142	22	126	38	27	0	123	53	693
Vertical gill net	0	0	0	0	0	0	23	0	0	70	0	93
Trap net	6	820	924	883	916	836	1013	951	1013	887	901	9150
Trap net lead	0	827	930	889	921	839	1017	929	1018	913	905	9188
ODFW electrofisher	1	7	13	10	13	9	14	12	12	8	16	115
USFWS electrofisher	1	34	48	34	51	44	54	16	14	29	35	360
Angling	0	8	12	9	10	14	20	13	30	12	8	136
USFWS trawl	0	6	0	5	0	7	0	0	0	2	0	20

[a]U.S. Fish and Wildlife Service.
[b]Oregon Department of Fish and Wildlife.
[c]Boat restricted zone.

Table A.3. Total catch (and catch per hour) of walleye (>250 mm), northern squawfish (>250 mm) and smallmouth bass (>200 mm) by gear and area, John Day Reservoir, March 24-September 2, 1985. Dashes indicate no effort.

Species Gear	Area All	John Day forebay	Forebay to Arlington	Arlington	Arlington-Paterson	Irrigon-Paterson	McNary tailrace	McNary tailrace BRZ[a]
Walleye								
Bottom gill net (sm mesh)	218 (0.32)	0	--	7 (0.06)	3 (0.11)	61 (0.22)	142 (0.82)	5 (0.08)
Bottom gill net (lg mesh)	163 (0.12)	2 (0.01)	--	12 (0.05)	21 (0.05)	41 (0.19)	86 (0.40)	1 (0.13)
Surface gill net	0	--	--	--	0	--	--	0
Vertical gill net	0	0	--	--	--	--	--	--
Trap net	40 (d)	--	--	1 (d)	--	20 (0.01)	19 (0.01)	--
Trap net lead	5 (d)	1 (d)	--	0	--	0	4 (d)	--
ODFW[b] electrofisher	75 (0.66)	1 (d)	--	0	0	4 (0.13)	68 (2.52)	2 (0.40)
USFWS[c] electrofisher	88 (0.23)	0	0	5 (0.04)	0	25 (0.32)	51 (1.05)	7 (0.37)
Angling	0	0	--	--	--	--	--	0
USFWS trawl	53 (2.68)	--	--	--	--	--	53 (2.68)	--
Angler survey	50	0	--	--	8	23	15	0
Total	692	4	0	25	32	174	438	15
Northern squawfish								
Bottom gill net (sm mesh)	1809 (1.34)	450 (1.66)	--	298 (1.20)	223 (0.61)	334 (1.53)	482 (2.22)	12 (1.57)
Bottom gill net (lg mesh)	118 (0.17)	11 (0.44)	--	48 (0.38)	0	24 (0.09)	8 (0.05)	27 (0.44)
Surface gill net	10 (0.32)	--	--	--	10 (0.32)	--	--	--
Vertical gill net	5 (0.05)	5 (0.05)	--	--	--	--	--	--
Trap net	465 (0.05)	123 (0.08)	--	82 (0.03)	--	176 (0.07)	84 (0.04)	--
Trap net lead	769 (0.08)	78 (0.05)	--	81 (0.03)	--	331 (0.13)	279 (0.12)	--
ODFW electrofisher	483 (4.24)	43 (2.09)	--	17 (1.37)	18 (1.00)	46 (1.48)	104 (3.85)	255 (51.00)
USFWS electrofisher	1138 (3.02)	238 (2.77)	31 (1.98)	137 (1.09)	3 (0.93)	70 (0.89)	92 (1.90)	567 (30.30)
Angling	298 (2.19)	--	--	--	--	--	--	298 (2.19)
USFWS trawl	25 (1.27)	--	--	--	--	--	25 (1.27)	--
Angler survey	8	3	--	--	0	4	0	1
Total	5128	958	31	663	264	985	1074	1160
Smallmouth bass								
Bottom gill net (sm mesh)	184 (0.13)	52 (0.19)	--	38 (0.15)	38 (0.10)	21 (0.09)	34 (0.15)	1 (0.13)
Bottom gill net (lg mesh)	29 (0.04)	0	--	19 (0.15)	0	8 (0.03)	1 (0.01)	1 (0.02)
Surface gill net	3 (0.10)	--	--	--	3 (0.10)	--	--	--
Vertical gill net	0	0	--	--	--	--	--	--
Trap net	63 (0.01)	22 (0.01)	--	13 (d)	--	9 (d)	19 (0.01)	--
Trap net lead	24 (d)	11 (0.01)	--	2 (d)	--	6 (d)	5 (d)	--
ODFW electrofisher	705 (6.18)	196 (9.51)	--	108 (8.71)	177 (9.84)	198 (6.39)	26 (0.96)	0
USFWS electrofisher	1205 (3.20)	363 (4.22)	66 (4.23)	482 (3.82)	15 (4.67)	242 (3.08)	34 (0.70)	3 (0.16)
Angling	0	--	--	--	--	--	--	0
USFWS trawl	0	--	--	--	--	--	0	--
Angler survey	505	449	--	--	7	24	21	3
Total	2718	1093	66	662	240	508	140	8

[a]Boat restricted zone
[b]Oregon Department of Fish and Wildlife
[c]U.S. Fish and Wildlife Service
[d]Catch per hour <0.005

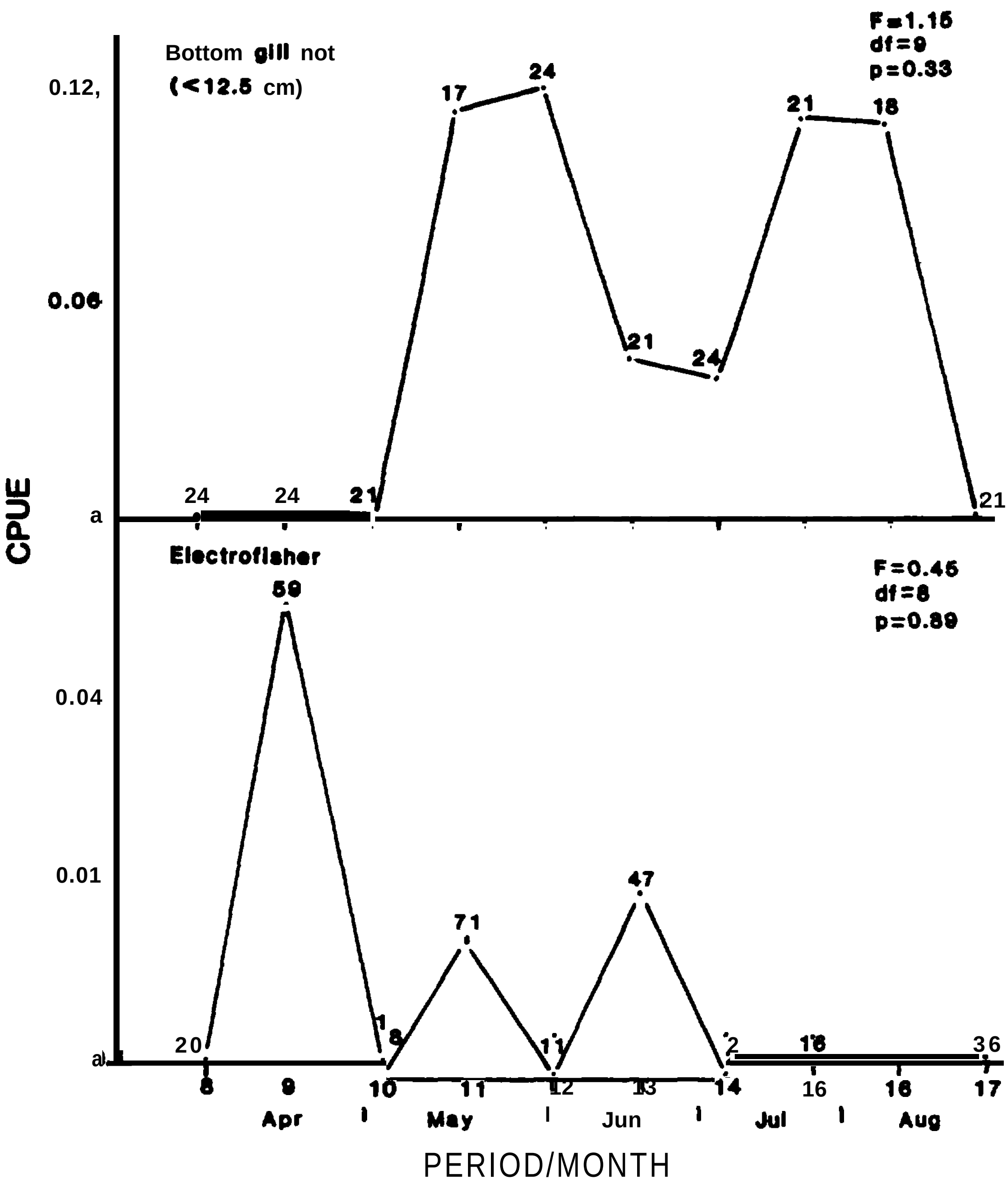

Figure A.1. Catch per unit effort (CPUE) of walleye by gear in Arlington, 1985. Units of effort are net hour (bottom gill net) and 900 seconds current-on time (electrofisher). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

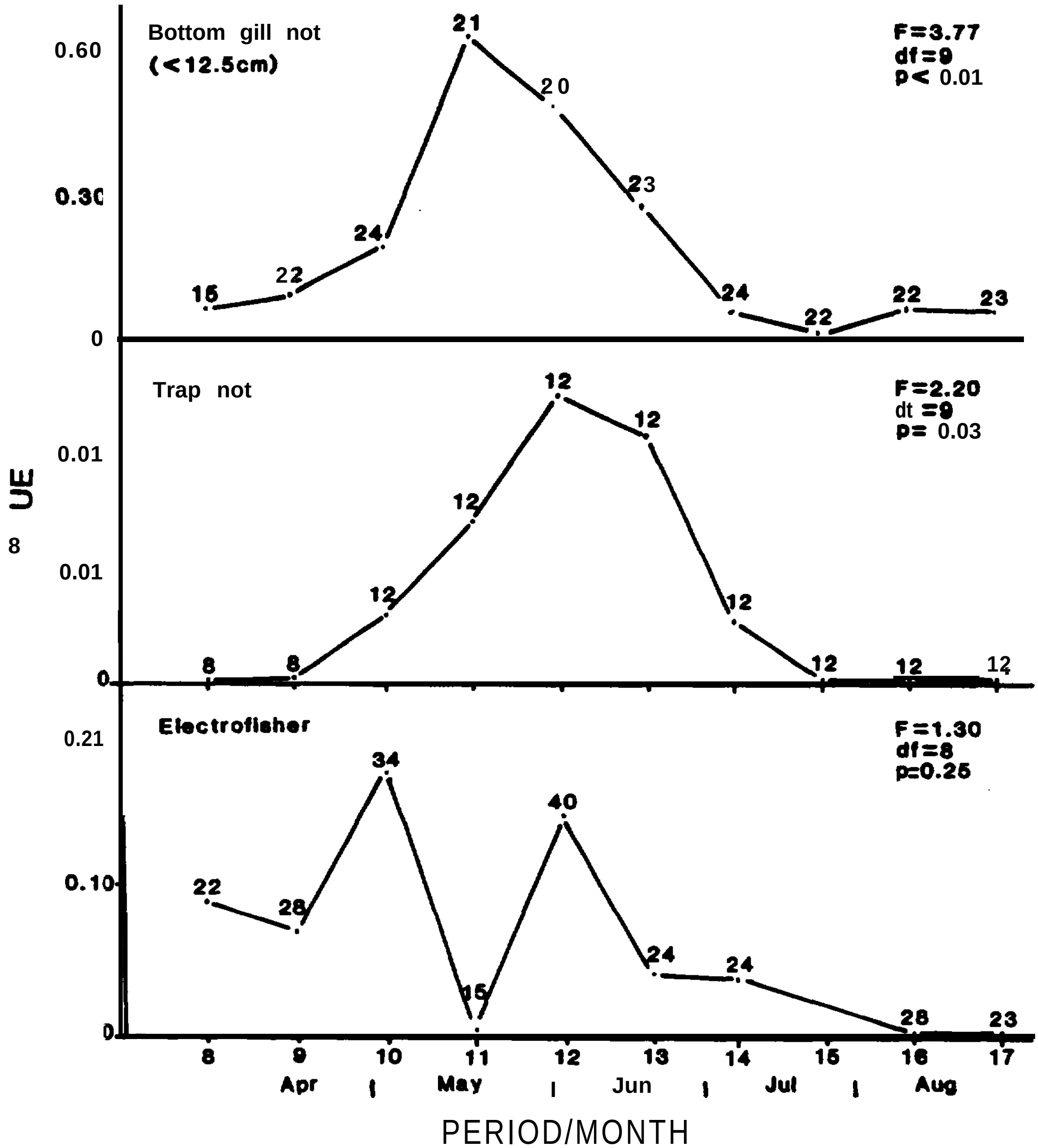

Figure A.2. Catch per unit effort (CPUE) of walleye by gear in Irrigon-Paterson, 1985. Units of effort are net hour (bottom gill net), net day (trap net) and 900 seconds current-on time (electrofisher). Total effort within a period is above each point. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods.

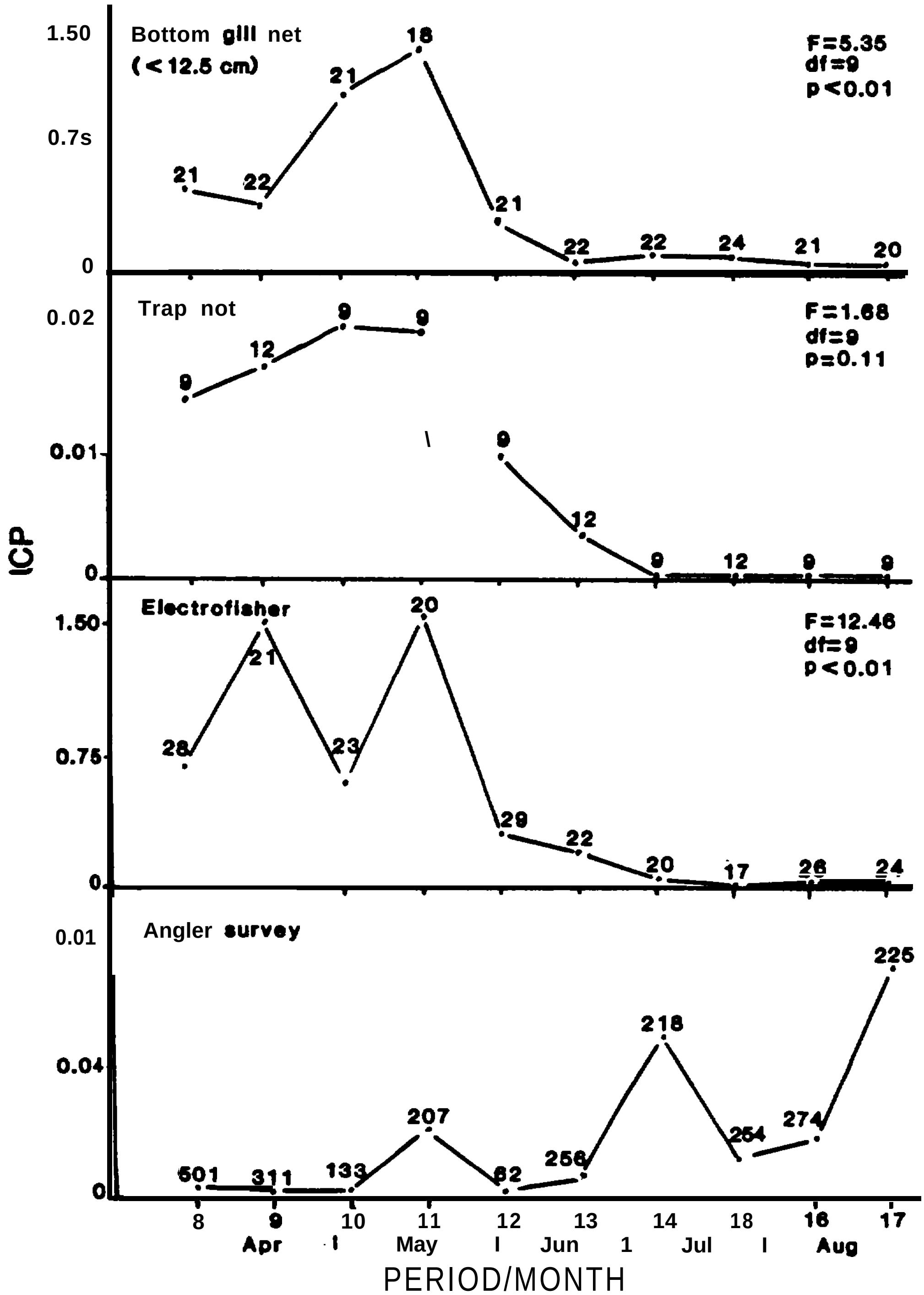

Figure A.3. Catch per unit effort (CPUE) of walleye by gear in McNary tailrace, 1985. Units of effort are net hour (bottom gill net), net day (trap net), 900 seconds current-on time (electrofisher) and angler hour (angler survey). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods where appropriate. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

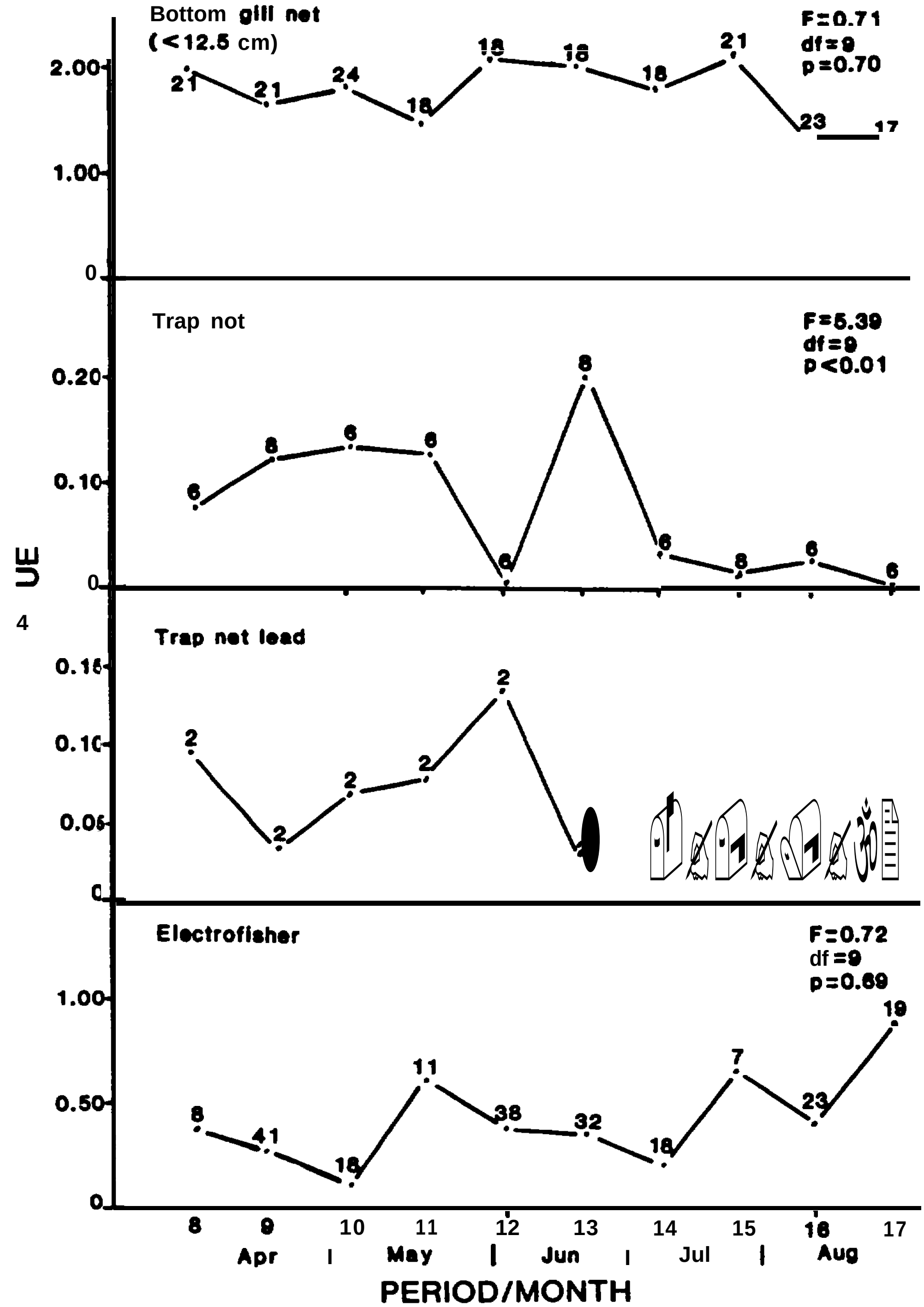

Figure A.4. Catch per unit effort (CPUE) of northern squawfish in John Day forebay, 1985. Units of effort are net hour (bottom gill net), net day (trap net and trap net lead) and 900 seconds current-on time (electrofisher). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods where appropriate. Maximum (<12.5 cm) mesh size of bottom gill nets is in parenthesis.

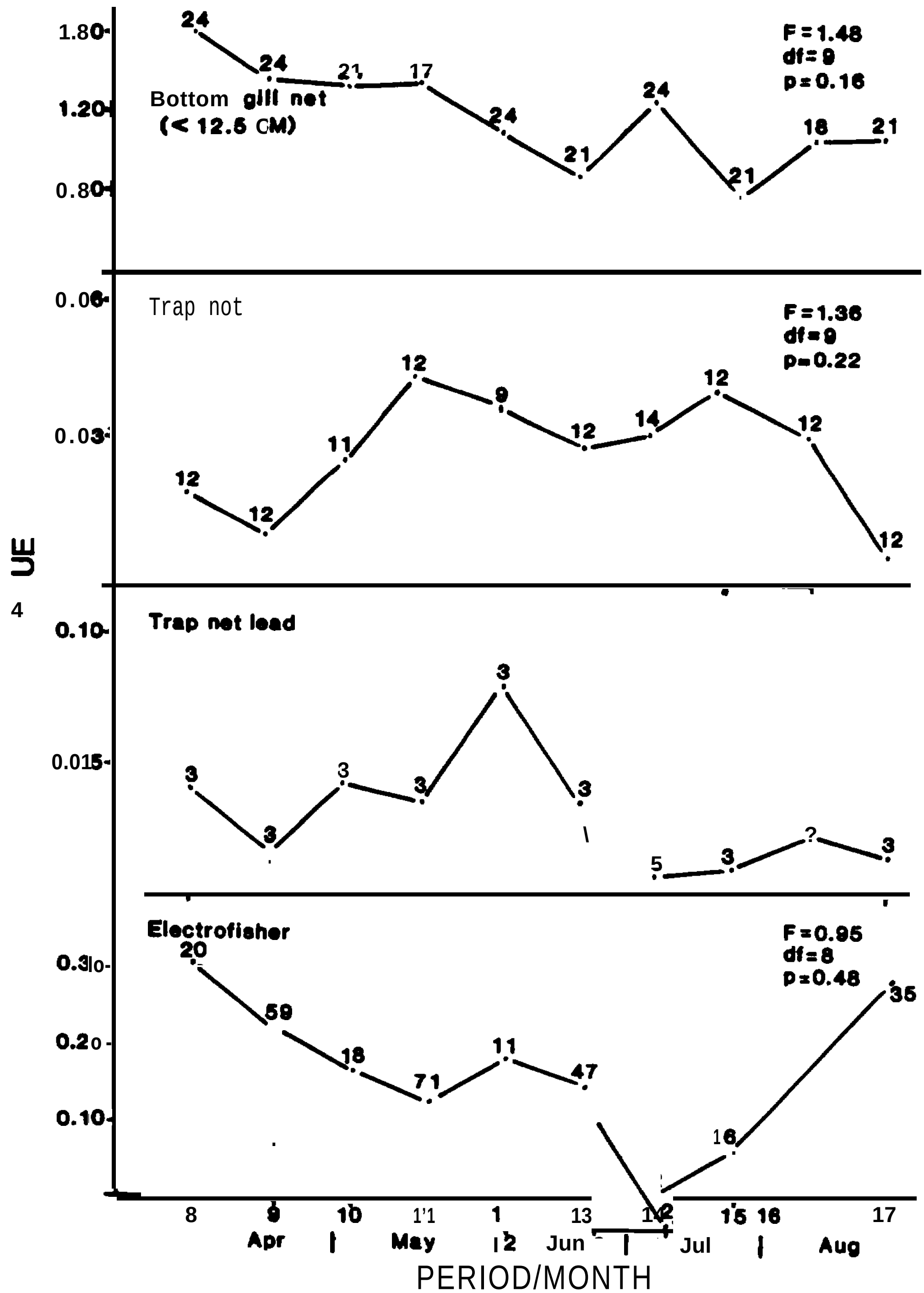

Figure A.5. Catch per unit effort (CPUE) of northern squawfish by gear in Arlington, 1985. Units of effort are net hour (bottom gill net), net day (trap net and trap net lead) and 900 seconds current-on time (electrofisher). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods where appropriate. Maximum (412.5 cm) mesh size of bottom gill nets is in parentheses.

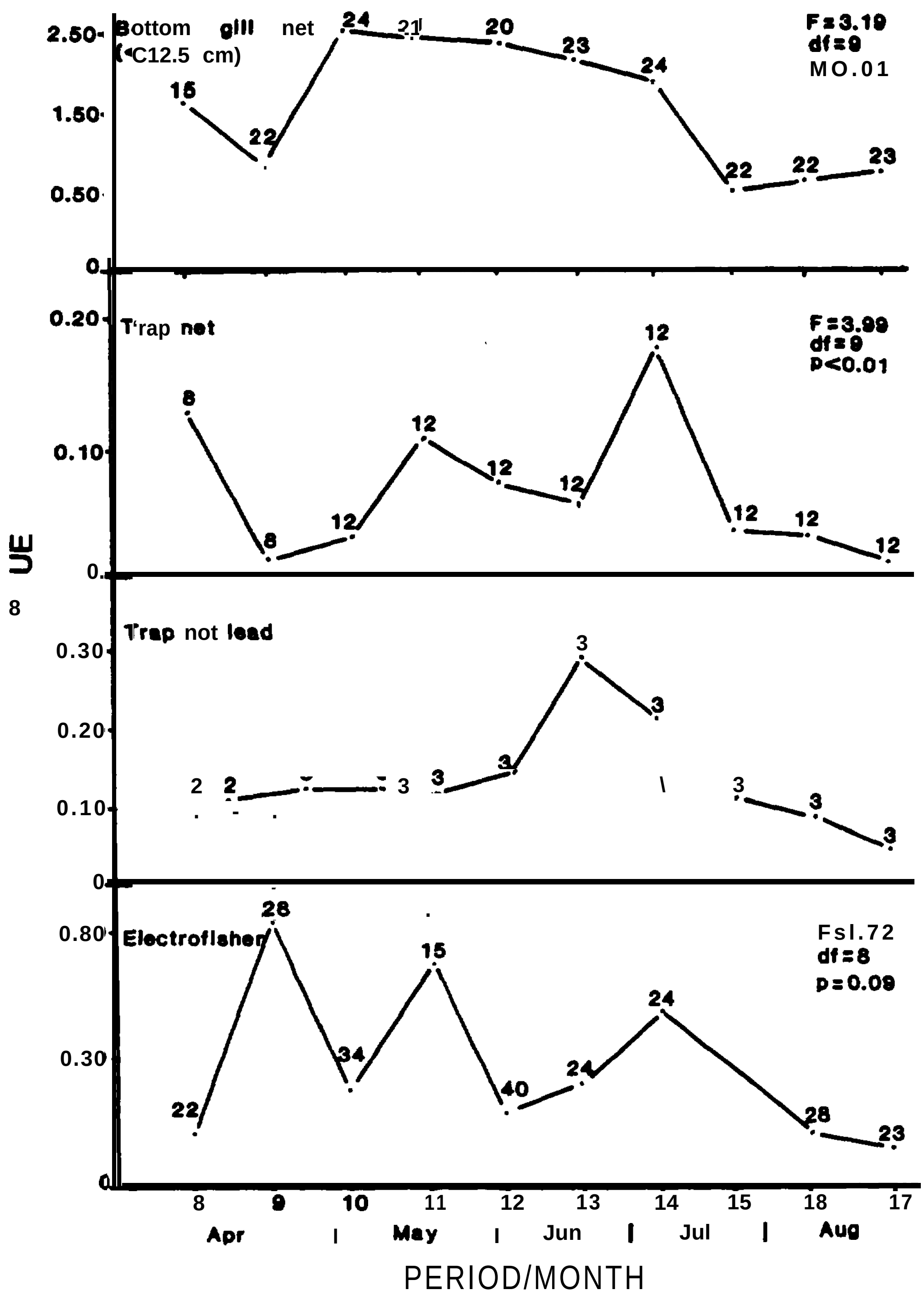

Figure A.6. Catch per unit effort (CPUE) of northern squawfish by gear in Irrigon-Paterson, 1985. Units of effort are net hours (bottom gill net), net day (trap net and trap net lead) and 900 seconds current-on time (electrofisher). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods where appropriate. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

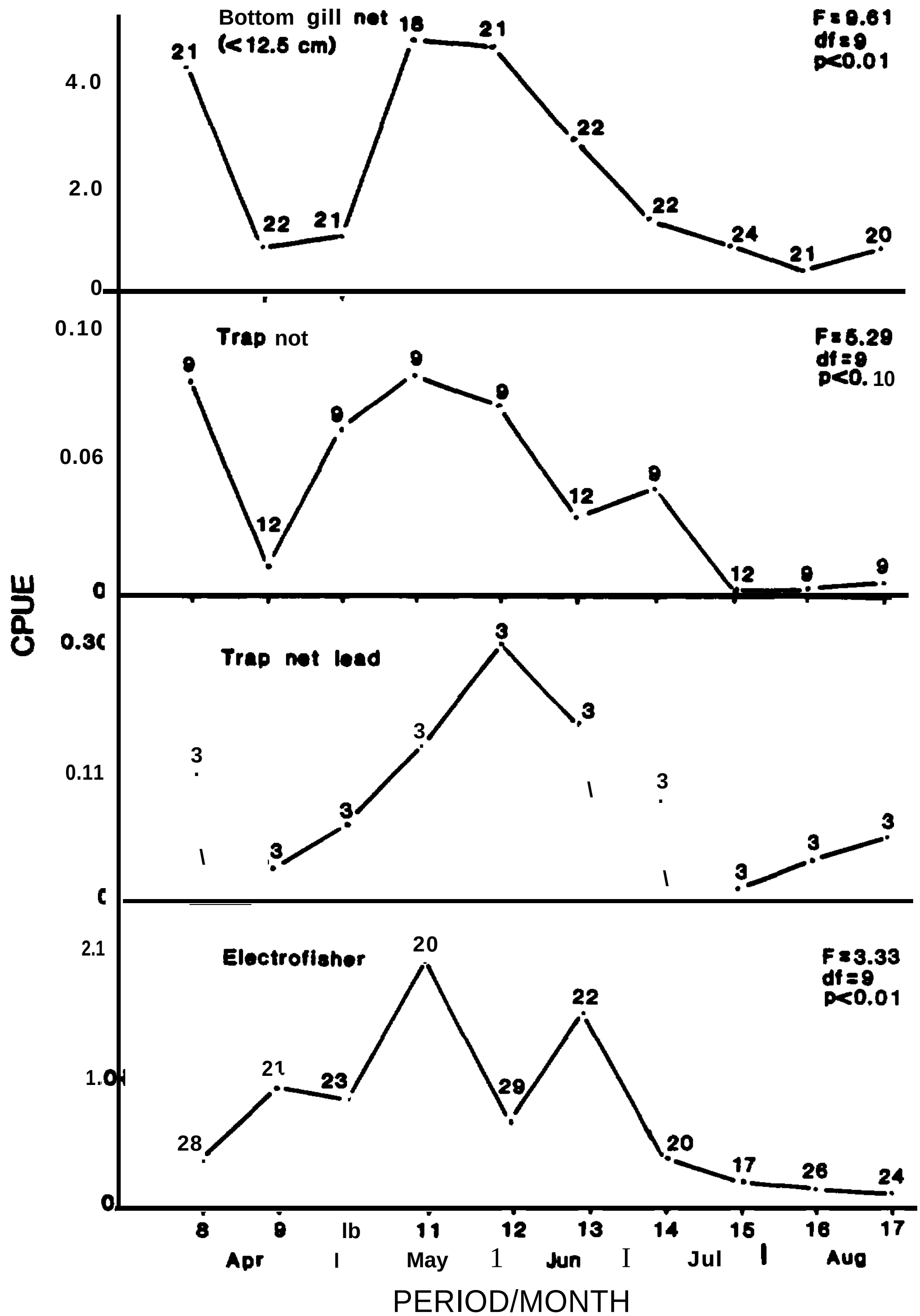

Figure A.7. Catch per unit effort (CPUE) of northern squawfish by gear in McNary tailrace, 1985. Units of effort are net hour (bottom gill net), net day (trap net and trap net lead) and 900 seconds current-on time (electrofisher). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods where appropriate. Maximum (~12.5 cm) mesh size of bottom gill nets is in parentheses.

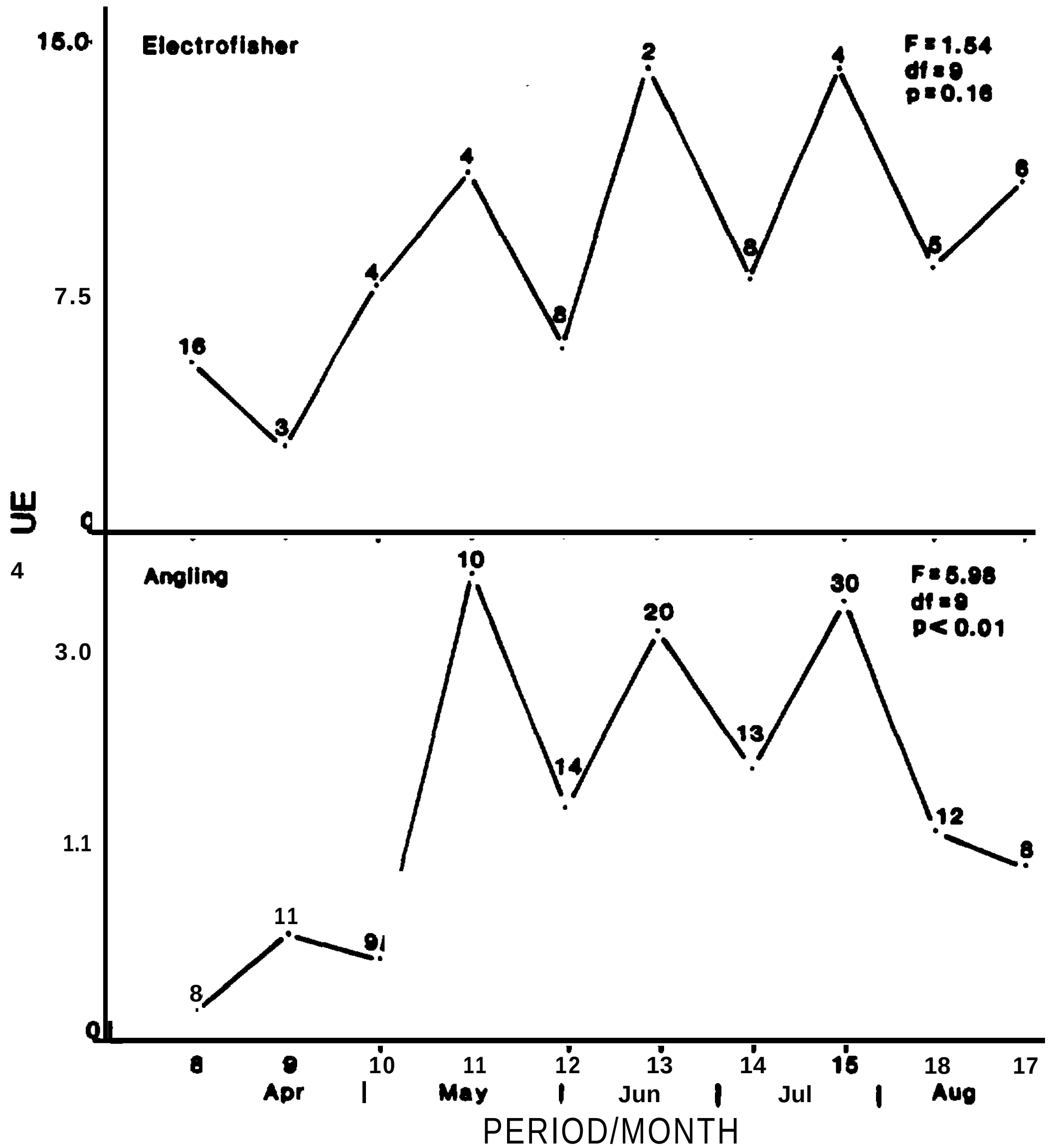

Figure A.8. Catch per unit effort (CPUE) of northern squawfish by gear in McNary tailrace boat-restricted zone, 1985. Units of effort are 900 seconds current-on time (electrofisher) and angler hour (angling). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods.

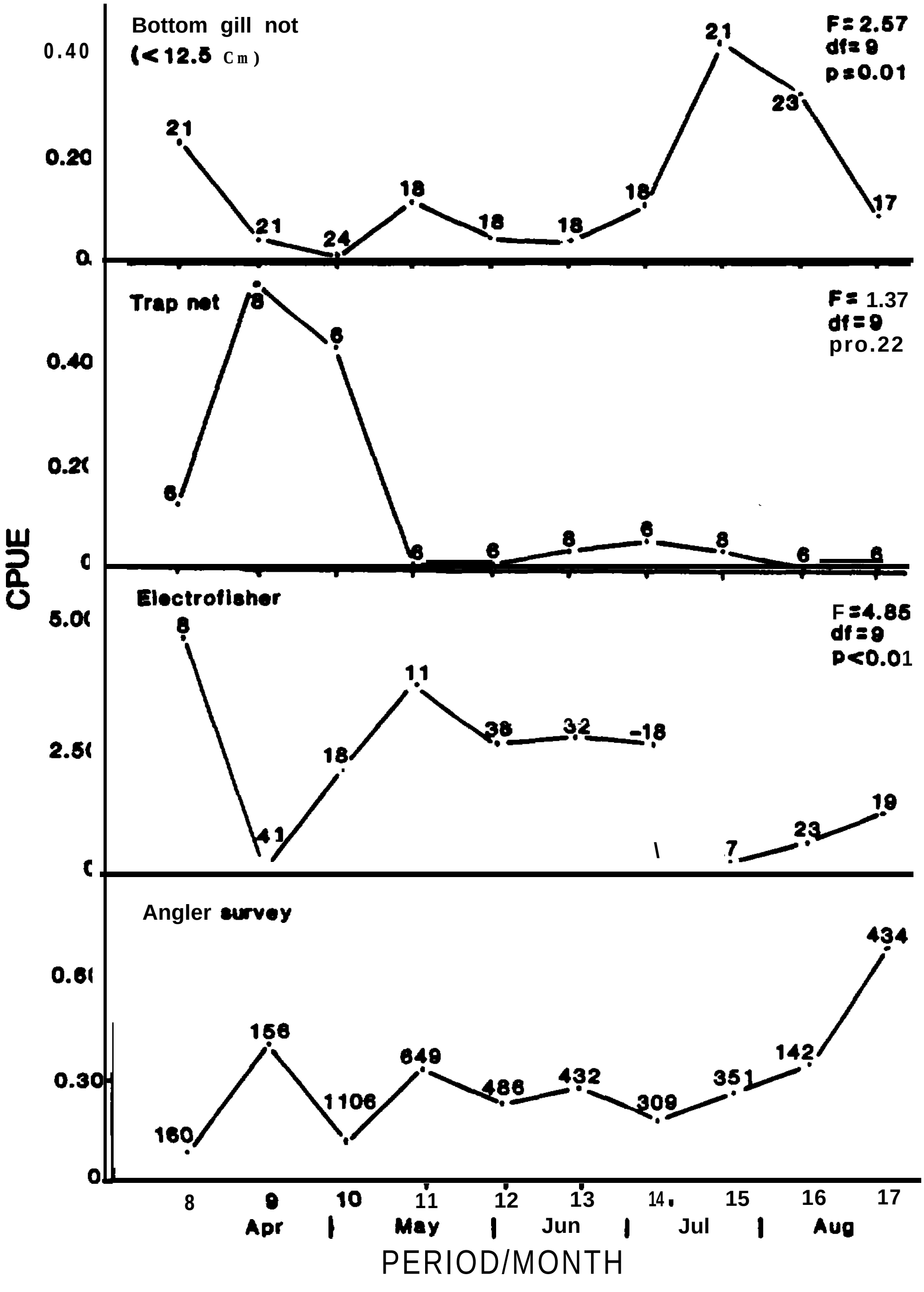

Figure A.9. Catch per unit effort (CPUE) of smallmouth bass by gear in John Day forebay, 1985. Units of effort are net hours (bottom gill net), net day (trap net), 900 seconds current-on time (electrofisher) and angler hours (angler surveys). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

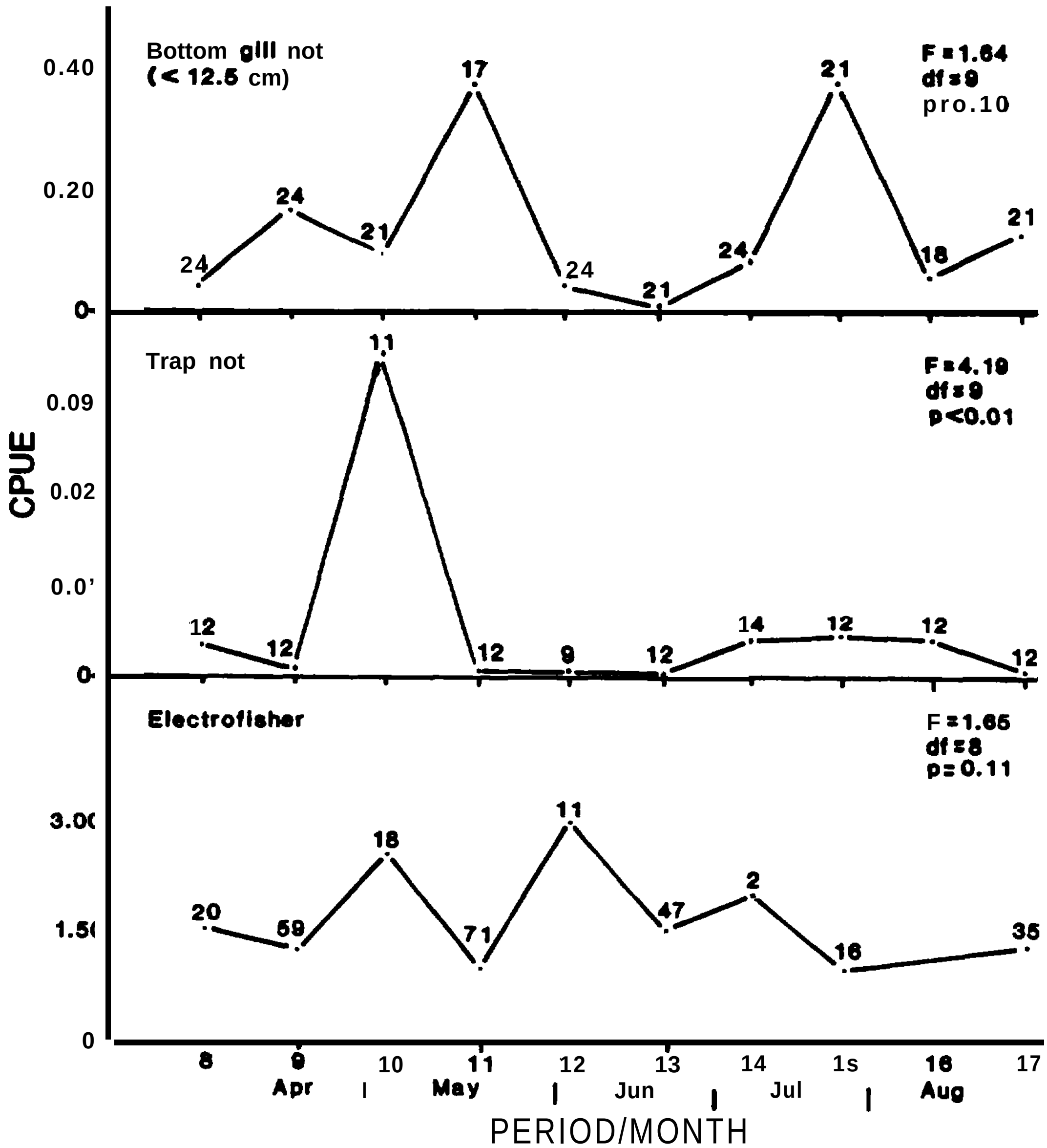

Figure A.10. Catch per unit effort (CPUE) of smallmouth bass by gear in Arlington, 1985. Units of effort are net hours (bottom gill net), net day (trap net) and 900 seconds current-on time (electrofisher). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

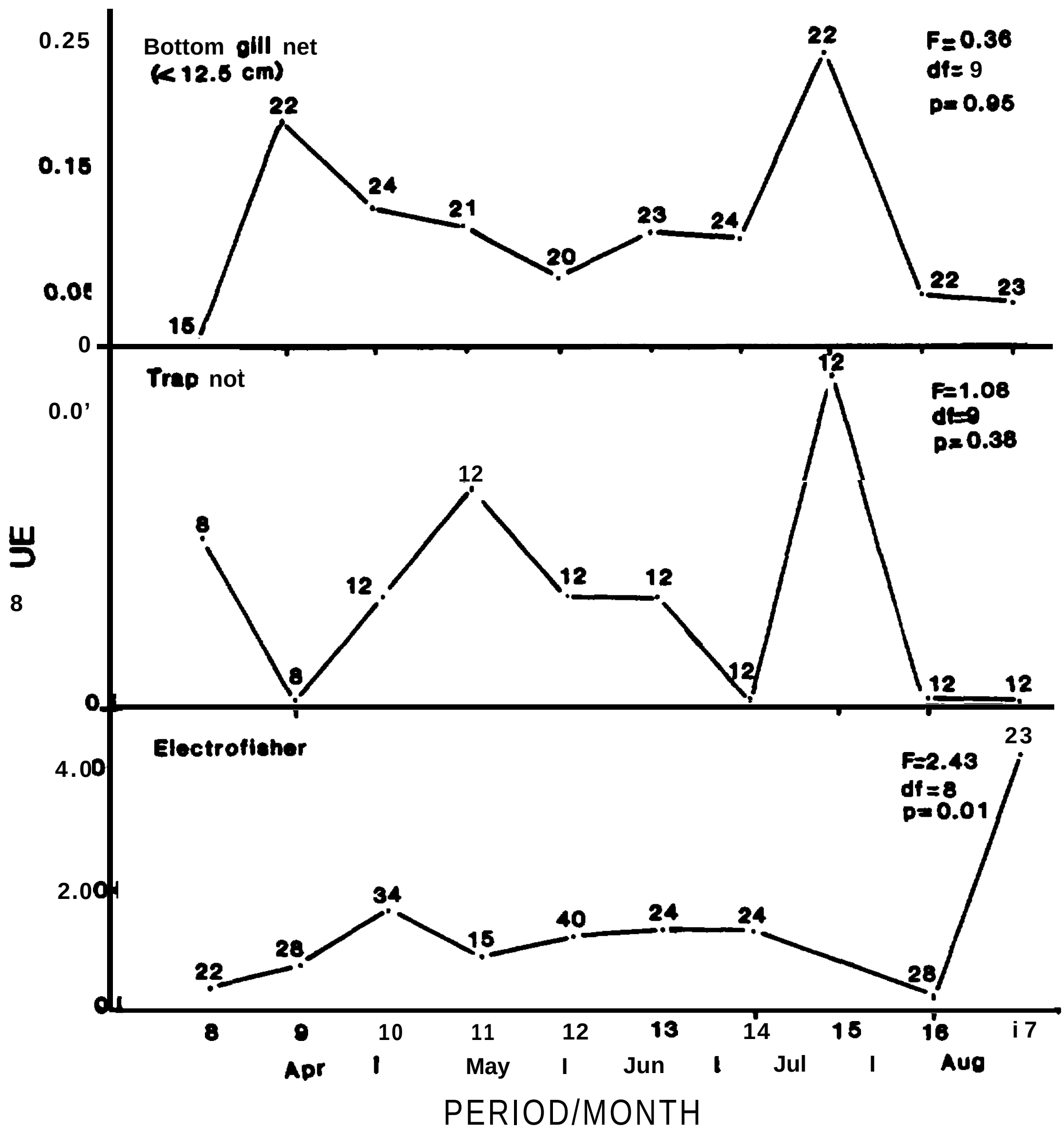

Figure A.11. Catch per unit effort (CPUE) of smallmouth bass by gear in Irrigon-Paterson, 1985. Units of effort are net hours (bottom gill nets), net day (trap net) and 900 seconds current-on time (electrofisher). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests for differences between periods. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

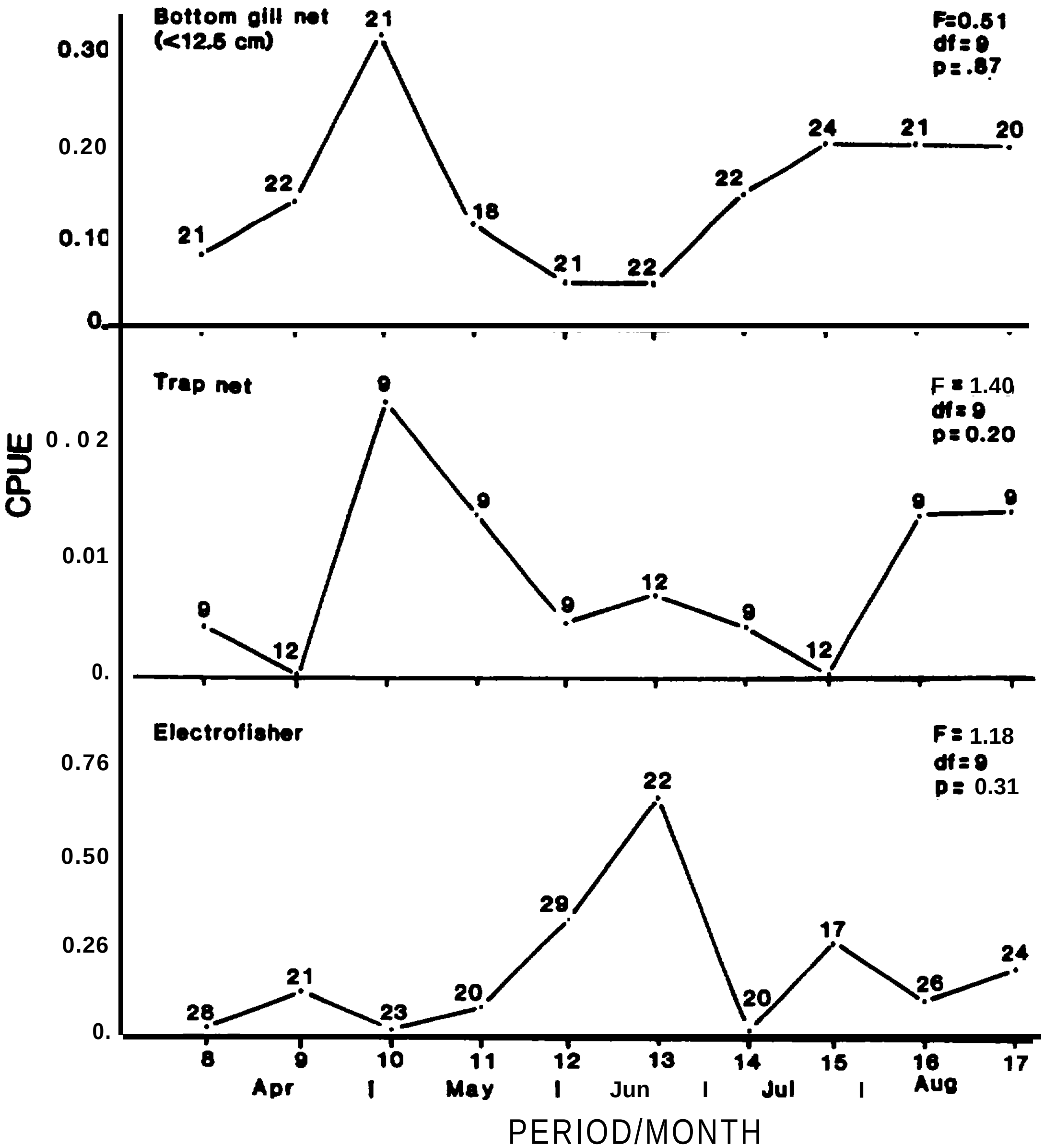

Figure A.12. Catch per unit effort (CPUE) of smallmouth bass by gear in McNary tailrace, 1985. Units of effort are net hour (bottom gill net), net day (trap net) and 900 seconds current-on time (electrofisher). Total effort within a period is above each point. Results of F tests with degrees of freedom and observed probabilities by gear are included for tests fcrdifferences between periods. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

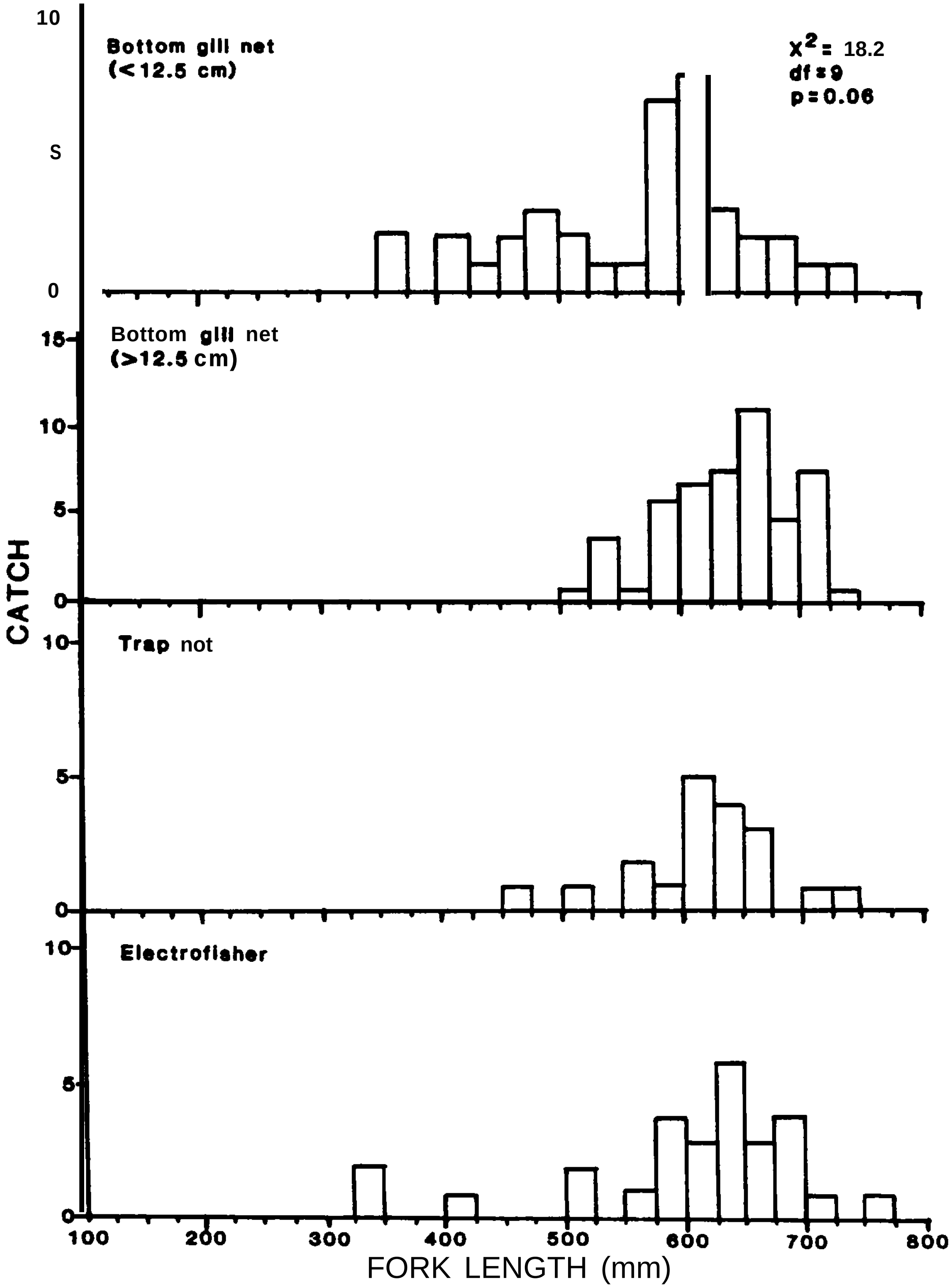

Figure A.13. Length-frequency distributions of walleye collected in Irrigon-Paterson, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum (<12.5 cm) and minimum (>12.5 cm) mesh sizes of bottom gill nets are in parentheses.

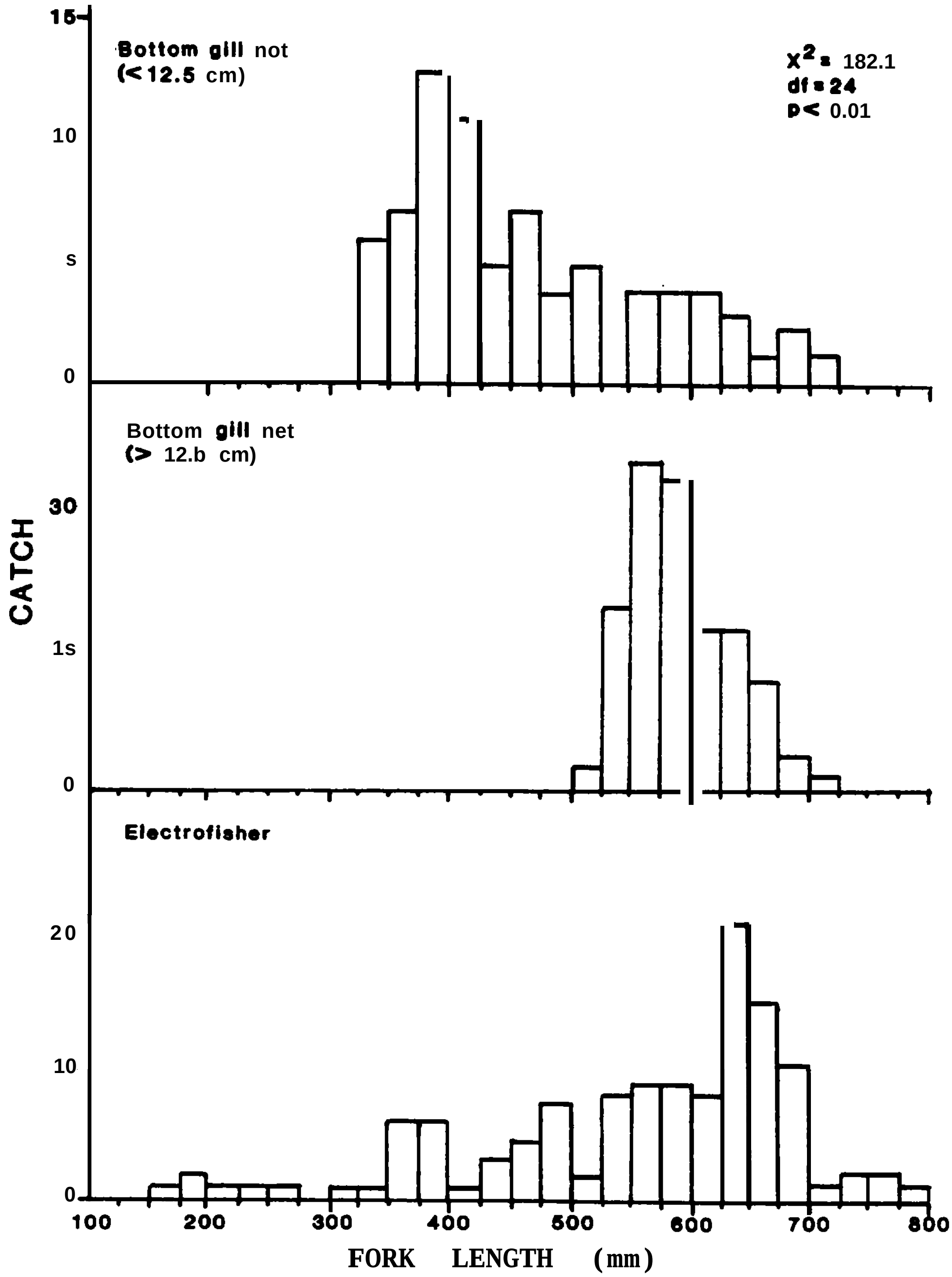

Figure A.14. Length-frequency distributions of walleye collected in McNary tailrace, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum (<12.5 cm) and minimum (>12.5 cm) mesh sizes of bottom gill nets are in parentheses.

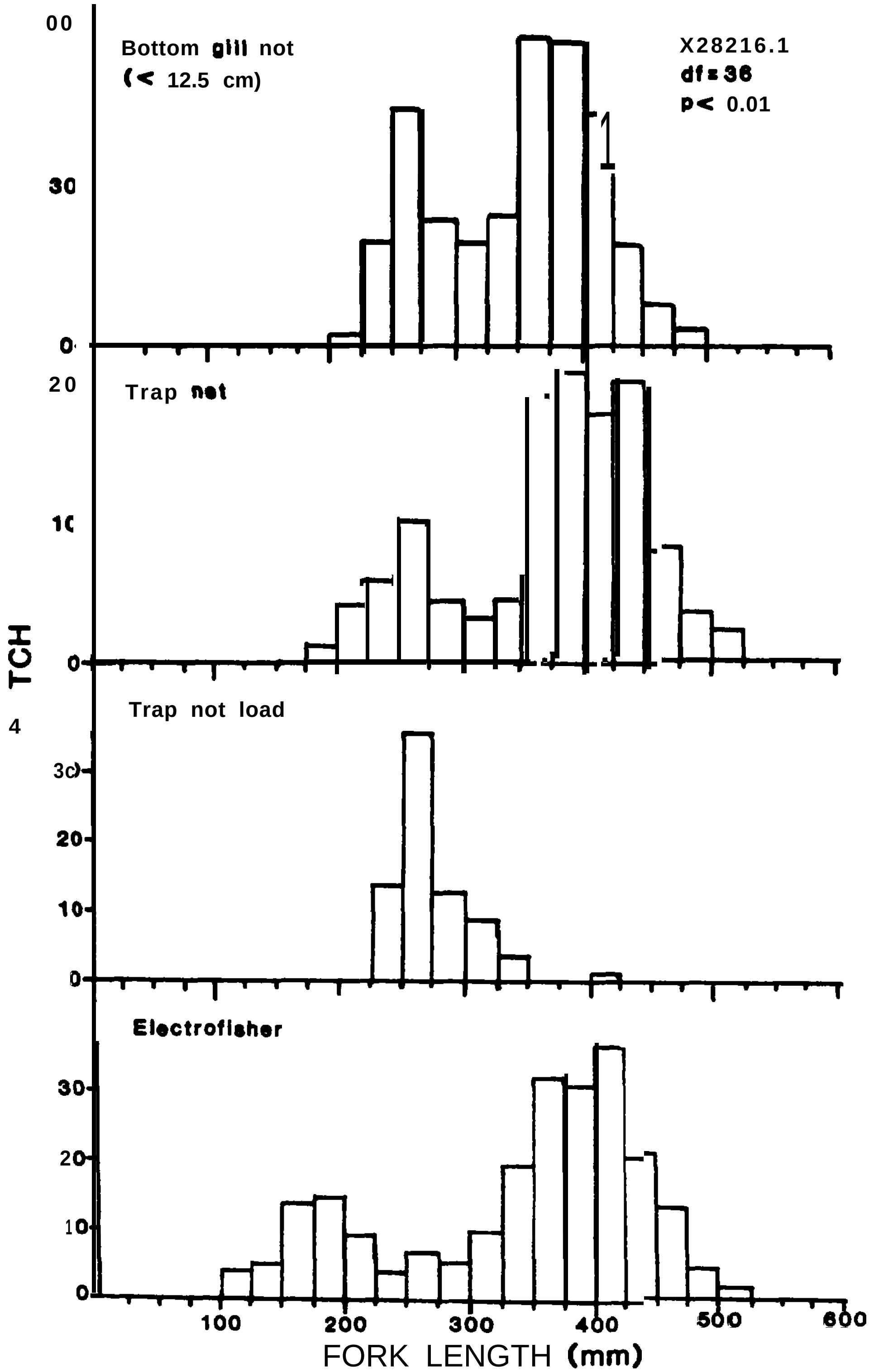

Figure A.15. Length-frequency distributions of northern squawfish collected in John Day forebay, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

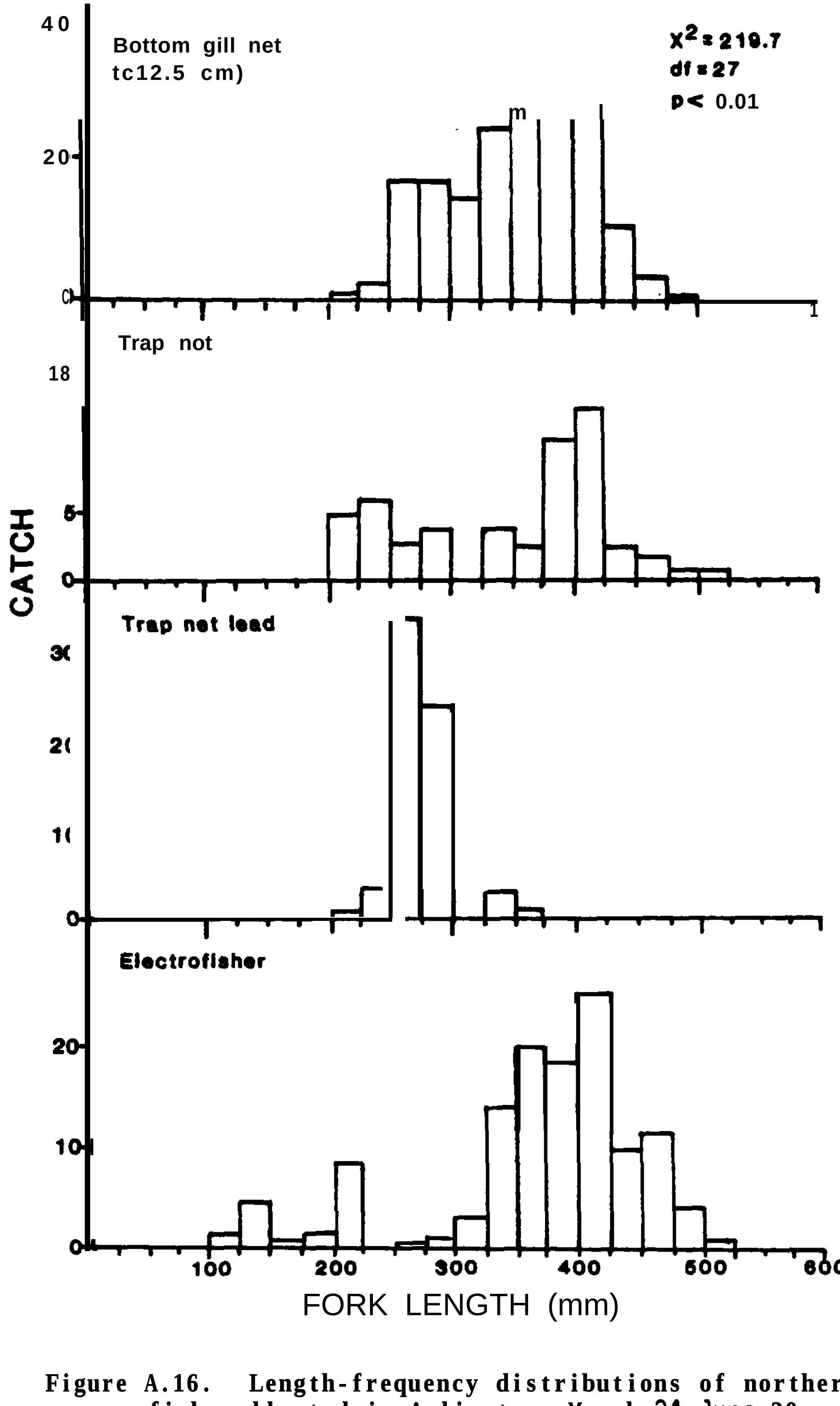

Figure A.16. Length-frequency distributions of northern squawfish collected in Arlington, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

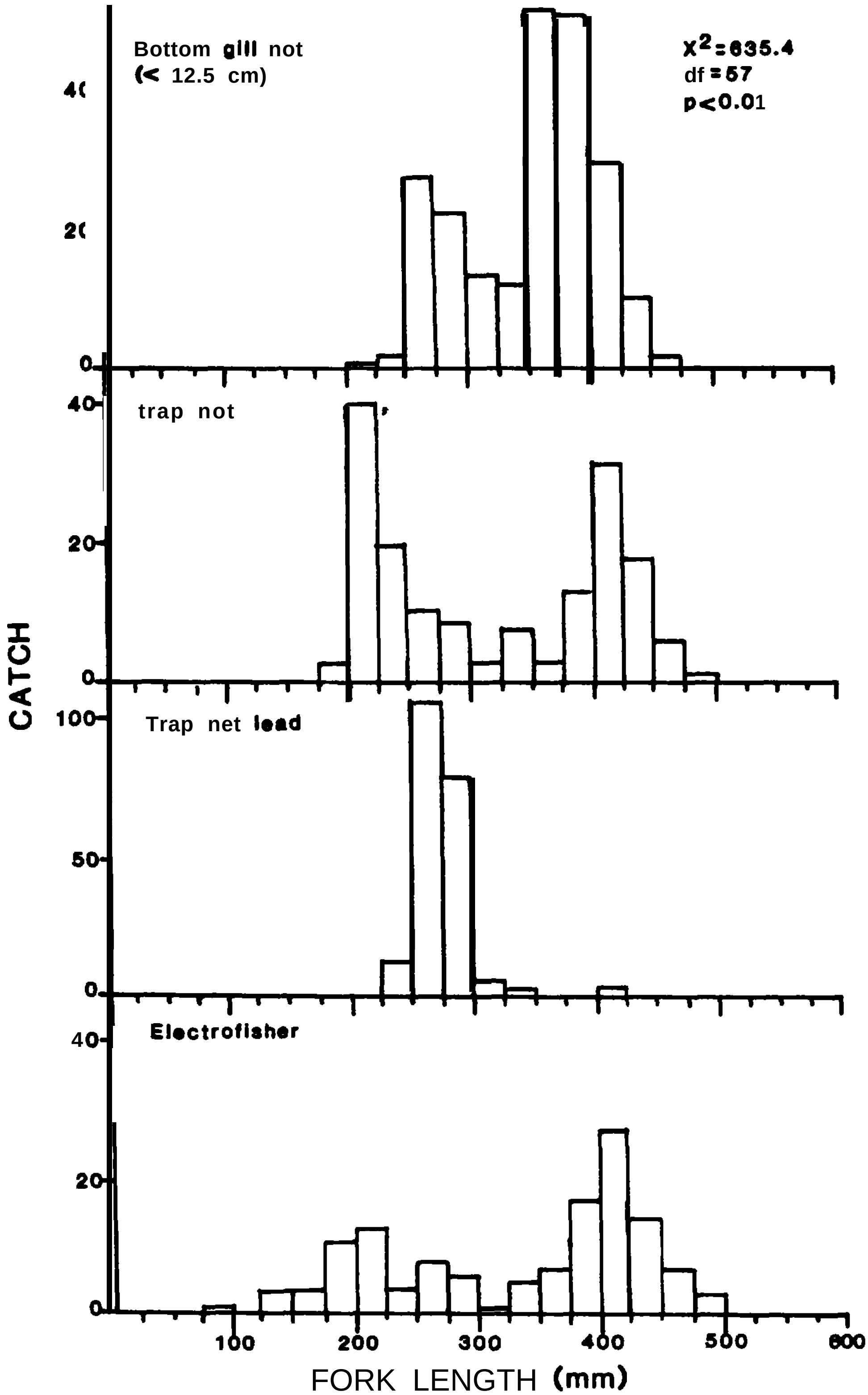

Figure A.17. Length-frequency distributions of northern squawfish collected in Irrigon-Paterson, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

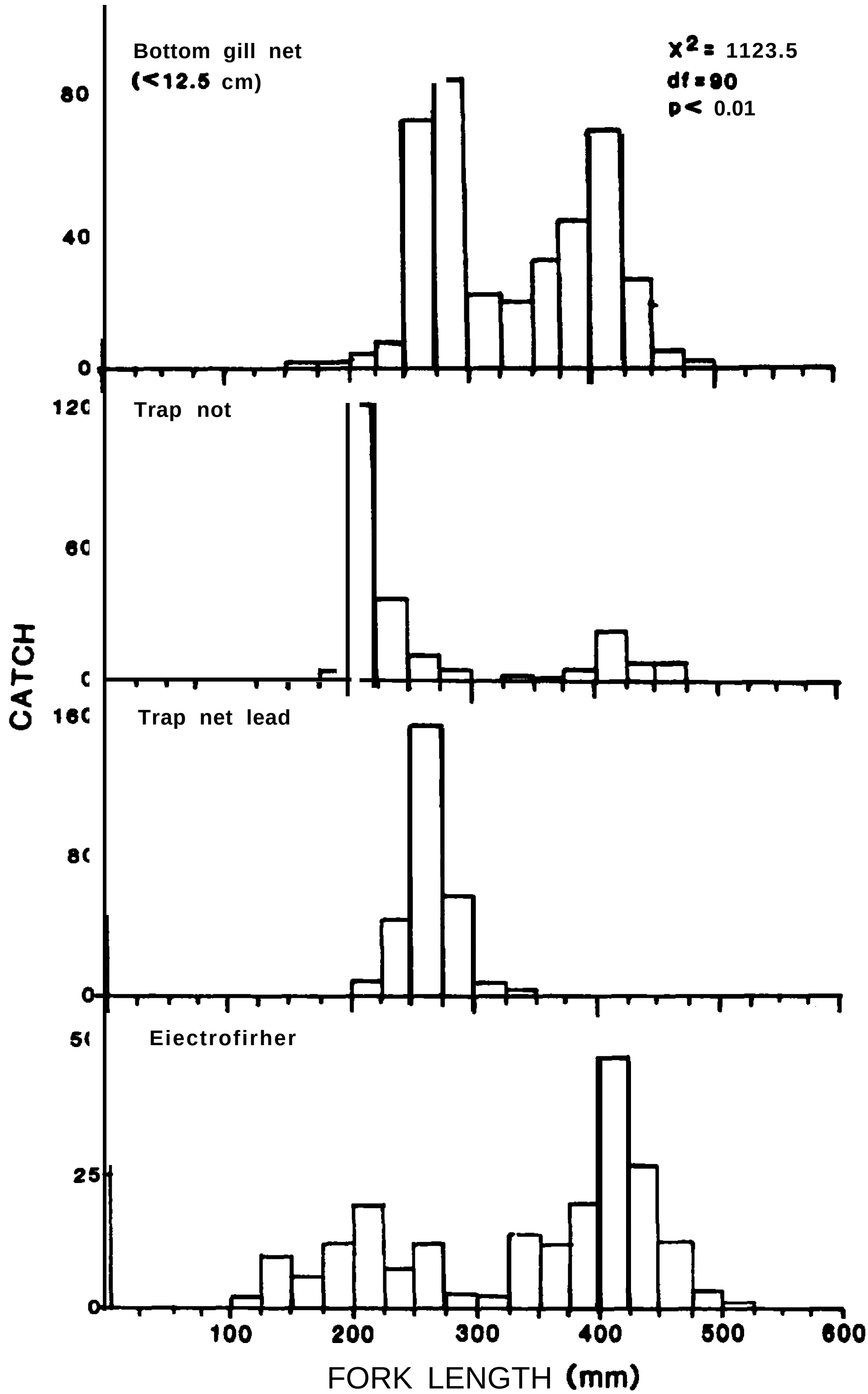

Figure A.18. Length-frequency distributions of northern squawfish collected in McNary tailrace, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum (<12.5 cm) mesh size of bottom gill nets is in parentheses.

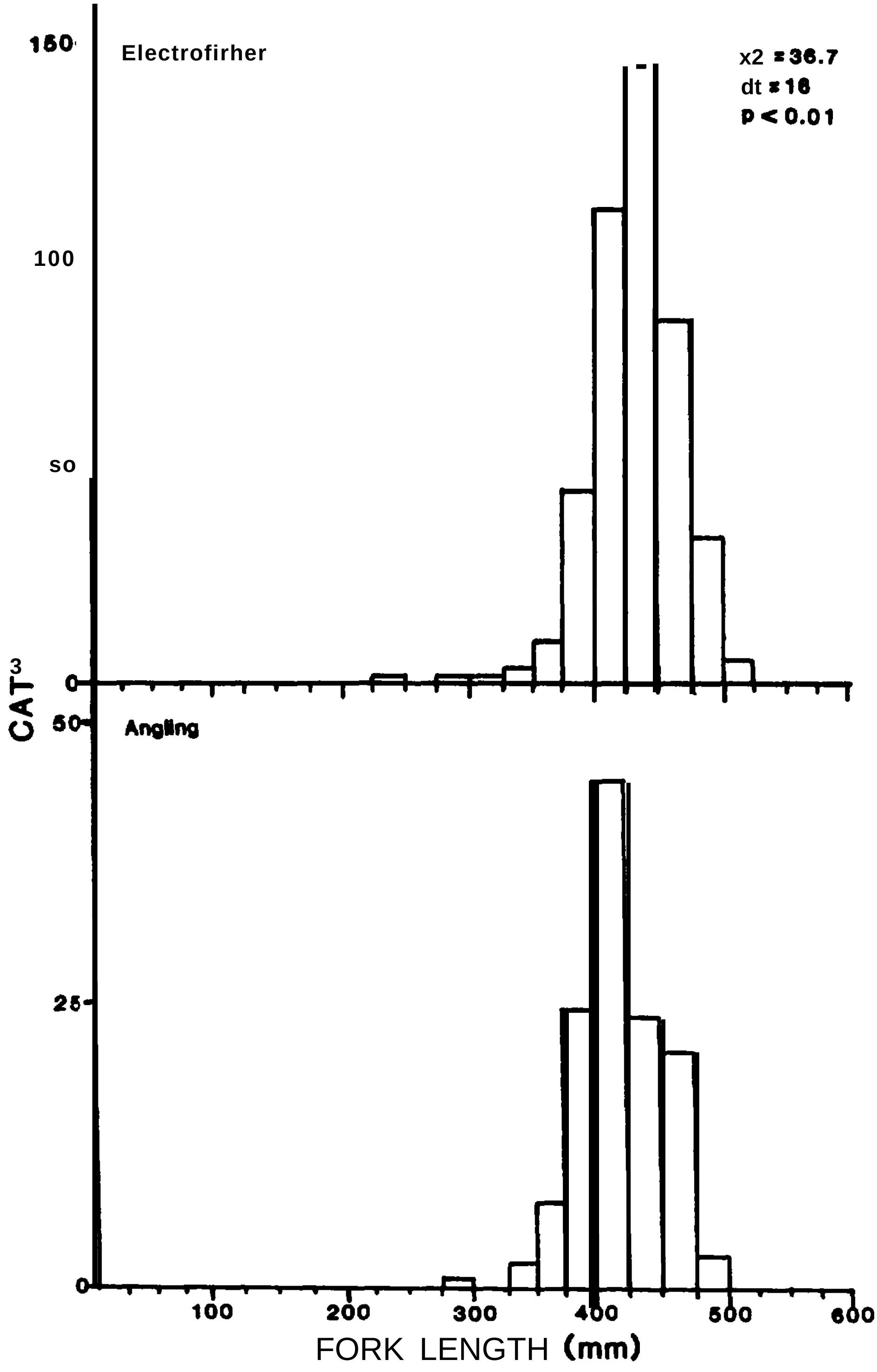

Figure A.19. Length-frequency distributions of northern squawfish collected in McNary tailrace boat-restricted zone, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length.

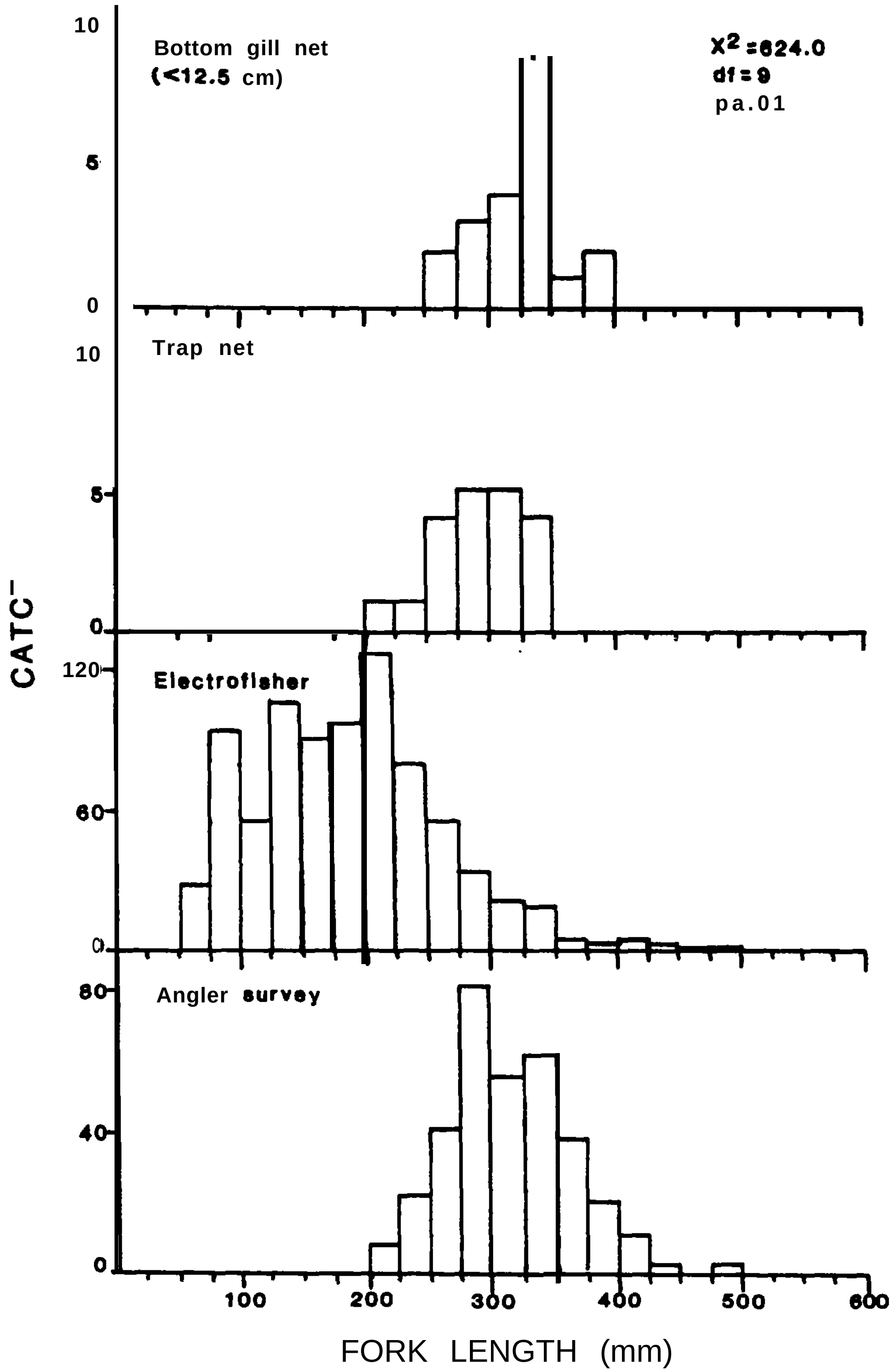

Figure A.20. Length-frequency distributions of small-mouth bass collected in John Day forebay, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum (412.5 cm) mesh size of bottom gill nets is in parentheses.

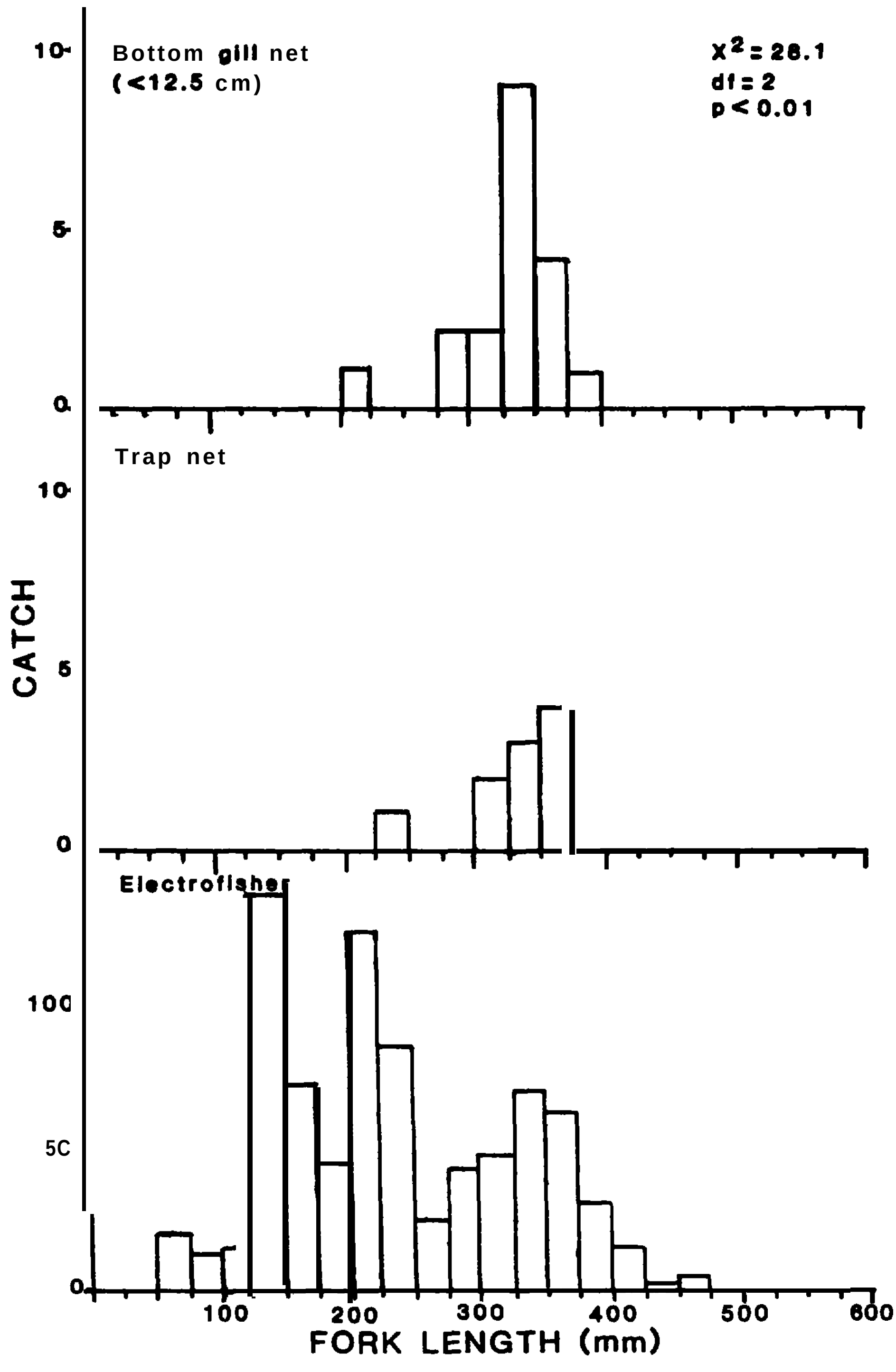

Figure A.21. Length-frequency distributions of smallmouth bass collected in Arlington, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum ((12.5 cm) mesh size of bottom gill nets is in parenthes.

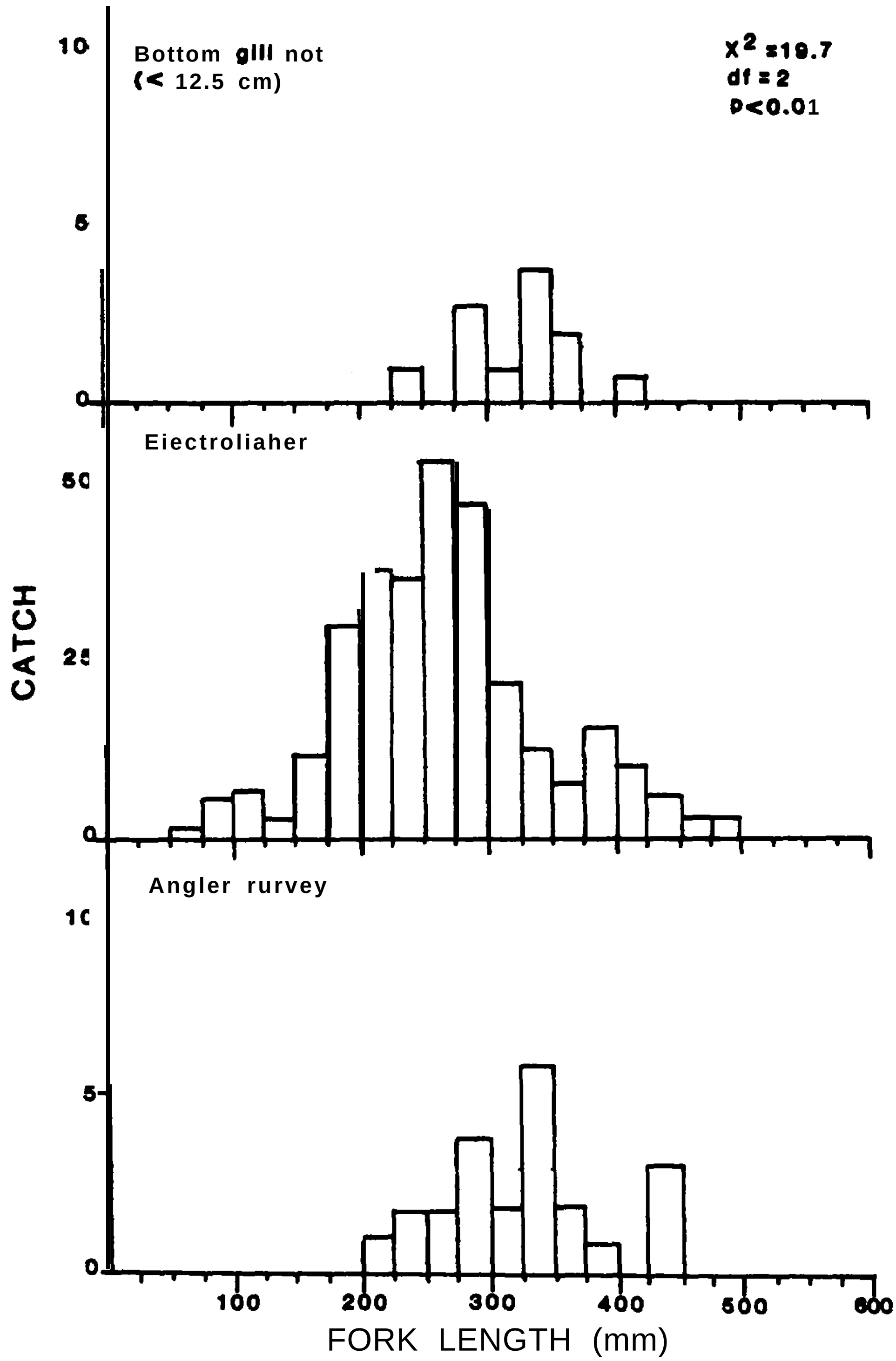

Figure A.22. Length-frequency distributions of small-mouth bass collected in Irrigon-Paterson, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum (<12.5 cm) mesh sizes of bottom gill nets are in parentheses.

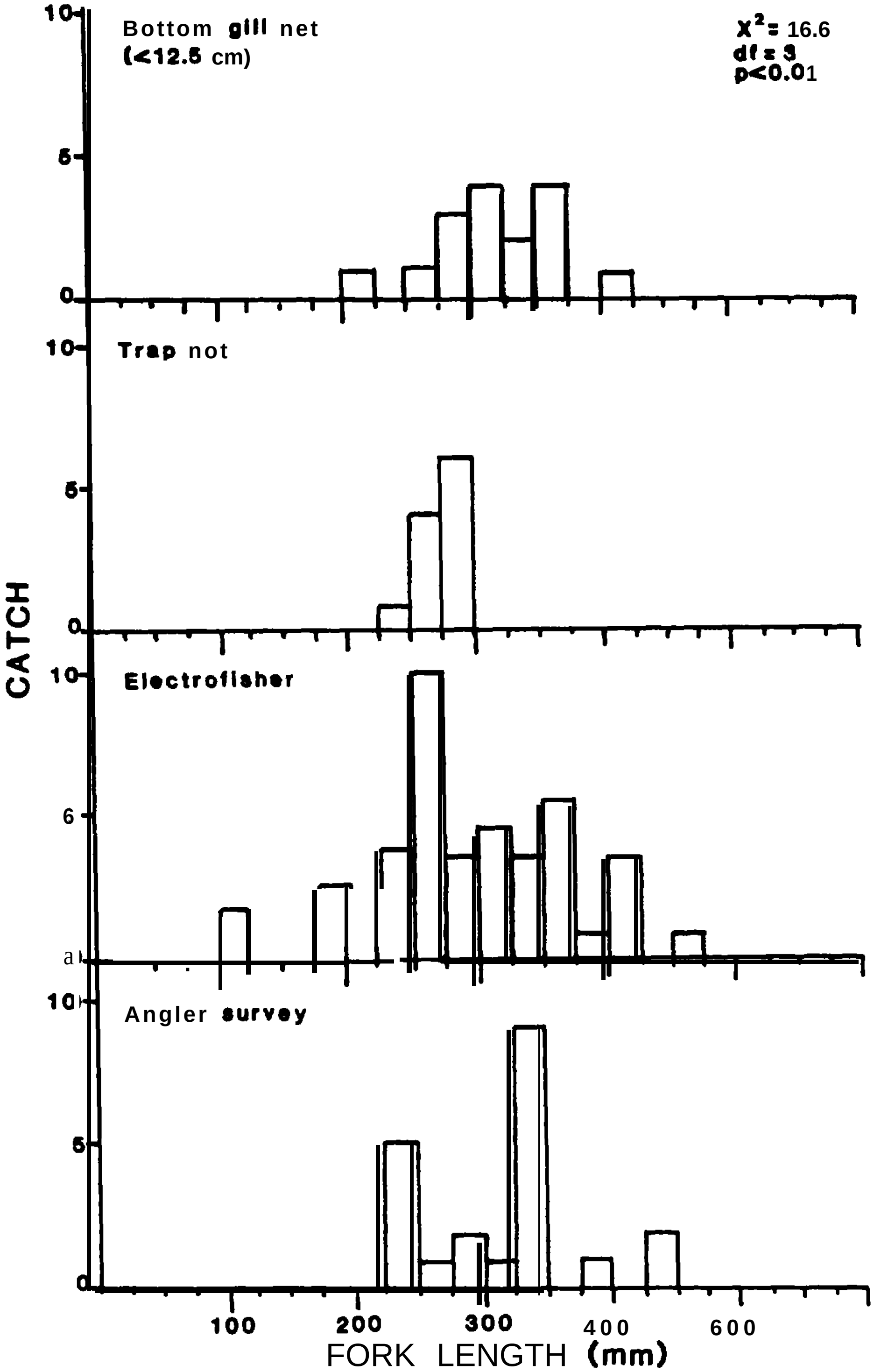

Figure A.23. Length-frequency distributions of smallmouth bass collected in McNary tailrace, March 24-June 30, 1985. Chi-square values with degrees of freedom and observed probabilities are included for tests of independence between gear and length. Maximum (<12.5 cm) mesh sizes of bottom gill nets are in parentheses.

APPENDIX B

Movements of Radiotagged Walleye and Northern Squawfish

Table B.l. Descriptive data on twenty walleye radiotagged and released in McNary tailrace during November and December, 1984.

Transmitter frequency (MHz)	Fork length (mm)	Weight (g)	Release	
			Date	River kilometer
49.614	670	4,300	11-27	465
49.634	631	3,520	11-14	468
49.652	687	4,190	11-15	467
49.673	618	A300	11-16	467
49.682	622	3,060	12-03	469
49.714	678	4,300	11-29	469
49.731	662	3,740	11-20	465
49.801	711	6,050	11-16	468
49,813	693	4,240	11-20	468
49.822	628	3,300	11-19	468
49.832	694	4,970	11-20	468
49.843	602	2,800	11-19	468
49.853	609	2,820	11-29	469
49.902	631	3,580	11-15	468
49.914	756	5,560	11-14	468
49.944	621	3,090	11-14	467
49,954	626	3,260	11-15	469
49.974	662	3,570	11-14	467
49.982	647	3,800	11-15	468
49,993	656	3,390	12-03	469

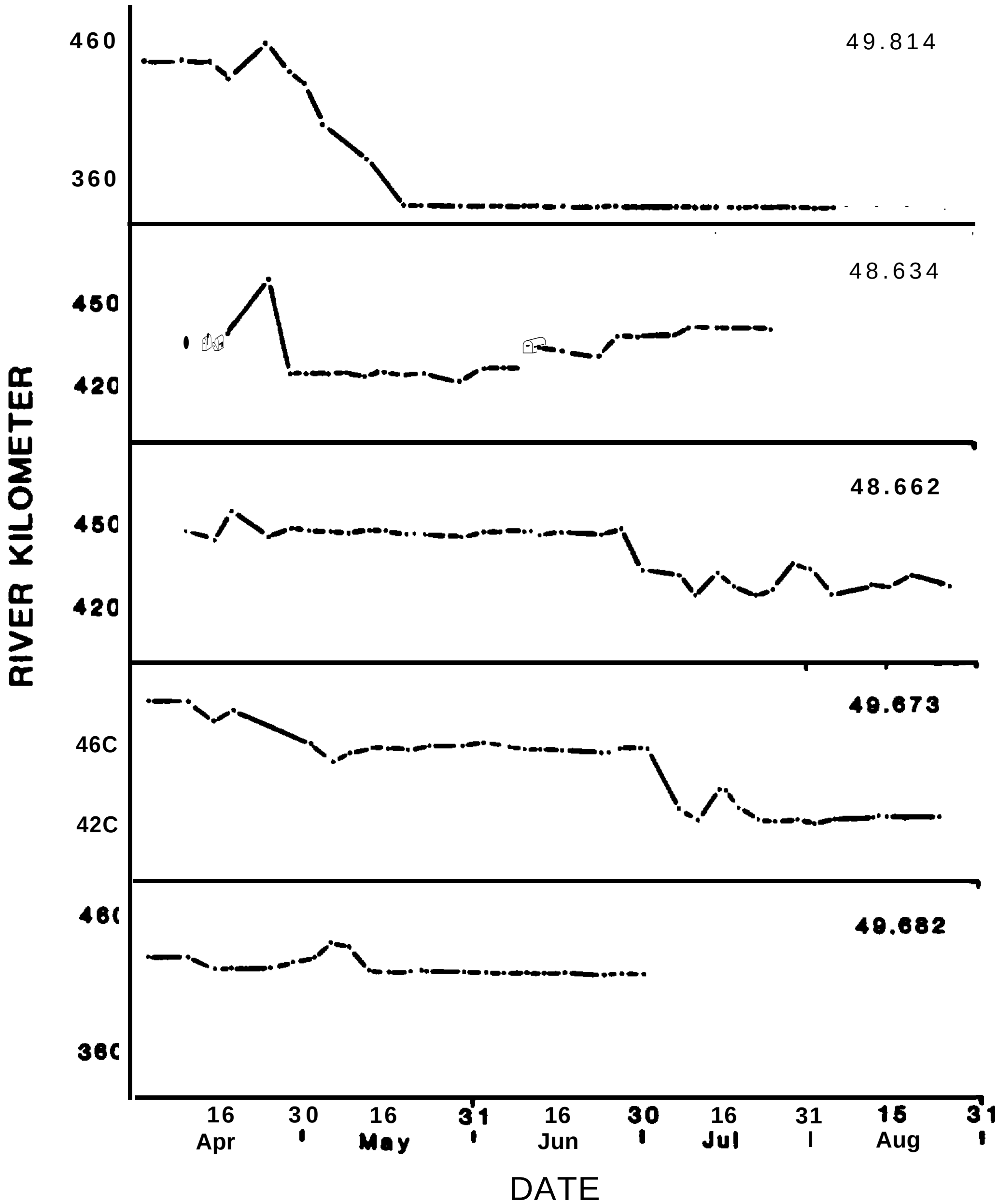

Figure 6.1. Movements of twenty radiotagged walleye released in McNary tailrace, 1985. Transmitter frequency (MHZ) is noted for each fish.

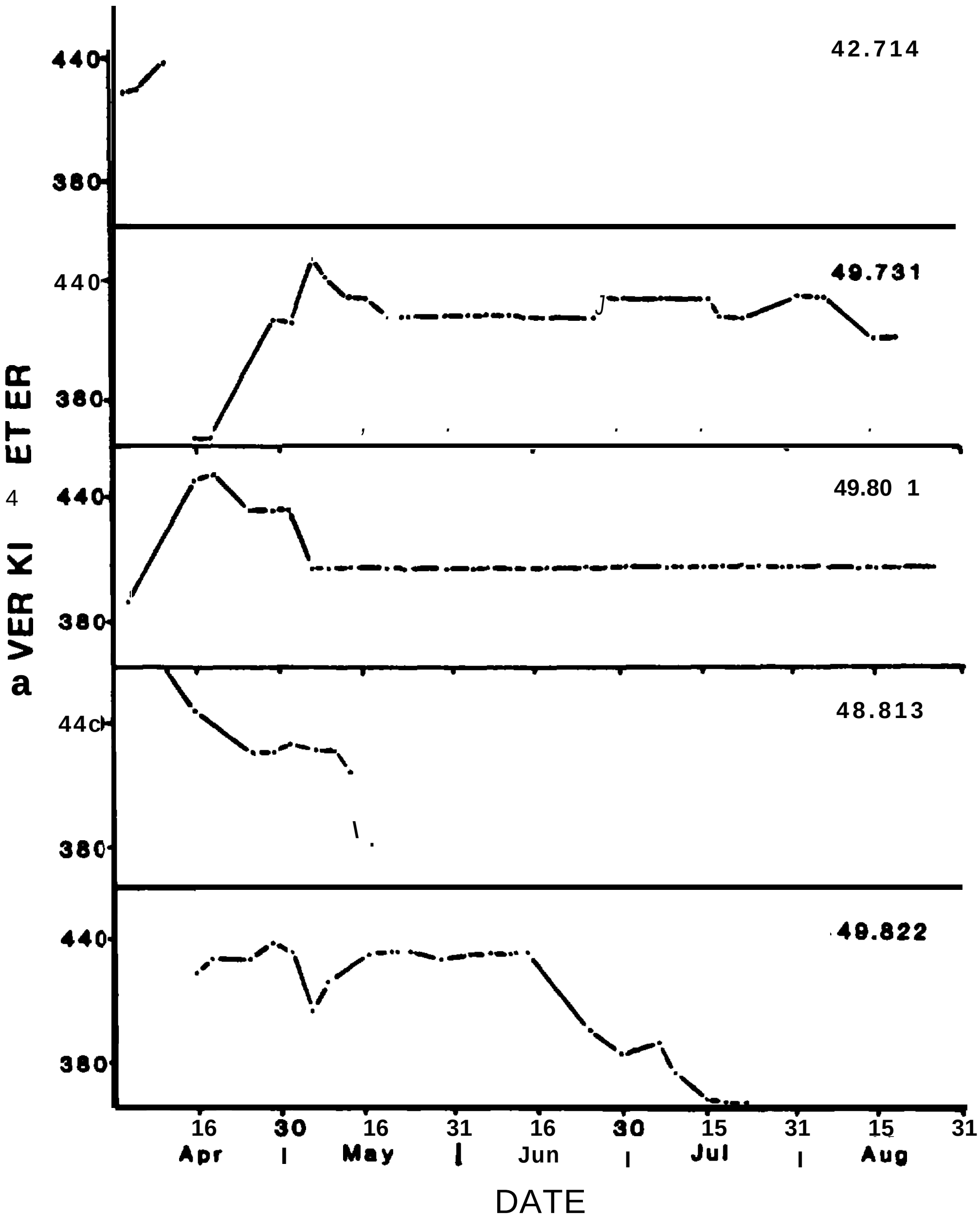

Figure B.l.' (continued)

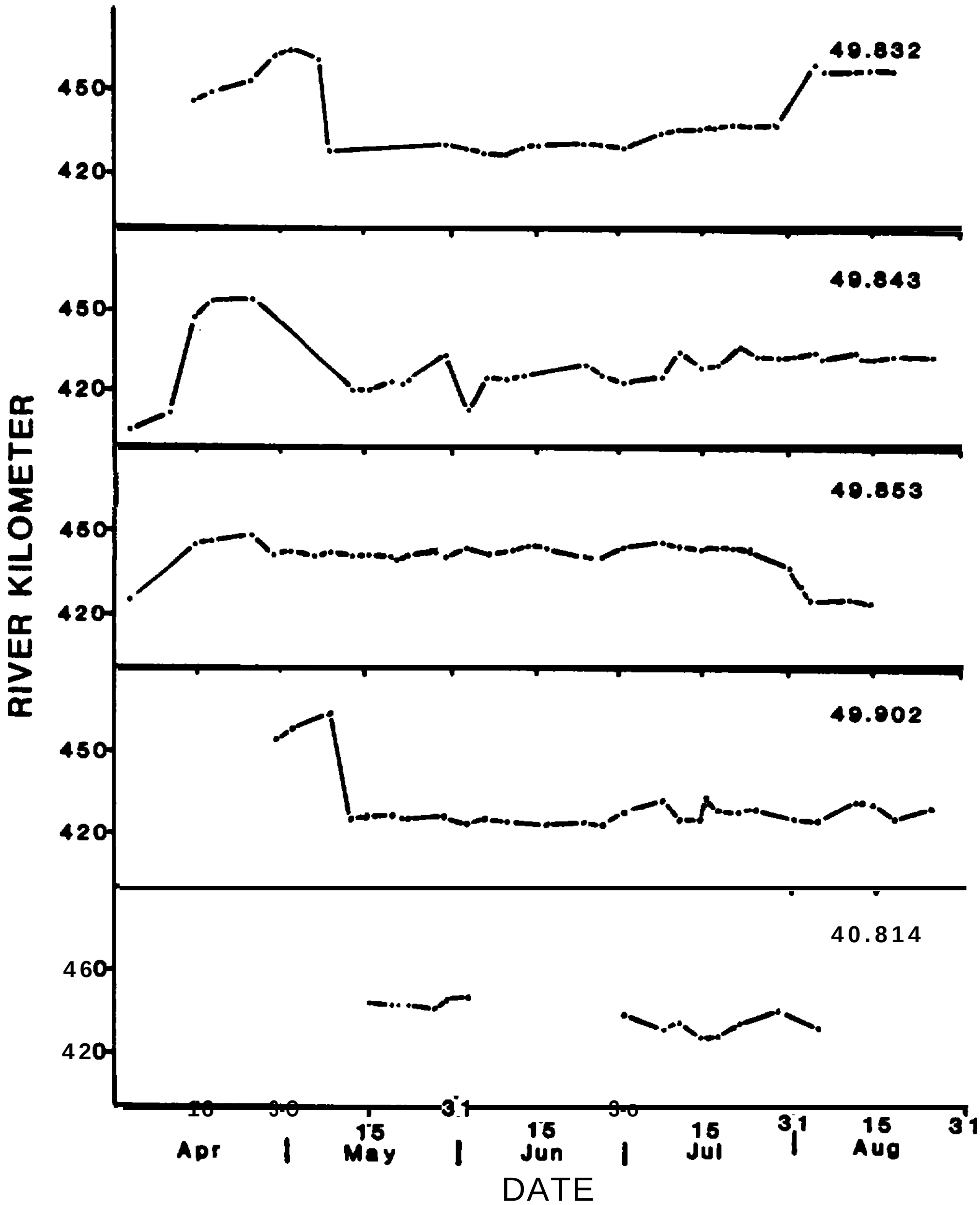

Figure B.l. {continued)

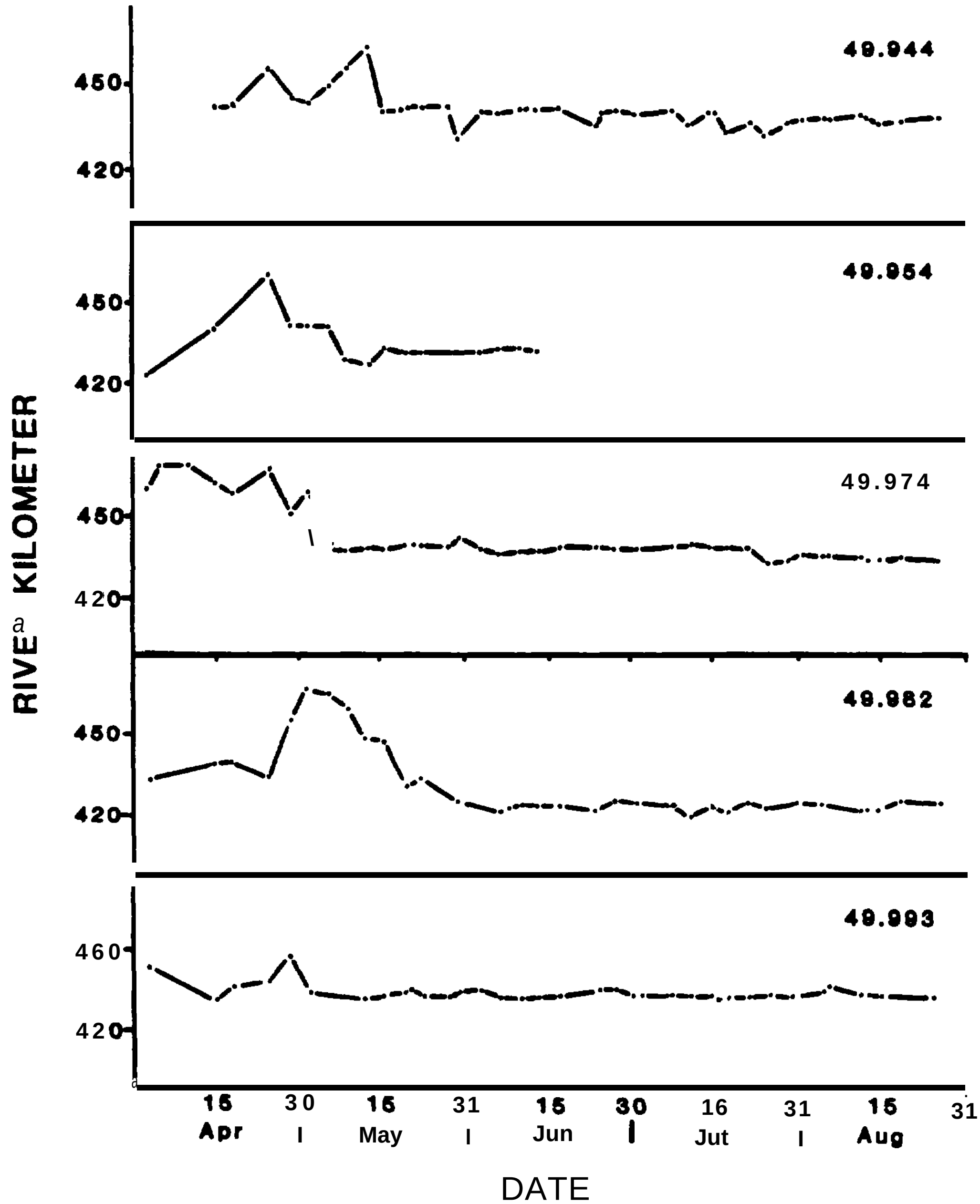

Figure B.1. (continued)

Table B.2. Descriptive data on twenty-three northern squawfish radiotagged and released in John Day Reservoir, 1985.

Location	Transmitter frequency (MHz)	Fork length (mm)	Weight (g)	Release	
				bate	River kilometer
John Day forebay	48.714	455	1,400	4-18	352
	48.864	478	1,500	4-25	351
	48.993	462		4-25	352
	49.048	459	1,700	4-30	352
	49.093	438	1,300	4-30	349
	49.301	470	1,400	5-01	349
	49.317	460	1,470	5-01	351
	49.382	464	1,620	5-01	349
Arlington	49.152	471	1,420	4-30	389
	49.328	464	1,883	5-01	389
McNary tailrace	48.184	460	1,475	4-10	470
	48.209	501	1,702	4-10	470
	48.333	505	2,185	4-10	470
	48.373	469	1,559	4-10	470
	48.414	479	1,502	4-14	470
	48.492	485	1,587	4-14	470
	48.553	445	1,530	4-14	470
	48.638	456	1,530	4-14	470
	48.658	474	1,587	4-14	470
	48.679	464	1,474	5-03	470
	49.598	453	1,531	6-04	470
	49.779	455	1,418	6-05	470
	48.209[a]	450	1,474	5-03	470

[a]Transmitter returned by an angler and subsequently implanted in a second fish.

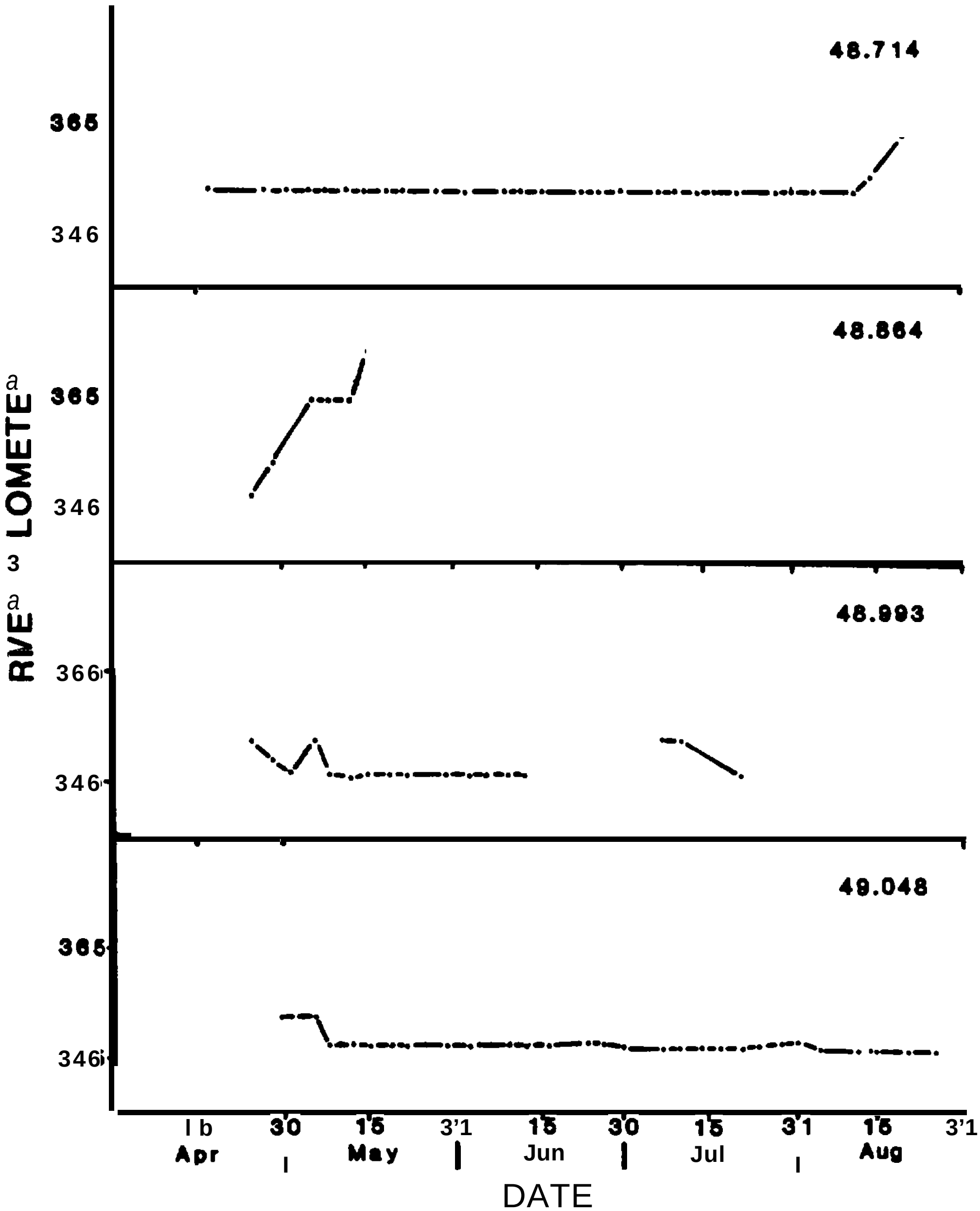

Figure B.2. Movements of eight radiotagged northern squawfish released in John Day forebay, 1985. Transmitter frequency (MHz) is noted for each fish.

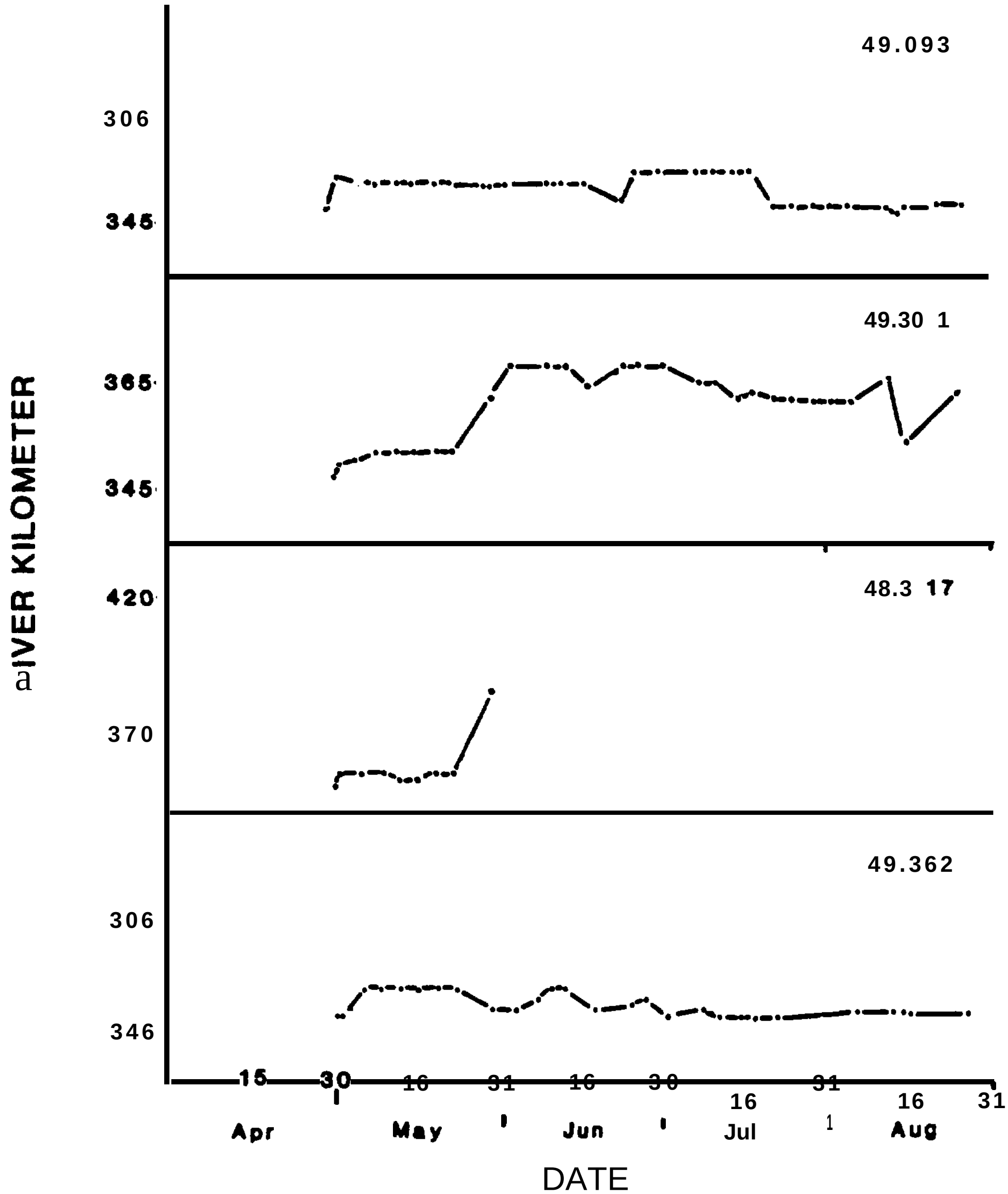

Figure B.2. (continued)

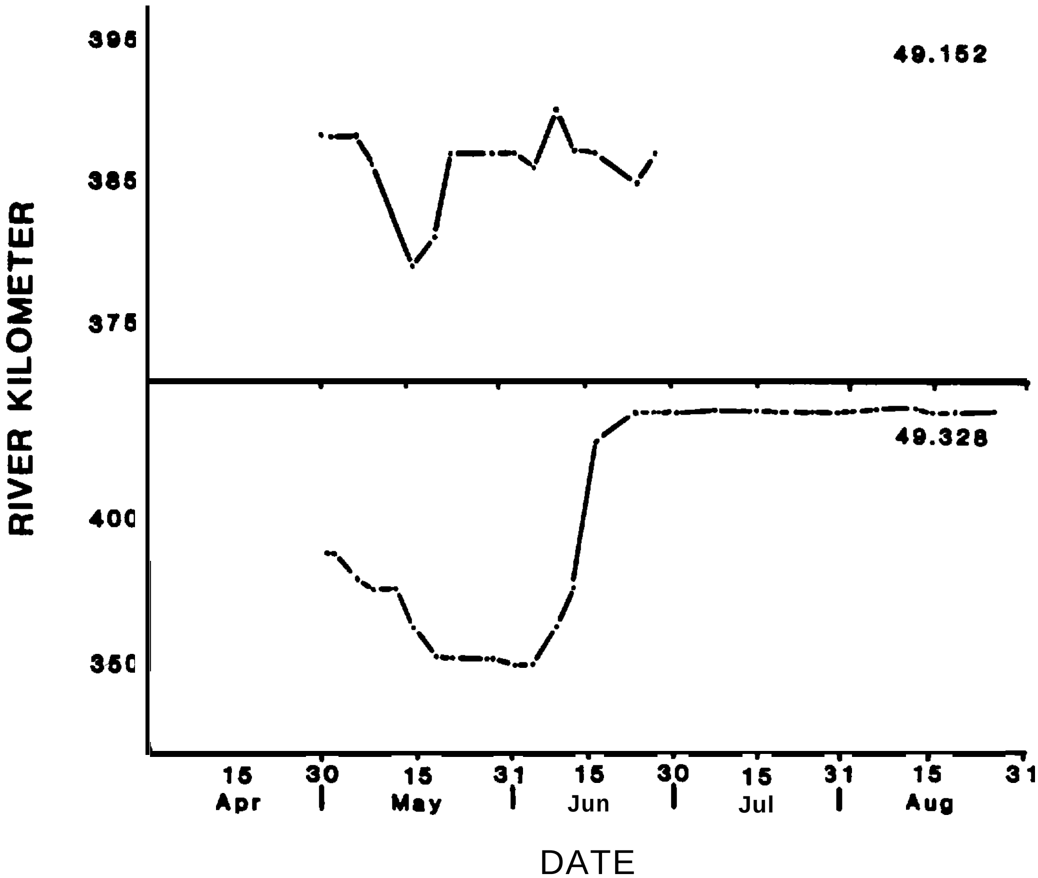

Figure 8.3. Movements of two radiotagged northern squawfish released in Arlington, 1985. Transmitter freqeuncy (MHz) is noted for each fish.

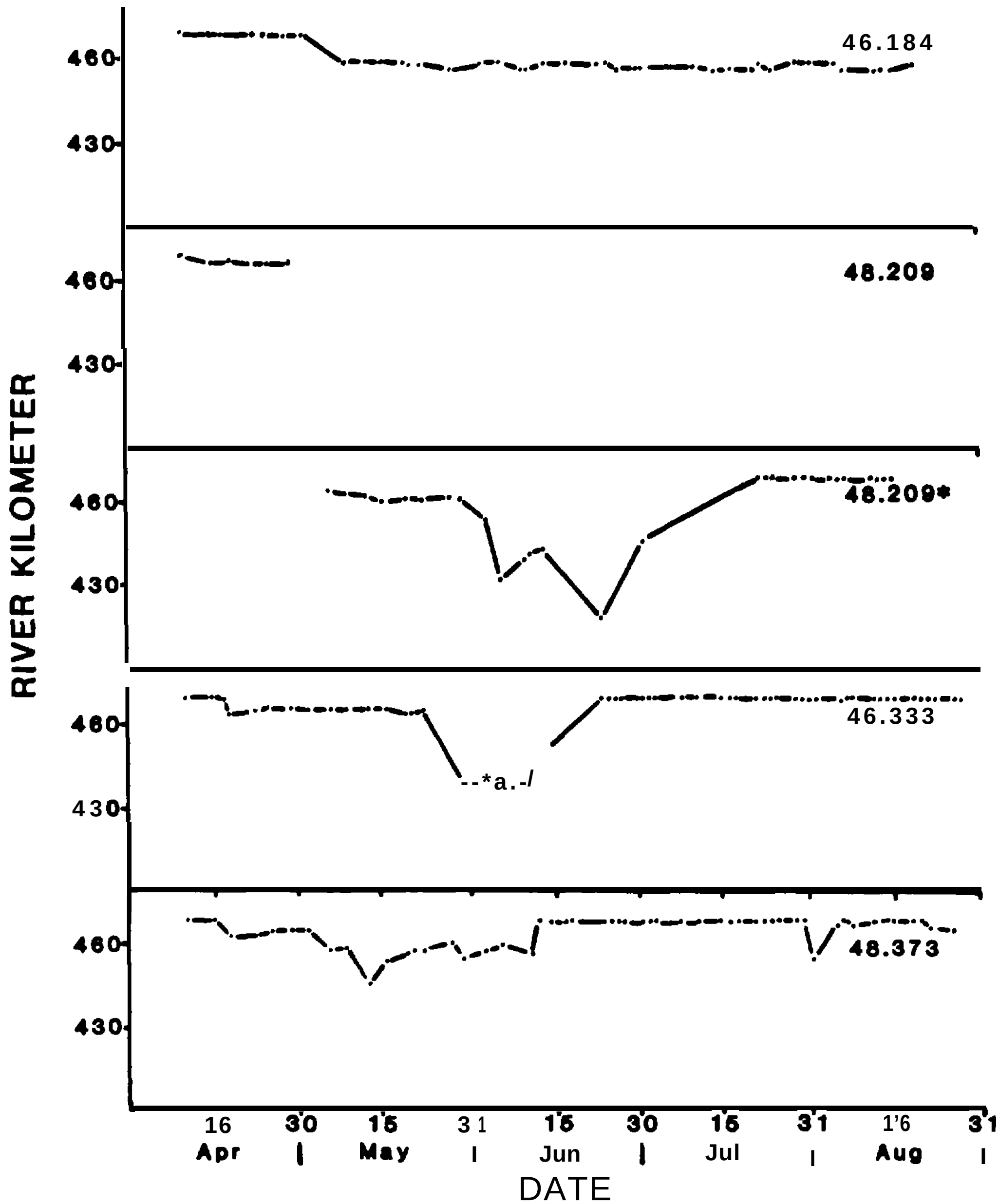

Figure 8.4. Movements of thirteen radiotagged northern squawfish released in McNary tailrace, 1985. Transmitter frequency (MHz) is noted for each fish. Asterisk indicates transmitter was returned by an angler and subsequently implanted in a second fish.

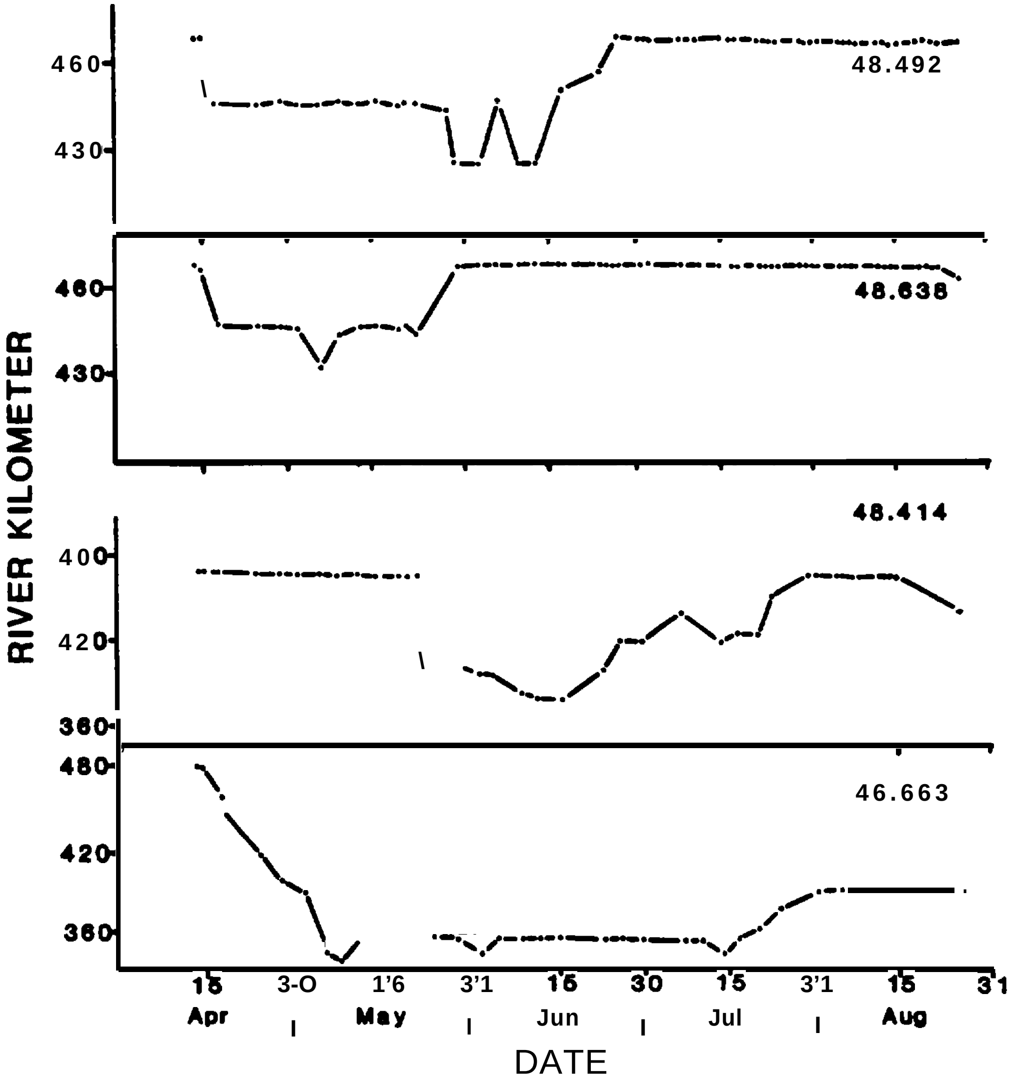

Figure 8.4. (continued)

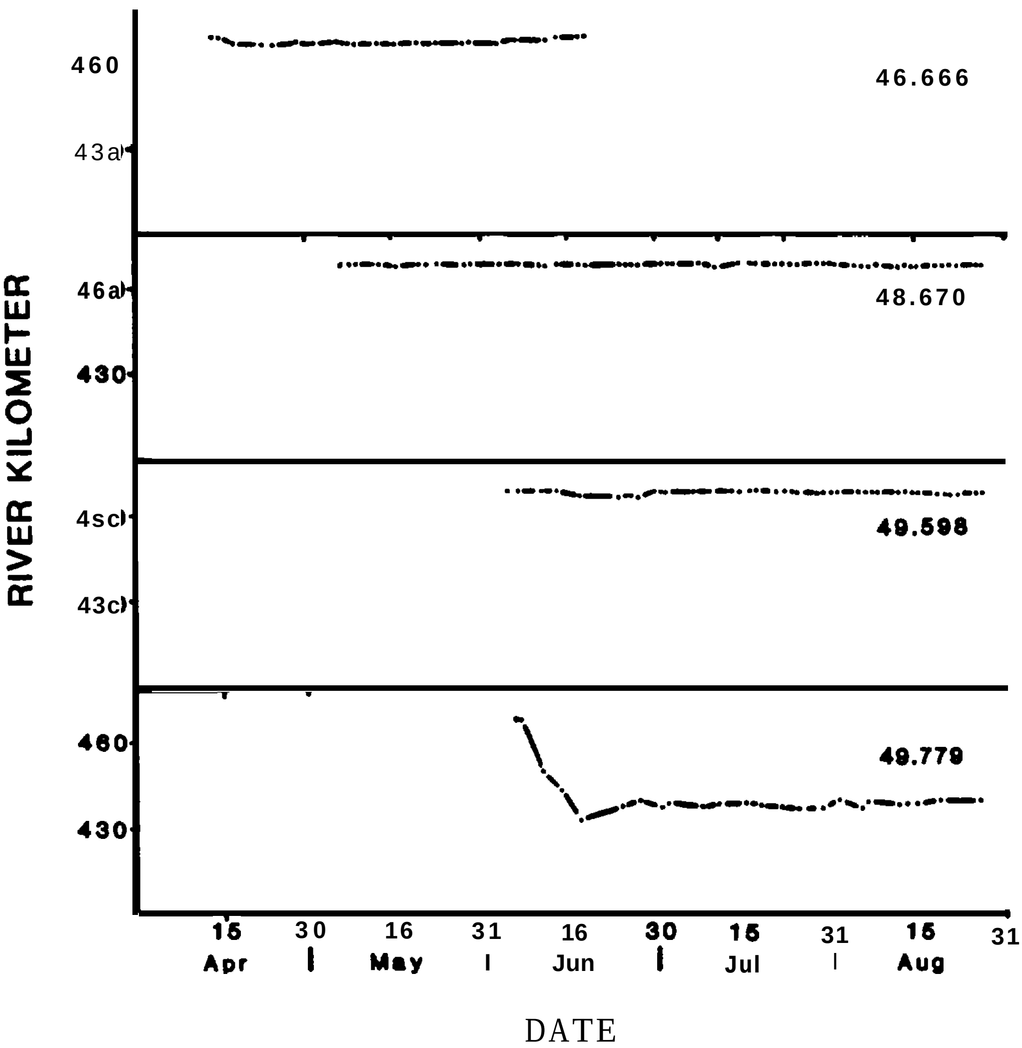

Figure B.4. (continued)

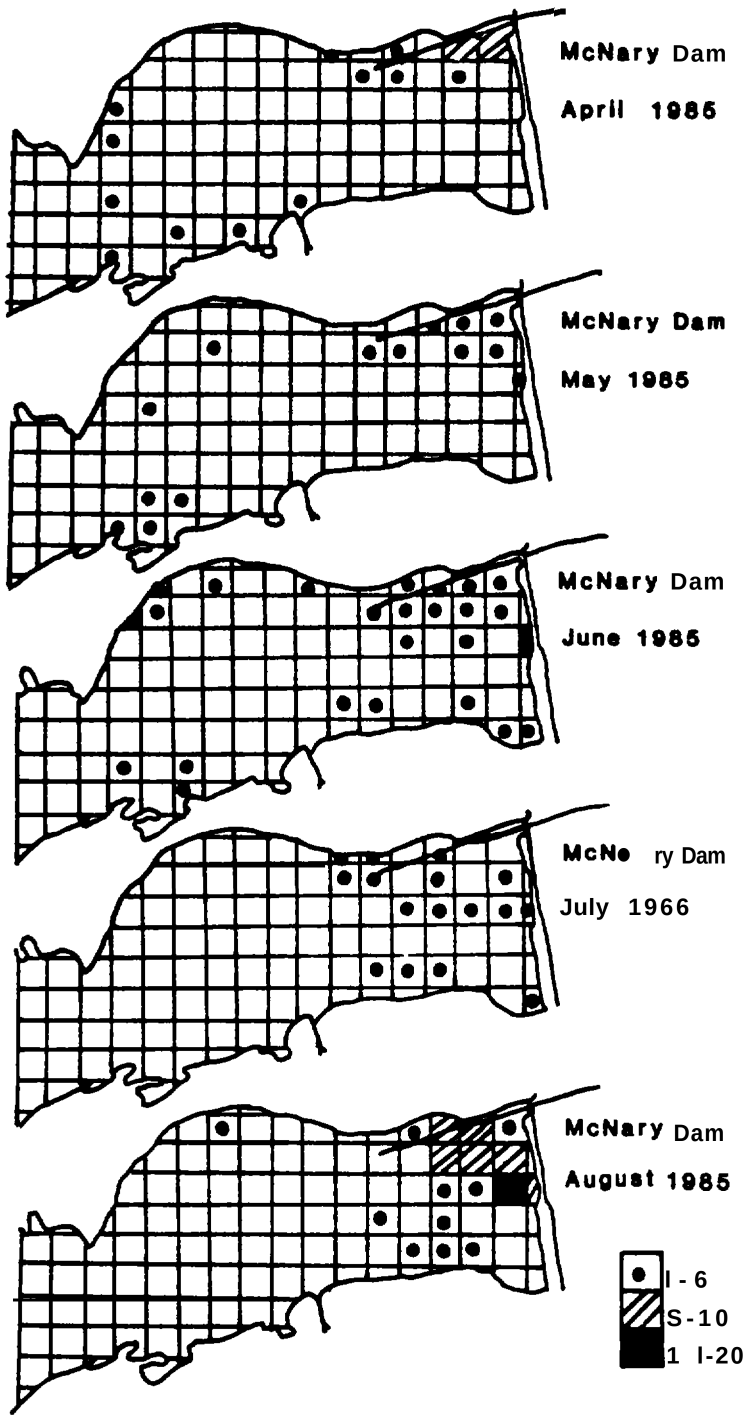

Figure B.5. Distribution of radiotagged northern squawfish in McNary tailrace, April 7-September 2, 1985. Frequency of observations are presented for grid squares where fish were located.

APPENDIX C

Angler Survey Data Used to Estimate Angler Harvests

Table C.l. **Numbers of days available and surveyed during angler surveys, John Day Reservoir, April 7-September 2, 1985.**

Area Period	Weekdays		Weekends and holidays	
	Available	Surveyed	Available	Surveyed
Lower reservoir				
8	10	4	4	3
9	10	4	4	1
10	10	3	4	4
11	9	3	5	2
12	10	3	4	3
13	14	5	7	4
14	10	4	4	2
15	10	4	4	2
16	10	4	4	1
17	10	4	6	3
Plymouth and Paterson sloughs				
8	10	2	4	1
9	10	1	4	4
10	10	2	4	2
11	9	1	5	4
12	10	1	4	1
13	14	3	7	4
14	10	2	4	3
15	10	2	4	4
16	10	1	4	2
17	10	2	6	5
Upper reservoir main channel				
8	10	2	4	4
9	10	2	4	3
10	10	2	4	3
11	9	2	5	4
12	10	2	4	3
13	14	2	7	5
14	10	2	4	3
15	10	2	4	2
16	10	3	4	3
17	10	2	6	4

Table C.2. Numbers of angler counts made by time of day and period, John Day Reservoir, April 7-September 2, 1985. Counts began within one-half hour of the times indicated.

Area / Time	8	9	10	11	12	13	14	15	16	17	Sum
	Period										
Lower reservoir											
0600	3	0	0	0	1	2	3	2	3	2	16
0700	3	2	2	1	1	4	2	1	2	3	21
0800	1	3	4	4	2	3	1	3	0	2	23
0900	3	1	3	1	2	3	3	2	3	2	23
1000	3	2	2	4	3	3	2	2	2	3	26
1100	1	2	3	0	2	3	1	2	0	2	16
1200	3	1	2	1	2	4	3	2	3	2	23
1300	4	2	2	4	2	2	2	2	2	3	25
1400	1	2	3	0	3	3	2	2	1	2	19
1500	2	1	2	1	2	4	2	3	2	2	21
1600	3	2	2	3	2	2	2	2	2	3	23
1700	1	2	3	0	3	5	4	3	3	4	28
1800	3	1	2	1	2	3	2	2	2	3	21
1900	2	2	2	3	3	3	1	2	0	2	20
2000	0	2	3	0	1	0	0	0	0	0	6
Plymouth and Paterson sloughs											
0600	0	2	1	0	0	1	2	3	0	1	10
0700	2	2	2	3	1	3	2	0	0	1	16
0800	1	0	1	0	1	1	0	1	1	2	8
0900	0	3	1	0	0	3	2	3	2	2	16
1000	0	2	1	4	1	3	2	1	0	2	16
1100	3	0	2	1	1	1	0	2	2	3	15
1200	0	3	1	0	0	3	3	4	1	2	17
1300	0	2	2	3	1	3	2	1	0	2	16
1400	3	0	1	1	0	1	1	1	2	3	13
1500	0	3	1	1	1	3	2	4	1	2	18
1600	0	2	2	3	1	3	2	1	0	2	16
1700	0	0	1	0	1	1	1	1	2	3	10
1800	3	1	0	0	0	1	0	1	1	1	8
1900	0	0	0	2	0	0	1	1	0	1	5
2000	0	0	0	0	0	1	0	0	0	0	1
Upper reservoir main channel											
0600	2	1	2	3	1	2	1	0	1	2	15
0700	3	0	0	1	1	2	2	1	2	1	13
0800	1	3	2	1	2	2	1	2	0	0	14
0900	1	2	3	3	1	3	2	0	2	3	20
1000	3	0	0	2	2	2	2	1	3	1	16
1100	1	3	2	1	2	2	1	3	1	2	18
1200	2	2	3	3	1	3	2	0	2	3	21
1300	2	0	0	2	1	2	2	1	4	3	17
1400	1	3	3	0	3	2	1	2	0	1	16
1500	3	2	2	4	1	2	2	0	2	4	22
1600	1	0	0	1	2	2	2	2	4	1	15
1700	1	3	2	0	2	2	2	2	0	1	15
1800	0	1	1	0	0	0	0	0	2	1	5
1900	0	0	0	1	0	0	0	1	1	0	3
2000	0	0	0	0	1	0	0	0	0	0	1

Table C.3. Numbers of anglers interviewed, John Day Reservoir, April 7-September 2, 1985.

Area Angler type	Period										
	8	9	10	11	12	13	14	15	16	17	**Sum**
Lower reservoir											
Boat, sturgeon	0	0	0	0	0	5	0	0	0	0	5
Boat, other	42	33	194	138	81	94	63	65	33	101	844
Bank, sturgeon	0	0	0	0	0	1	0	0	0	0	1
Bank, other	32	14	14	14	28	21	2	6	0	1	132
Upper reservoir											
Boat, sturgeon	25	16	33	35	42	43	59	47	67	58	425
Boat, other	109	74	39	46	25	61	39	59	57	49	558
Bank, sturgeon	92	83	43	76	48	48	22	0	0	2	414
Bank, other	19	57	37	71	21	16	1	0	0	5	227

Table C.4. Estimated efforts (hours) of anglers, John Day Reservoir, April 7-September 2, 1985.

Area Angler type	Period 8	9	10	11	12	13	14	15	16	17	Sum
Lower reservoir											
Boat, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Boat, other	443.5	505	3043.7	3946.7	4304.7	3219.6	2616.5	2828.6	2620.8	2756.9	26286.0
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, shad	195.1	96.3	373.:	424.;	632.3	419 0	234.5 0	258 0	390.2	377.3 0	3400.9 0
Bank, other											
Plymouth and Paterson sloughs											
Boat, sturgeon		0	0	0	0		0		0	0	
Boat, other	598.:	161.2	412.8	1047	381.5	548.:	168.3	25.6 0	12.9	39	3395.03
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, shad	379.:	289.1	503.9	855.5	422.:	419	104.9	0	5.8	203.80	3184 0
Bank, other											
Upper reservoir main channel											
Boat, sturgeon	1459.9	1530.9	1207.7	1974.7	2970.6	5395	3725.1	3257.4	4566.2	4088	30175.5
Boat, other	2123.3	1610.6	337.7	536.6	337.3	1811.2	924.9	770.5	484.1	1340.4	10276.6
Bank, sturgeon	1403.8	2159.5	1310.1	1628.1	3152	4476.2	2897.8	2526	2118.4	1977.4	23649.3
Bank, shad	0		0	7.7	766.9						
Bank, other	225	266.:	100.8	317.4	319.3	694.6 1753	265.4 142	510 315	14.5 104	245.1 0	3194.1 2853

Table C.5. Catch per hour by anglers of walleye (>250 mm), northern squawfish (>250 mm) and smallmouth bass (>200 mm), John Day Reservoir, April 7-September 2, 1985.

Area Angler type	Period 8	9	10	11	12	13	14	15	16	17	Sum
Lower reservoir											
Northern squawfish											
Boat	0.206	0.378	0.312	0.194	0.094	0.119	0.039	0.149	0.042	0.097	0.184
Bank	0.160	0.125	0.039	0.151	0.088	0	0	0	0	0	0.096
Smallmouth bass											
Boat	0.093	0.403	0.188	0.337	0.239	0.291	0.200	0.269	0.364	0.703	0.388
Bank	0	0.042	0.166	0.604	0.117	0.224	1.230	0	0	0	0.164
Upper reservoir											
Walleye											
Boat, sturgeon		0	0	0	0		0	0.004			0
Boat, other	0.0100	0	0	0.021	0	0.00:	0.051	0.012	0.01:	0.07;	0.016
Bank, sturgeon	0	0	0	0	0	0	0	0	0	0	0
Bank, other	0	0	0	0	0	0	0	0	0	0	0
Northern squawfish											
Boat, sturgeon	0.018	0	0	0.006	0	0	0.009	0.021	0.006	0.008	0.007
Boat, other	0.022	0.016	0.024	0.011	0.192	0.024	0.014	0.055	0.004	0.027	0.032
Bank, sturgeon	0	0.006	0.010	0	0.048	0	0	0	0	0	0.010
Bank, other	0	0.038	0.011	0.015	0	0.031	0	0	0	0	0.016
Smallmouth bass											
Boat, sturgeon			0	0.006	0	0	0	0	0	0.004	0.001
Boat, other	0.00:	0	0.008	0.016	0.036	0.083	0.030	0.000	0.000	0.013	0.011
Bank, sturgeon	0	0.015	0	0	0	0	0	0	0	0	0
Bank, other	0		0.215	0.055	0	0.343				0	0.079

Table C.6. Harvest per hour by anglers of walleye (>250 mm), northern squawfish (>250 mm) and smallmouth bass (>200 mm), John Day Reservoir, April 7-September 2, 1985.

Area/Species Angler type	Period 8	9	10	11	12	13	14	15	16	17	Sum
Lower reservoir											
Northern squawfish											
Boat	0.075	0.090	0.158	0.071	0.021	0.053	0.036	0.057	0.014	0.072	0.082
Bank	0.133	0.042	0	0.030	0	0	0	0	0	0	0.038
Smallmouth bass											
Boat	0.025	0.314	0.188	0.051	0.087	0.135	0.072	0.264	0.189	0.308	0.164
Bank	0	0	0.166	0.06	0.049	0.056	0	0	0	0	0.048
Upper reservoir											
Walleye											
Boat, sturgeon	0	0	0	0	0			0.004	0	0	
Boat, other	0.010	0	0	0.011	0	0.00:	0.0460	0.012	0.018	0.071	0.01:
Bank, sturgeon	0		0	0	0	0	0	0	0	0	0
Bank, other	0	0	0	0	0	0	0	0	0	0	0
Northern s'quawfish		0						0			
Boat, sturgeon	0	0.013	0	0.006	0	0	0.009	0.012	0	0.008	0 003
Boat, other	0.008		0.008	0	0.036	0	0.005		0.022	0.009	0.010
Bank, sturgeon	0	0	0.005	0	0.048	0	0	0	0	0	0.010
Bank, other	0	0	0	0.010	0	0.031	0	0	0	0	0.005
Smallmouth bass											
Boat, sturgeon	0	0	0		0	0	0	0	0	0	0
Boat, other	0.004	0.010	0.008	0.00:	0	0.028	0.009	0	0	0	0.007
Bank, sturgeon	0			0	0	0	0	0	0	0	
Bank, other	0	0.00:	0.188	0.055	0	0.249	0	0	0	0	0.06;

Table C.7. Mean hours fished per angler trip, John Day Reservoir, April 7-September 2, 1985. Boat anglers were interviewed upon completion of trip. Bank anglers were interviewed before trip's completion.

Area Angler type	Period										
	8	9	10	11	12	13	14	15	16	11	Sum
Lower reservoir											
Boat, sturgeon											
Boat other	3.8	4.7	5.7	4.7	6.0	4.6	4.9	5.4	4.3	4.3	5.0
Bank, sturgeon	--	--	--	--	--	--	--	--	--	--	--
Bank, other	2.3	1.7	1.8	2.4	3.7	1.7	2.0	1.6	3.1	1.9	2.4
Upper reservoir											
Boat, sturgeon	4.8	5.0	5.4	4.8	4.8	4.7	5.5	5.0	4.9	4.7	5.0
Boat other	4.6	4.2	3.4	4.5	3.4	4.2	5.6	4.3	4.8	4.6	4.4
Bank, sturgeon	4.5	4.2	4.8	3.9	8.6	8.3	9.3	--	--	11.0	5.6
Bank, other	1.3	2.3	2.5	2.8	2.5	2.0	3.3	--	--	3.7	2.4

APPENDIX D

Mark and Recapture Data Used to Estimate Population Abundances

Table D.1. Walleye catch, recapture, marking and removal data, John Day Reservoir, April 7-July 6, 1985. Includes fish with fork lengths equal to or greater than 250 mm at the start of the study.

Period	Catch	Recaptures	Number marked	Removals Marked	Removals Unmarked	Marked fish at large
8	92	0	83	0	31	0
9	56	0	55	0	0	83
10	242	1	228	0	12	138
11	96	2	74	0	36	366
12	84	3	65	1	16	440
13	38	1	21	0	25	504
Total	608	7	526	1	120	

Table D.2. Northern squawfish catch, recapture, marking and removal data, John Day Reservoir, March 24-September 2, 1985. Includes fish between 250 and 375 mm fork length at the start of the survey.

Period	Catch	Recaptures	Number marked	Removals Marked	Removals Unmarked	Marked fish at large
7		0	9	0	2	0
8	2::	0	151	0	123	9
9	168	1	85	1	113	160
10	201	1	103	0	331	244
11	370	1	151	0	367	347
12	303	3	121	3	310	498
13	357	3	119	5	312	616
14	288	3	146	1	201	730
15	167	3	93	1	129	875
16	110	3	43	2	83	967
17	151	4	0	2	187	1008
Total	2361	22	1021	15	2158	

Table D.3. Northern squawfish catch, recapture, marking and removal data, John Day Reservoir, March 24-September 2, 1985. Includes fish larger than 375 mm fork length at the start of the survey.

Period	Catch	Recaptures	Number marked	Removals Marked	Removals Unmarked	Marked fish at large
7	34	0	32	0	2	0
8	334	0	218	0	153	32
9	201	2	148	0	82	250
10	264	4	113	1	408	398
11	421	5	266	0	314	510
12	302	8	144	0	296	776
13	345	5	209	5	215	920
14	260	9	153	4	167	1124
15	212	5	175	1	93	1273
16	174	4	68	2	124	1447
17	198	7	5	2	192	1513
Total	2745	49	1531	15	2046	

Table D.4. Smallmouth bass catch, recapture, marking and removal data, lower John Day Reservoir, April 7-August 17, 1985. Includes fish between 200 and 225 mm fork length at the start of the survey.

Length (mm)	Period	Catch	Recaptures	Number marked	Removals Marked	Removals Unmarked	Marked fish at large
ZOO-225	8	10	0	10	0	1	0
	9	31	2	27	0	12	10
	10	23	3	19	2	45	37
	11	81	4	71	1	18	54
	12	41	6	30	3	29	124
	13	86	25	36	1	57	151
250-275	14	20	6	10	1	14	186
	15	32	1	4	6	72	195
	16	13	2	5	1	38	193
	17	27	9	0	0	64	197
Total		364	58	212	15	350	

Table D.5. Smallmouth bass catch, recapture, marking and removal data, lower John Day Reservoir, April 7-September 2, 1985. Includes fish larger than 225 mm fork length at the start of the survey.

Length (mm)	Period	Catch	Recaptures	Number marked	Removals Marked	Removals Unmarked	Marked fish at large
>225	8	73	0	69	0	10	0
	9	183	1	133	7	44	69
	10	309	13	75	23	547	195
	11	135	19	114	12	199	247
	12	141	10	90	33	345	349
	13	164	25	77	6	463	406
>275	14	26	8	12	6	167	477
	15	37	1	14	54	646	483
	16	16	2	6	1	458	443
	17	64	13	3	4	788	448
Total		1148	92	593	146	3667	

Table D.6. Smallmouth bass catch, recapture, marking and removal data, upper John Day Reservoir, April 7-September 2, 1985. Includes fish larger than 199 mm fork length at the start of the survey.

Length (mm)	Period	Catch	Recaptures	Number marked	Removals Marked	Removals Unmarked	Marked fish at large
>199	8	23	0	20	0	13	0
	9	35	0	31	0	22	20
	10	141	4	116	2	119	51
	11	86	2	66	6	80	165
	12	107	3	95	3	5	225
	13	108	8	65	4	84	317
>249	14	26	4	17	6	9	378
	15	34	1	13	1	6	389
	16	36	1	34	0	1	401
	17	45	0	0	1	0	435
Total		641	23	457	23	339	

APPENDIX E

Population Age-Frequency Distributions, Backcalculation Tables and Age-Specific Catch Per Unit Effort

Table E.1. Age-frequency distribution by length interval of a subsample of of walleye, John Day Reservoir, March 24-June 30, 1985.

Fork length interval (mm)	Age 1	2	3	4	5	6	7	8	9	10	11	12	Sum
176-200	1												1
201-225													0
226-250		2											2
251-275													0
276-300						1[a]							1
301-325		2											2
326-350		7		1									8
351-375		9	1										10
376-400		10											10
401-425		10											10
426-450		2	6	1	1								10
451-475			7	3									10
476-500			7	1	2								10
501-525				5	1	5							10
526-550				1	2	8	2	2					10
551-575													10
576-600				2		5	3						10
601-625				2		4	3	1					10
626-650					2	7		1					10
651-675					1	9	2	1		2			10
676-700						4			1				10
701-725								5			1		10
726-750								4					4
751-775											11		2
776-800													0
801-825							1						1

[a]Excluded from calculations of age-frequency distribution.

Table E.2. Age-frequency distribution by length interval of a subsample of northern squawfish, John Day Reservoir, March 24-June 30, 1985.

Fork length interval (mm)	Age 1	2	3	4	5	6	1	8	9	10	11	12	13	14	15	16	17	Sum
76-100	1	1																2
101-125	2	3																5
126-150		10																10
151-175		8	2															10
176-200			10															10
201-225			9	1														10
226-250			4	5	1													10
251-275				9	1													10
276-300				8	2													10
301-325				1	5	2	1											9
326-350						4		2	3									9
351-375						1	4	3	1	1								10
376-400								2	4	4								10
401-425							1	2	2	3	1		1					10
426-450								1		1	5	2	1					10
451-475									2		6	1	1					10
476-500										1	1	2	3	2				9
501-525										1		5	1	2	2			11
526-550																	1	1

Table E.3. Age-frequency distribution by length interval of a subsample of smallmouth bass, lower John Day Reservoir, March 24-June 30, 1985.

Fork length interval (mm)	Age 1	2	3	4	5	6	7	8	9	10	Sum
26-50	2										2
51-75	10										10
76-100	10										10
101-125											10
126-150	4	6	1								11
151-175											10
176-200		6	4								10
201-225			11								11
226-250		1	9								10
251-275			7	2		1					10
276-300			4	2		41					11
301-325											9
326-350			1	12		9	1				10
351-375											9
376-400						1		3			10
401-425						2	2 13	7	1		7
426-450											1
451-475								1		1	1

Table E.4. Age-frequency distribution by length interval of a subsample of smallmouth bass, upper John Day Reservoir, March 24-June 30, 1985.

Fork length interval (mm)	Age									
	1	2	3	4	5	6	7	8	9	Sum
76-100	3									3
101-125	7									7
126-150	1									1
151-175		10								10
176-200		9								9
201-225		7	3							10
226-250			10							10
251-275			9	1						10
276-300			9	1						10
301-325			10							10
326-350			4		6					10
351-375			1	1	4	4				10
376-400					4	6				10
401-425					1	5	1	2		9
426-450								3	1	4
451-475								2		2
476-500		1[a]						1	1	3

[a]Excluded from calculations of age-frequency distribution.

Table E.5. Mean backcalculated fork lengths[a] (mm) of walleye randomly subsampled without respect to sex, John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8	9	10	11	12
1984	1	171											
1983	62	208	370										
1982	71	192	376	458									
1981	75	193	365	447	511								
1980	44	214	363	447	498	548							
1979	36	227	388	477	533	581	612						
1978	39	227	400	492	541	574	607	623					
1977	43	251	426	533	583	608	636	667	681				
1976	8	202	364	470	537	581	610	637	665	681			
1975	11	212	348	446	503	545	572	592	604	602	670		
1974	22	223	397	512	571	616	645	669	686	699	728	748	
1973	17	227	401	511	570	616	644	670	686	699	714	752	772
1972	3	206	385	481	529	573	610	632	645	659	669	677	665
N		532	490	384	317	241	181	104	73	51	36	12	2
Mean		216	383	480	541	587	621	652	669	681	713	733	724
SD		37	52	64	69	68	71	73	78	85	71	57	69
Increment		216	167	97	61	46	34	31	17	12	32	20	

[a]Fork length = 40.46+1.89(anterior scale radius)

Table E.6. Mean backcalculated fork lengths[a] (mm) of male walleye, John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8	9	10	11	12
1983	9	220	398										
1982	8	190	380	459									
1981	35	193	371	454	488								
1980	22	225	366	446	475	513							
1979	77	218	373	454	505	537	564						
1978	13	214	382	466	514	547	572	602					
1977	29	244	417	514	556	575	599	625	643				
1976	5	220	366	461	528	572	600	625	644	638			
1975	6	204	343	432	489	530	559	574	588	581	670		
1974	7	216	384	506	539	583	609	630	644	656	679	686	
1973	6	206	364	469	519	565	593	616	630	640	648	654	678
1972	2	217	370	456	515	569	615	638	652	666	674	680	675
N		219	215	194	160	123	99	59	41	20	15	8	3
Mean		35	47	454	557	553	583	617	634	636	665	673	677
SD		216	162	87	50	37	54	51	55	68	25	30	16
Increment							31	34	17	2	29	8	4

[a]Fork length = 40.46+1.89(anterior scale radius)

Table E.7. Mean backcalculated fork lengths[a] (mm) of female walleye, John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8	9	10	11	12
1983	6	212	422										
1982	9	198	373	409									
1981	9	203	370	498	603								
1980	5	230	427	515	573	657							
1979	43	236	397	497	561	621	673						
1978	16	233	411	510	570	603	637	653					
1977	11	258	438	545	600	633	662	693	718				
1976	4	207	365	481	540	578	600	620	633	655			
1975	1	191	340	487	563	623	659	680	699	710			
1974	5	226	392	522	584	648	682	707	723	735	810		
1973	8	238	414	540	608	659	689	720	737	752	774	772	772
N		117	113	103	93	75	54	29	19	15	11	5	
Mean		229	400	507	573	623	660	690	713	737	784	772	77:
SD		40	51	51	50	50	51	58	66	65	60	25	
Increment		229	171	107	66	50	37	30	23	24	47		

[a]Fork length = 40.46+1.89(anterior scale radius)

Table E.8. Mean backcalculated fork lengths[a] (mm) of northern squawfish randomly subsampled without respect to sex, John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1984	3	104																
1983	25	66	141															
1982	42	75	141	205														
1981	75	71	131	207	266													
1980	55	71	130	194	251	292												
1979	47	72	128	186	247	285	335											
1978	42	72	136	201	252	291	320	368										
1977	47	77	144	206	253	294	326	351	381									
1976	47	72	132	194	244	286	321	348	363	388								
1975	45	73	131	189	239	277	311	343	371	397	419							
1974	66	75	133	188	237	277	313	344	373	401	423	447						
1973	52	75	133	190	234	275	309	340	369	394	414	446	487					
1972	31	79	139	191	236	275	309	339	367	395	420	439	451	469				
1971	17	76	133	187	228	263	293	324	353	381	406	429	449	472	506			
1970	7	75	139	187	226	266	301	326	352	384	407	433	454	477	495	528		
1969	2	68	125	187	215	254	286	304	337	364	393	412	436	458	468			
1968	1	63	148	209	267	296	345	382	405	420	438	454	471	489	504	516	529	541
																3	1	
Mean		603	594	595	244	207	344	303	368	398	468	499	458	432	493	524	529	54:
SD		13	21	26	28	26	28	30	31	33	37	29	33	24	21	15		
Increment		**73**	**61**	**61**	**49**	**37**	**33**	**29**	**25**	**27**	**22**	**22**	**18**	15	23	29	5	12

[a]Fork length = 23.95+1.93(anterior scale radius)

Table E.9. Mean backcalculated fork lengths[a] (mm) of male northern squawfish, John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1982	15	76	144	214												
1981	32	74	142	210	265	307										
1980	25	76	138	200	253	290										
1979	25	75	131	196	254	288	333									
1978	18	77	139	204	254	295	324	342								
1977	21	76	141	196	245	283	313	337	361							
1976	14	74	135	191	234	271	302	329	348	355						
1975	16	73	136	296	238	276	307	334	357	370	392					
1974	11	75	136	186	239	274	298	320	340	361	378	397				
1973	2	70	124	178	227	264	285	298	316	335	350	347	359			
1972	9	79	131	183	226	260	289	312	336	361	379	395	400	423		
1971	1	62	107	148	209	243	279	310	328	359	389	403	431	444	464	
1970	1	69	121	170	213	231	256	281	305	326	351	394	429	447	462	478
N		190	190	189	165	130	99	74	60	43	29	17	11	5	2	1
Mean		75	137	199	247	281	308	327	346	361	379	393	402	432	463	478
SD		13	20	25	26	27	27	26	27	26	28	25	25	26	2	
Increment		75	62	62	48	34	27	19	19	15	18	14	9	30	31	15

[a]Fork length = 23.95+1.93(anterior scale radius)

Table E. 10. Mean backcalculated fork lengths[a] (mm) of female northern squawfish, John Oay Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1982	18	72	141	213												
1981	33	79	145	213	270											
1980	25	70	130	193	250	294										
1979	21	72	128	184	239	279	327									
1978	22	80	144	206	251	293	328	366								
1977	21	77	146	212	257	299	333	357	388							
1976	24	73	136	203	252	290	325	351	370	397						
1975	22	75	135	194	243	285	316	346	371	393	410					
1974	31	74	130	188	238	277	311	340	368	394	417	447				
1973	20	75	135	189	233	276	307	337	366	393	418	444	482			
1972	14	81	142	193	235	272	304	331	358	386	409	429	452	462		
1971	4	82	129	184	225	266	300	329	355	382	406	426	452	478	491	
1970	2	68	133	191	228	269	313	343	370	399	423	451	467	477	499	515
N		257	257	256	229	190	164	144	123	102	77	51	23	12	3	
Mean		75	137	199	247	284	317	345	369	393	414	439	464	470	494	51:
SD		13	21	26	26	26	27	29	28	31	30	30	31	22	5	
Increment		75	62	62	48	37	33	28	24	24	21	25	25	6	24	21

[a]Fork length = 23.95+1.93(anterior scale radius)

Table E.11. Mean backcalculated fork lengths[a] (mm) of smallmouth bass randomly subsampled without respect to sex, lower John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8	9	10
1984	27	79									
1983	42	82	143								
1982	109	81	153	223							
1981	21	74	140	217	287						
1980	48	80	141	209	258	301					
1979	87	79	135	191	248	300	345				
1978	18	97	165	238	297	325	347	384			
1977	27	90	149	222	274	313	345	372	392		
1976	1	68	113	171	278	330	371	383	397	415	
1975	1	80	171	248	330	362	384	405	435	453	463
N		381	335	345	176	140	70	33	16	2	
Mean		81	145	210	261	306	346	375	395	434	46:
SD		14	27	40	39	36	29	24	21	27	
Increment		81	64	65	51	45	40	29	20	39	29

[a]Fork length = 34.46+1.67(anterior scale radius)

Table E.12. Mean backcalculated fork lengths[a] (mm) of male smallmouth bass, lower John Day Reservoir (1983-1985 combined).

Year class	N	Aae					
							6
1982	1	80	152	239			
1980	2	83	167	257	319	375	
1979			136	180	224	262	320
N		7	7	7	3	3	1
Mean		83	149	225	256	300	320
SD		11	17	37	59	70	
Increment		83	66	76	31	44	20

[a]Fork length = 34.46+1.67(anterior scale radius)

Table E.13. Mean backcalculated fork lengths[a] (mm) of female smallmouth bass, lower John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8
1984	1	170							
1983	2	81	124						
1982	1		70	234					
1981	3	75	145	116	176				
1980	9	78		205	262	330			
1979	6	84	150	211	267	317	341		
1977		**94**	**156**	**231**	284	323	351	380	378
N		26	22	21	19	16	9	6	2
Mean		87	126	232	232	325	325	332	378
SD		**15**	59	68	53	53	28	32	**16**
Increment		87							

[a]Fork length = 34.46+1.67(anterior scale radius)

Table E.14. Mean backcalculated fork lengths[a] (mm) of smallmouth bass randomly subsampled without respect to sex, upper John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8	9	10	11	12
1984	11	98											
1983	28	94	177										
1982	90	106	198	277									
1981	32	100	180	263	303								
1980	66	96	176	257	325	361							
1979	44	97	172	244	308	358	389						
1978	13	94	186	257	305	343	403	403					
1977	21	104	184	268	327	365	396	425	447				
1976	8	102	205	293	345	377	403	410	440	463			
1975	1	79	123	196	281	338	374	402	421	442			
1973	1	77	123	187	250	312	345	391	406	436	459	476	
1971	1	99	155	205	276	315	337	367	384	399	413	440	449
N		316	292	221	136	87	52	31	18	5	2	2	1
Mean		17	130	261	317	358	393	416	437	440	436	458	449
SD		100	83	37	36	32	24	27	25	32	33	25	
Increment				78	56	41	35	23	21	3		22	

[a]Fork length = 45.33+1.47(anterior scale radius)

Table E.15. Mean backcalculated fork lengths[a] (mm) of male smallmouth bass, upper John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5
1983	2	194	208			
1982	4	97	167	247		
1981	3		189	290		
1980	2	91	164	243	298	
1979		86	188	276	337	
1978	1		216	322	361	389
N		13	13	11	4	1
Mean		95	181	262	333	389
SD		11	23	27	26	
Increment		95	86	81	71	56

[a]Fork length = 45.33+1.47(anterior scale radius)

Table E.16. Mean backcalculated fork lengths[a] (mm) of female smallmouth bass, upper John Day Reservoir (1983-1985 combined).

Year class	N	Age 1	2	3	4	5	6	7	8
1982	3	107	202	294					
1981	2	105	198	275	337				
1980	6	98	186	272	341	380			
1979	3	114	184	265	344	358			
1978	2	106	207	285	329	362			
1977	6	103	179	261	320	365	397	427	
1976	2	101	235	318	364	386	406	425	440
N		24	24	24	18	14	8	7	2
Mean		104	193	275	336	370	399	426	440
SD		14	23	27	28	20	12	12	14
Increment		104	89	82	61	34	29	27	14

[a]Fork length = 45.33+1.47(anterior scale radius)

Table E.17. Walleye survival estimates (S) from catch per 100 hours of bottom gill-net effort (CPUE), upper John Day Reservoir, 1984-1985.

Year class	1984 Age	1985 Age	1984 CPUE	1985 CPUE	S
1983	1	2	1.6	15.3	--
1982	2	3	10.5	5.7	0.543
1981	3	4	13.4	5.7	0.425
1980	4	5	8.1		0.185
1979	5	6	21.4	1:::	0.519
1978	6	7	5.7	3.4	0.596
1977	7	8	4.5	1.5	0.333
1976	8	9	0.4		0
1975	9	10	0.4	0.9	1.000
1974	10	11	0.8	0	0

Table E.18. Northern squawfish survival estimates (S) from catch per 100 hours of bottom gill-net effort (CPUE), John Day Reservoir, 1984-1985.

Year class	1984 Age	1985 Age	1984 CPUE	1985 CPUE	S
1982	2	3	0.4	4.2	--
1981	3	4	2.0	73.2	--
1980	4	5	9.0	22.3	--
1979	5	6	18.0	10.9	0.609
1978	6	7	15.1	13.6	0.899
1977	7	8	27.8	28.3	1.019
1976	8	9	8.2	31.3	1.112
1975	9	10	34.3	34.0	0.990
1974	10	11	58.8	27.9	0.475
1973	11	12	18.0	6.0	0.336
1972	12	13	13.1	1.5	0.112
1971	13	14	4.1	0.4	0.093

Table E.19. Smallmouth bass survival estimates (S) from catch per hour of electrofishing effort (CPUE), lower John Day Reservoir, 1984-1985.

Year class	1984 Age	1985 Age	1984 CPUE	1985 CPUE	S
1984	-	1	--	1.1	--
1983	1	2	0.4	2.2	--
1982	2	3	3.6	3.7	1.033
1981	3	4	0.5	0.2	0.389
1980	4	5	1.5	0.2	0.156
1979	5	6	2.5	1.0	0.398
1978	6	7	0.3	0.1	0.294
1977	7	8	0.2	0.3	1.381

Table E.20. Smallmouth bass survival estimates (S) from catch per hour of hour of electrofishing effort (CPUE), upper John Day Reservoir, 1984-1985.

Year class	1984 Age	1985 Age	1984 CPUE	1985 CPUE	S
1984	-	1	-	0.1	--
1983	1	2	0.1	0.5	--
1982	2	3	1.4	1.3	0.910
1981	3	4	0.4	0.1	0.205
1980	4	5	0.8	0.2	0.227
1979	5	6	0.3	0.2	0.567
1978	6	7	0.1	<0.1	0.167
1977	7	8	0.1	0.1	1.140
1976	8	9	<0.1	co.1	0.667

APPENDIX F

Draft Manuscript Entitled Effects of Variation of Flow on Distributions of Northern Squawfish (*Ptychocheilus oregonensis*) below McNary Dan on the Columbia River

Effects of Variation in Flow on Distributions of Northern Squawfish (*Ptychocheilus oregonensis*) below McNary Dam on the Columbia River

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Abstract

The movements of northern squawfish (Ptychochelius oregonensis) were monitored using radio-telemetry below a Columbia River hydroelectric dam during the outmigration of juvenile anadromous salmonids in 1984 and 1985. Squawfish were associated with protected shoreline areas in spring and early summer when discharge rates were high (above 5,664 m^3/sec) but moved into close proximity of the dam and the juvenile by-pass outflow area in mid to late summer when discharge rates decreased (below 5,664 m^3/sec). Similar trends in squawfish movements were found when abrupt changes in discharge occurred. Movements out of protected areas and into the main river channel were observed in 4 out of 5 northern squawfish monitored during short-term spill closures.

Surface water velocity measurements were taken at 81 locations where northern squawfish occurred in June, July and August, 1985, to determine if current velocity influenced their distribution. Surface water velocities where squawfish were located ranged from 0 to 70 cm/sec with a mean of 24.5 cm/sec. No preference within this range was determined, but we believe squawfish avoided areas with high velocity since they did not utilize a substantial portion of the tailrace where water velocities exceeded 100 cm/sec.

INTRODUCTION

Impoundments on rivers containing stocks of anadromous salmonids have warranted the development of facilities to by-pass downstream migrant juvenile steelhead trout (*Salmo gairdneri*) and salmon (*Oncorhyncus* sp.) around the dams. One concern at these by-pass facilities is that conditions created by dams can intensify the foraging efficiency of predators on juvenile salmonids. The by-pass facility at Red Bluff Diversion Dam, California, was found to induce stress on downstream migrants, which in turn attracted predators and resulted in high mortality due to predation (Vogel and Smith, 1984). Grey et al. (1983) noted that the frequency of occurrence of salmonids found in northern squawfish stomachs was higher for fish collected near dams of lower-Columbia River reservoirs than for squawfish collected in other areas. A significantly greater occurrence of Sacramento squawfish (*Ptychocheilus grandis*) was also observed at Horseshoe Bend's fish release site than at control sites in the Peripheral Canal, California (Anonymous 1980) however, no food habits studies were conducted.

The objectives of this study were to: (1) describe the distribution of northern squawfish in McNary tailrace, (2) determine how different flow regimes affected their distribution and (3) discuss the implications of predator distributions on the design of fish passage facilities.

STUDY AREA

McNary Dam is a hydroelectric facility located on the lower-Columbia River between Washington and Oregon (Pig. 1). A series of spillgates extend from the navigation channel and an adult fishway entrance on the north shore of the river to the center of the dam. The south half of the dam contains the turbines, which extend to the south shore and another adult fishway entrance. The smolt by-pass outlet and a third adult fishway entrance are situated in the center of the dam between the spillgates and turbines.

Variation in water discharge at McNary Dam results mainly from snow melt in the surrounding mountains of the Columbia Basin. Prom about March through mid-July, water discharge from McNary Dam may approach 11,400 m^3/sec and requires releases from the spillgates to pass the high volume of water, since maximum turbine outflow is 5,664 m^3/sec. By about mid-July, runoff is substantially reduced and water is no longer passed through the spillgates. Discharge stablizes from late summer through fall, and increases slowly throughout winter until the spring runoff surge initiates spillgate operations.

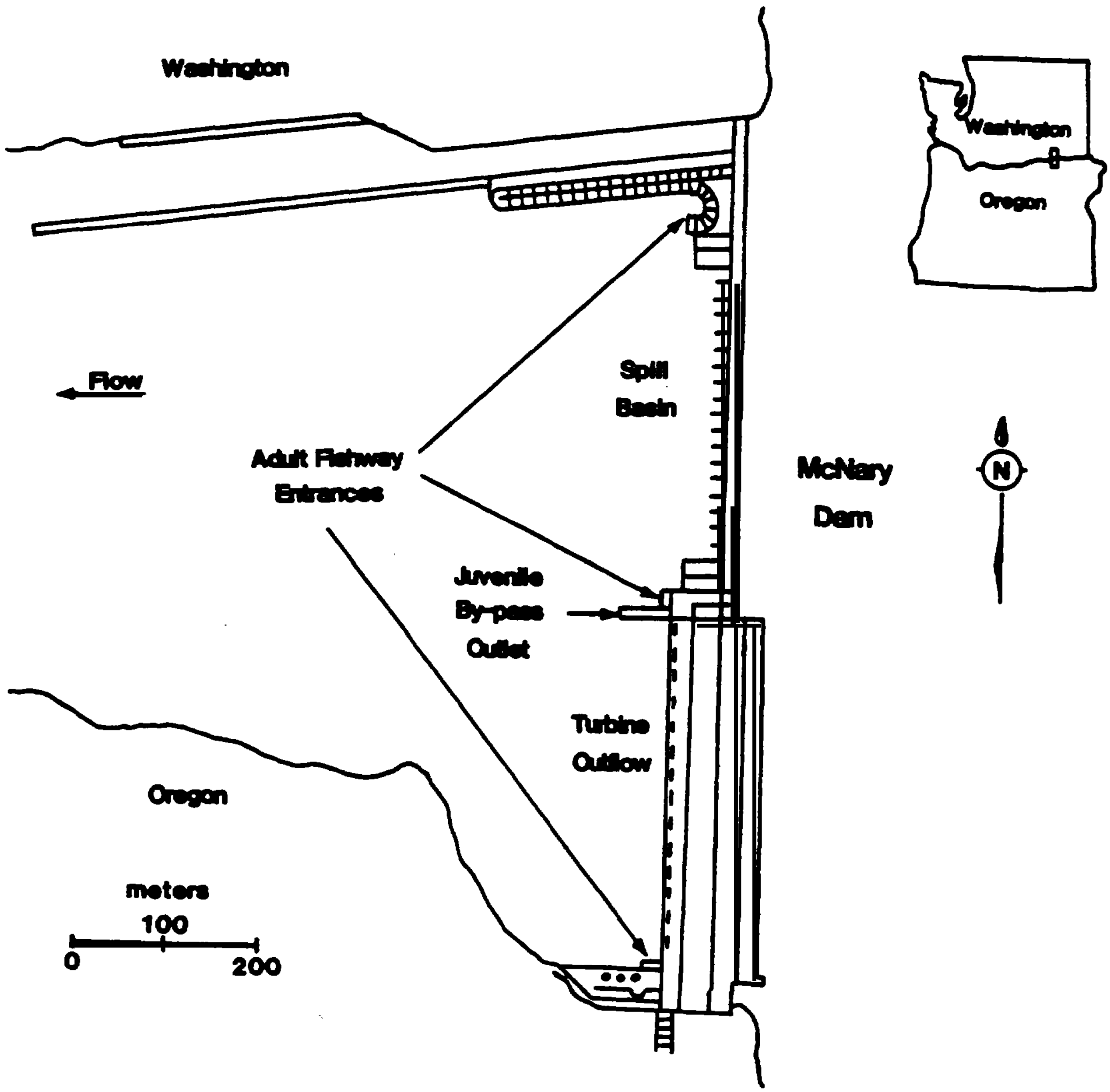

Figure 1. Locations of the juvenile by-pass outlet, spill basin, turbine outflow and adult fishways at McNary Dam, 1985.

The majority of outmigrating juvenile salmonids pass McNary Dam between March and August. The highest numbers of outmigrants, however, are usually not found in the by-pass system until mid to late summer when discharge is reduced and the spillgates are closed. At this time the outmigrants attempt to pass primarily through the turbines. Traveling screens (Bates 1970) guide the juveniles away from the turbines and into the by-pass system where the fish are identified and enmerated. The juvenile salmonids are then either released through the by-pass outlet into McNary tailrace or transported by barge or truck to the Bonneville tailrace and released.

METHODS

surface water velocity measurements were taken with a Marsh-McBirney[1] digital flowmeter at 63 randomly chosen locations in McNary tailrace during July and August, 1985 to map the tailrace flow regime. Individual measurements were triangulated to known landmarks with a Davis Mark IV sextant and the angles and landmarks were recorded with their corresponding water velocity measurement. Surface water velocity measurements were plotted on a U.S. Geological Survey map of the study area using a 3-arm protractor. Contour lines were drawn connecting points of similar surface water velocity.

We used radio-telemetry to study the movements and distribution of northern squawfish in McNary tailrace. The equipment used in this study was obtained from Advanced Telemetry Systems of Bethel, Minnesota. ATS "Challenger 200" receivers were equipped with David Clark noise attenuating headsets, and were capable of scanning programmed frequencies between 48 and 50 mhz. Transmitters had a life expectancy of 150 days and weighed 28 g in air which required recipient fish to weigh a minimum of '1,400 g (Winter et al. 1978). Frequencies were separated by 10 kHz increments (Table i) to allow for easy identification of individual fish and compensate for anticipated frequency drift when battery power declined. Transmitters were cylindrical and trailed a 35 cm fine wire antenna from one end.

Two antenna types were used to receive signals. Aerial monitoring was done with bi-directional loop antennas affixed beneath the wing of an aircraft. The antennas were oriented with the peak receiving end directed forward and the unit insulated from metal contact with the wing surface. Coaxial antenna wire was securely taped to the underwing and led into the cabin through an air vent. Boat tracking was

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[1] Mention of commercial services or equipment does not constitute U.S. Government endorsement.

Table 1. Descriptive data on 23 northern squawfish radiotagged and released in McNary tailrace, 1984 and 1985.

Year	Transmitter Frequency (MHz)	Fork Length (mm)	Weight (g)	Date of Release
1984	48.184	470	1,450	March-14
	48.210	500	1,910	March-15
	48.334	517	1,625	March-15
	48.373	467	1,370	March-15
	48.412	480	1,400	March-15
	48.493	465	1,440	March-20
	48.551	495	1,620	March-20
	48.637	481	1,330	March-22
	48.657	447	1,375	March-27
	48.678	466	1,380	March-27
1985	48.184	460	1,475	April-10
	48.209	501	1,702	April-10
	48.333	505	2,185	April-10
	48.373	469	1,559	April-10
	48.414	479	1,502	April-14
	48.492	485	1,587	April-14
	48.553	445	1,530	April-14
	48.638	456	1,530	April-14
	48.658	474	1,587	April-14
	48.679	464	1,474	May-3
	49.598	453	1,531	June-4
	49.779	455	1,418	June-5
	• 48.209	450	1,474	May-3

*Transmitter was returned by an angler and subsequently implanted in a second fish.

conducted from a 6.4 m fiberglass boat using a 4 element Yagi antenna (long range) attached to a telescoping 3.7 m mast with 360" rotational capability. Rand held bi-directional loop antennas (short range) were also used in the boat and from shore.

Al.1 northern squawfish to be radio-tagged were collected by electrofishing in McNary tailrace: 10 in March, 1984 and 13 in April and May, 1985. Upon capture, fish were anesthetized in a 105 mg/l solution of Tricaine-Methane-Sulfonate (X3-222). Each fish was weighed (g), fork length measured (mm) and surgically implanted with a radio transmitter (Table 1).

Surgical procedures were similar to those used by Hart and Synnerfekt (1975) with the following exception. An additional 0.5 cm incision was made in the abdominal cavity to allow for protrusion of a flexible wire antenna. The antenna exit hole was closed with a single suture. The sutured areas were swabbed with Betadine antiseptic, and the fish moved to fresh water for recovery. After the fish regained equilibrium and resumed swimming activity it was released at the point of capture.

Radio-tagged fish were monitored from aircraft, boat, and shore two to four times each week after release (Table 1) until September. Once a signal was received, the axis of maximum signal strength was followed. A reduction in the RF gain would take place until the observer was confident he had obtained an accurate location (fix). Individual fixes were recorded in respect to distance and direction from known landmarks, and classified as either inshore (< 100m from a natural shoreline) or offshore (> 100m from a natural shoreline). Each fix was assigned an x and y coordinate from a Cartesian grid system (150 m/side) overlaid upon a U.S. Geological Survey map of the study area.

Locations of radio-tagged northern squawfish were separated by time periods corresonding to mean daily discharge rates. Since preliminary results indicated that the presence or absence of spillgate discharge seems to effect the distribution of squawfish in the tailrace, maximum possible turbine flow (5,664 m^3/sec) was chosen to delineate periods of high and low discharge (Fig. 2). Periods of high discharge were defined as those in which mean daily discharge rates exceeded 5,664 m^3/sec, and periods of low discharge refer to mean daily discharge rates < 5,664 m^3/sec. Distributions of the predators within high and low discharge periods were examined, and a chi-square analysis was used to compare inshore-offshore movements during these periods. It should be noted, however, that mean daily discharge rates in excess of the maximum possible turbine flow do not imply consistent spillgate operations due to navigation and fish passage needs, and water availability.

The movements of 5 northern squawfish were also monitored during short term spill closures in May, 1985 to determine how abrupt changes in water discharge may affect squawfish distributions. The fish were monitored at 5-10 minute intervals for l-2 hours after the spill closures.

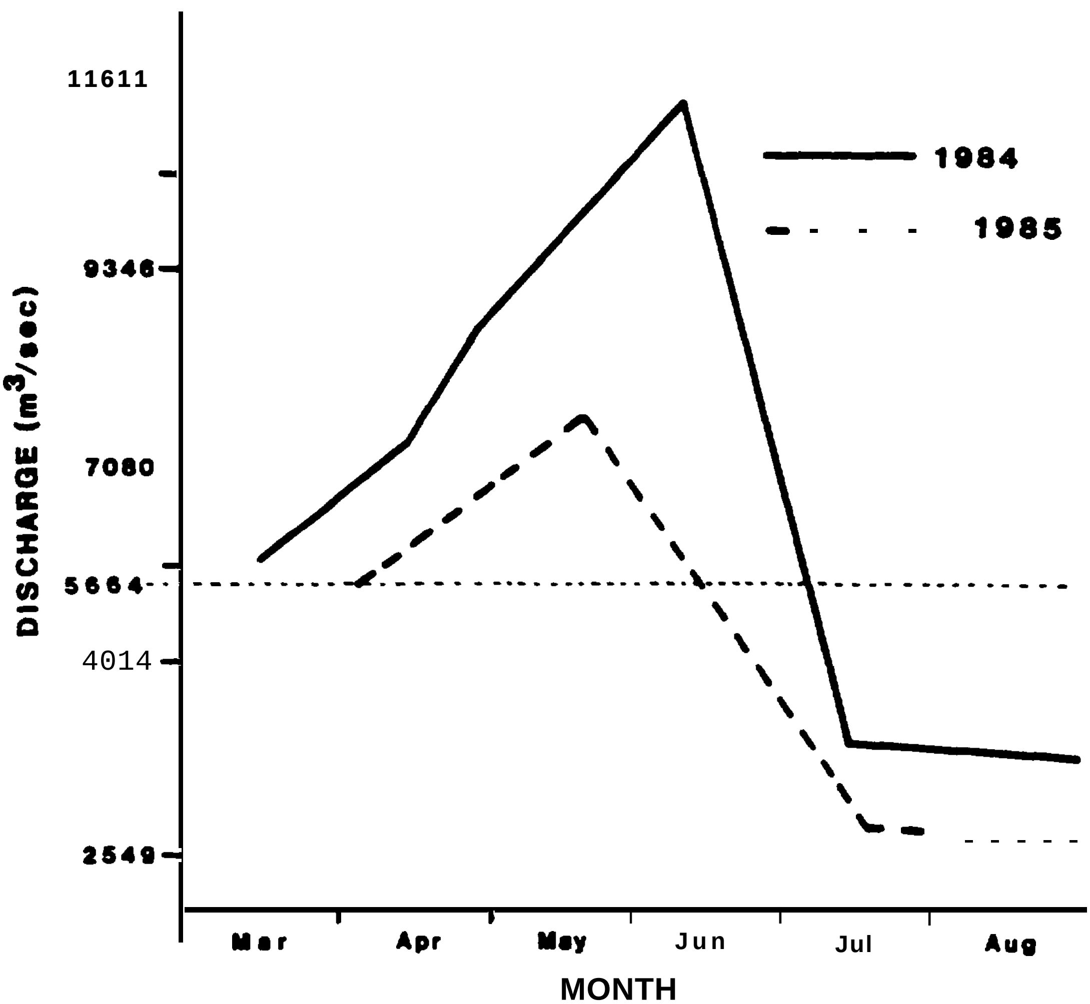

Figure 2. Mean daily discharge rates illustrating time periods when discharge exceeded maximum turbine outflow, McNary Dam, March through August, 1984 and 1985.

RESULTS AND DISCUSSION

In 1984 and 1985 radio-tagged northern squawfish were usually distributed in small backwaters and protected shoreline areas when spillgates were opened and water discharge exceeded 5,664 m^3/sec (Fig. 3), but moved into the main river channel and near the dam when spillgates were closed and discharge decreased below 5,664 m^3/sec (Fig. 4). Chi-square analysis showed a significant difference ($p < 0.01$) between the frequency of inshore and offshore observations during high and low discharge rates in 1984 and 1985 (Table 2). In spring and early summer when the spillgates were open and discharge rates were high, northern squawfish were often located a considerable distance downstream from the dam. In 1984, 7 northern squawfish (70%) were located farther than 2.5 km from McNary Dam. Locations from these fish outside the tailrace comprised 17.6% of all observations taken in 1984; 98.6% of these occurred when discharge exceeded 5,664 m^3/sec. Nine northern squawfish (75%) were located >2.5 km downstream from the dam in 1985. Again, this occurred primarily when discharge rates were high and spillgates were open. These locations comprised 38.6% of all observations in 1985, and 63.4% of these took place when discharge exceeded 5,664 m^3/sec. All 7 northern squawfish which left the tailrace in 1984, and 5 of the 9 which left in 1985 returned to <2.5 km from the dam by late July.

In mid to late summer when discharge was less than 5,664 m^3/sec, squawfish were primarily distributed in the spill basin (Fig. 4). During this period high concentrations of squawfish locations occurred near the smolt by-pass outflow and the Washington adult fishway entrance. Observations near the by-pass and fishway entrance comprised 70.4% of all locations taken during low water discharge in 1984 and 31.3% in 1985. The occurrence of tagged squawfish away from the dam during low water discharge was more common in 1985 than in 1984.

Northern squawfish distributions appeared to be associated with the surface velocity regimes in the tailrace. Water velocity data from July and August, 1985 demonstrates a pattern typical of late summer when spillgates are consistently closed (Fig. 5). A large area immediately downstream from the turbine outflow and a small area immediately downstream from the Washington fishway entrance had velocities in excess of 100 cm/sec. Velocities ranging from SO-99 cm/sec were observed bordering those areas in excess of 100 cm/sec, and velocities ranging from O-49 cm/sec were observed below the spill basin and along the Oregon shore downstream from the turbine outflow. A comparison of northern squawfish distributions to the current velocity regime indicates that they preferred areas with slow water velocity or flow shears bordering high velocity areas.

In order to confirm this observation we examined surface velocity measurements at 81 northern squawfish locations taken in June, July and August, 1985 during day, night and crepuscular time periods. Individual velocity measurements at squawfish locations ranged from O-70 cm/sec and averaged 24.2 cm/sec. Since a large proportion of the

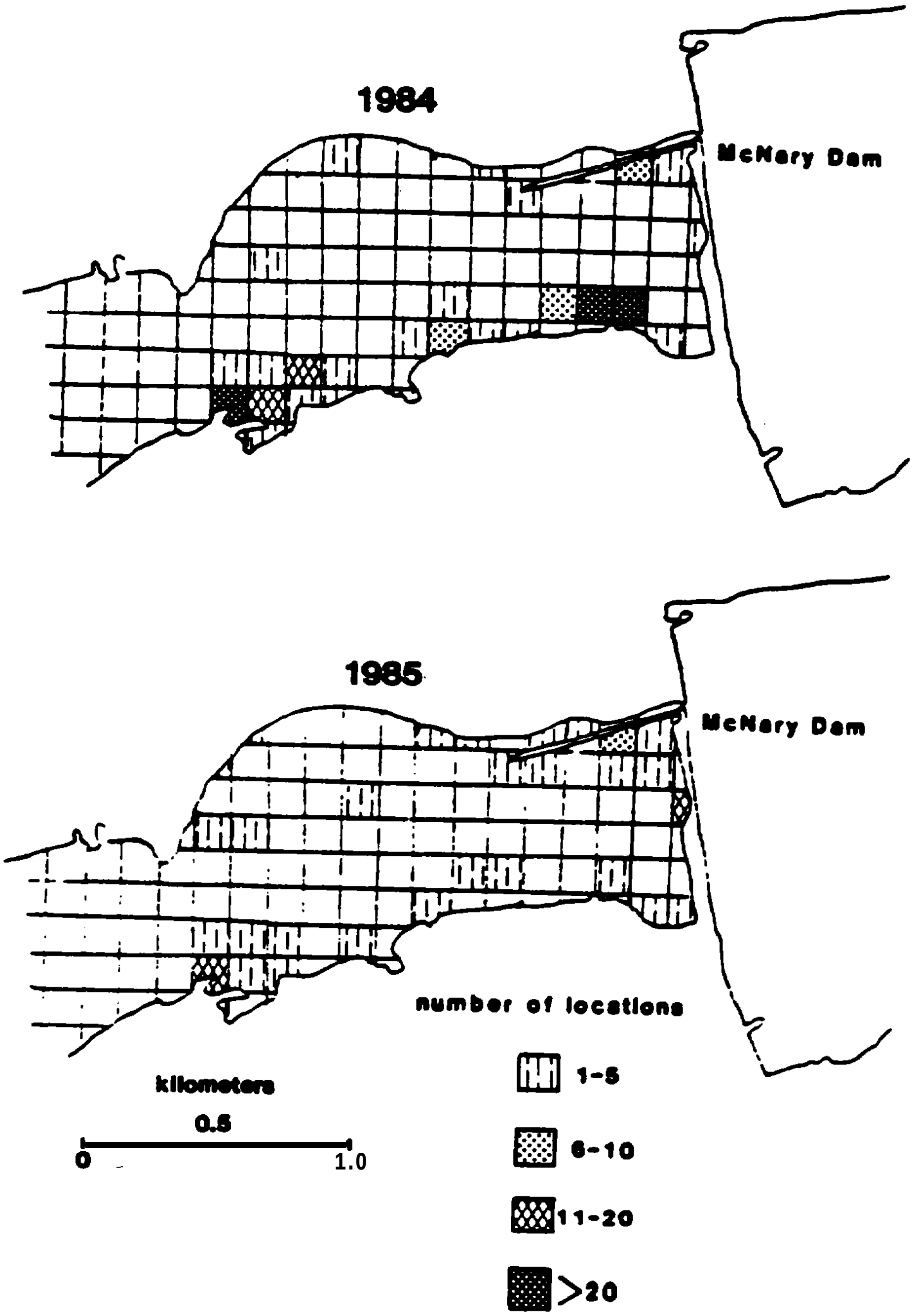

Figure 3. Distributions of radio-tagged northern squawfish during high discharge rates (5,664 m^3/sec) in McNary tailrace, March 14 - July 18, 1984 and April 17 - June 20, 1985.

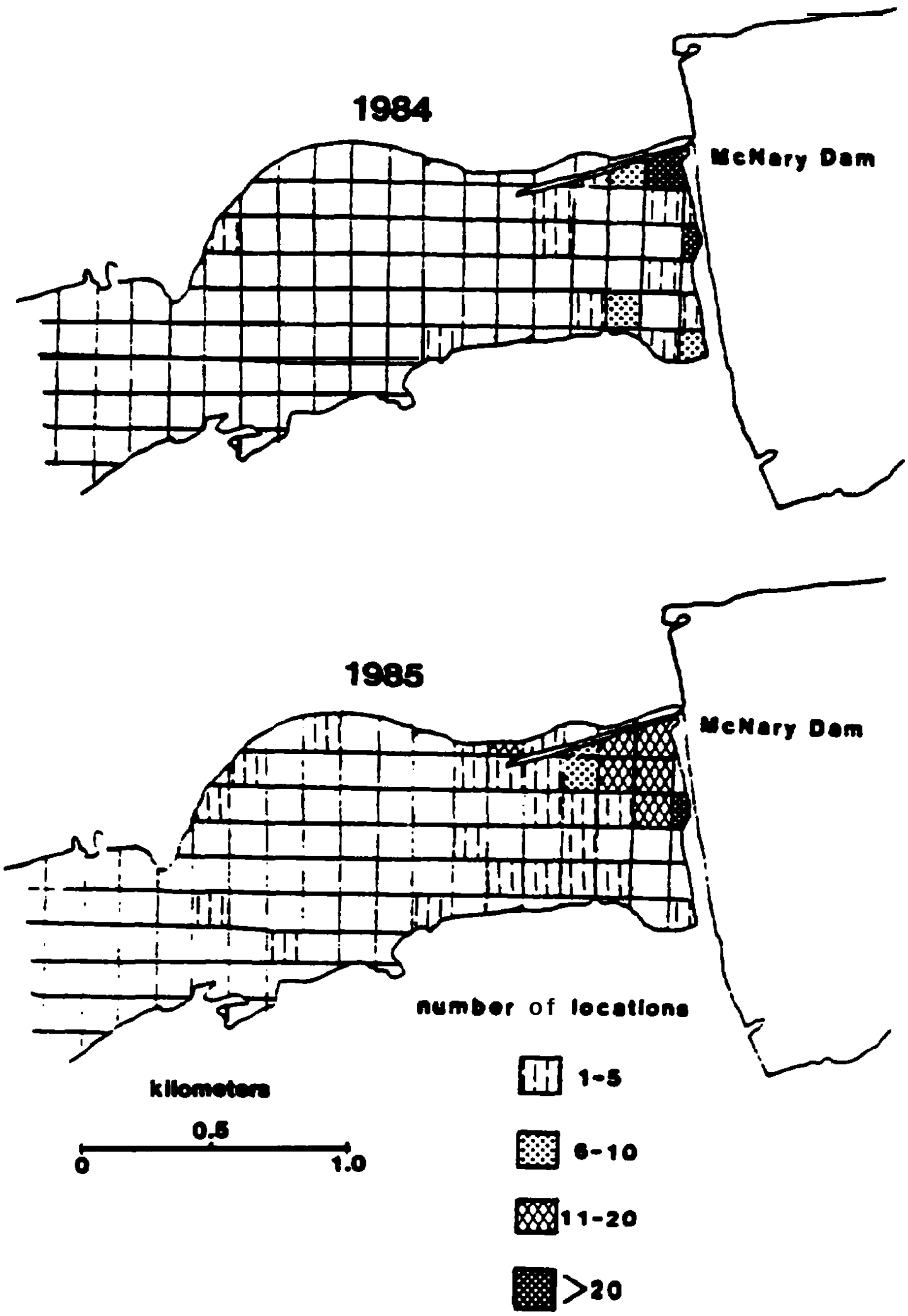

Figure 4. Distributions of radio-tagged northern squawfish during low discharge rates (5,664 m^3/sec) in McNary tailrace, July 19 - August 31, 1984 and June 21 - August 31, 1985.

Table 2. Frequency of inshore-offshore location at low ($\leq$5664 m^3/sec) and high (>5664 m^3/sec) discharge rates for radio-tagged northern squawfish in McNary tailrace, 1984 (n = 3461 and 1985 (n = 286).

Year	Discharge	Inshore	Offshore
1984	low	66	41
	high	214	25
1985	low	110	99
	high	66	11

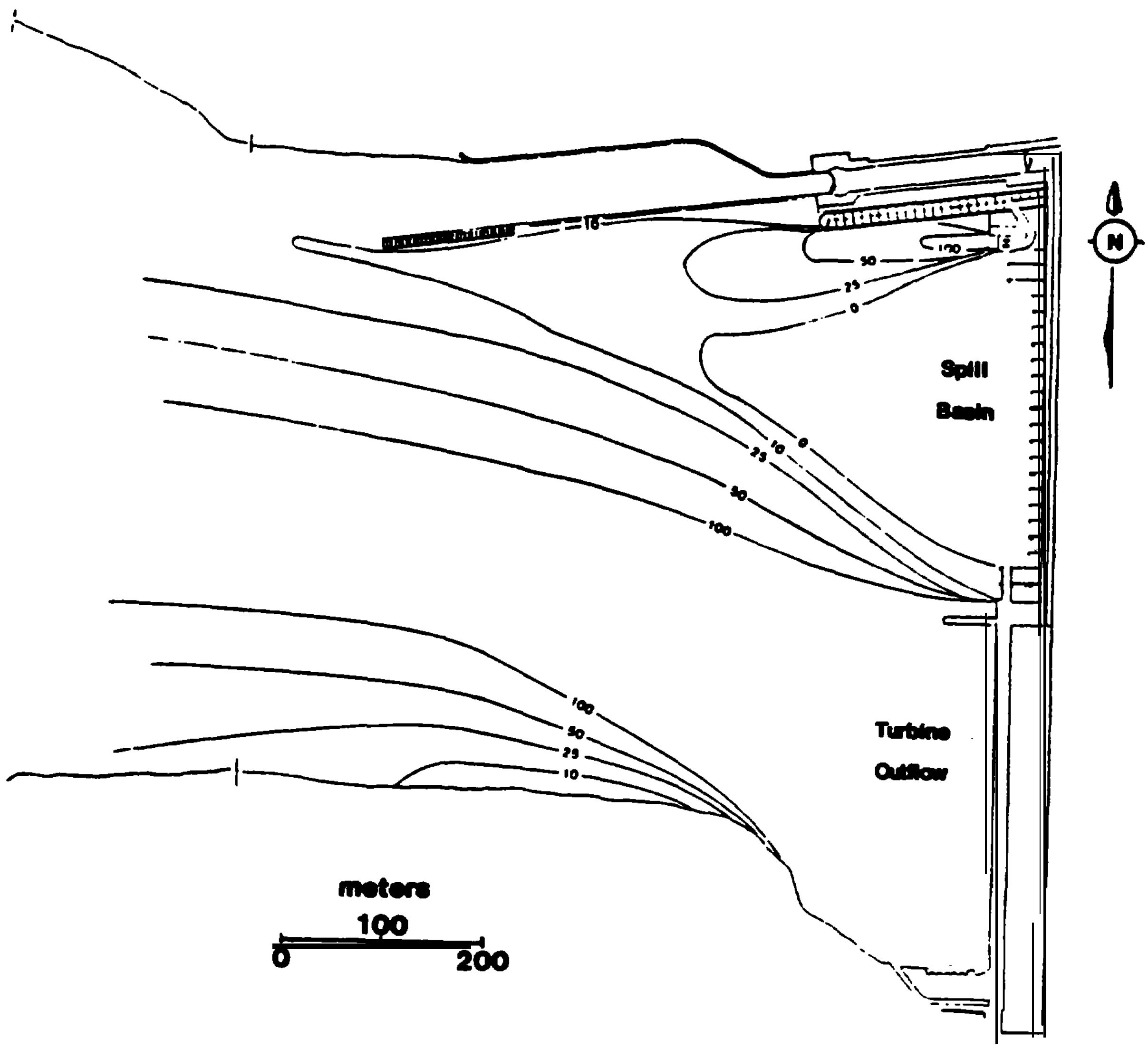

Figure 5. Contour map of water velocities (cm/sec) in McNary tailrace, July and August, 1985.

tailrace has velocities in excess of 70 cm/sec we believe this data confirms the avoidance of high water velocities by northsrn squawfish. The data did not reveal any preference for specific velocities by the predators, however 79.0% of the locations occurred where water velocities were less than 50 cm/sec.

In spring and early summer, turbulence from spillgate operations and high discharge rates provided conditions that made it impossible to map velocities in the tailrace. We assume that water velocities during high discharge rates and spillgate operations are invariably in excess of 100 cm/sec throughout the tailrace except for a back-eddy mid-way along the navigation lock wall, a slack-water area on the Oregon shore downstream of the turbine outflow and a slack-water area in the navigation lock channel. However , back-eddies or slack-water areas may exist in the spill basin if only a portion of the spillgates are opened, leaving points along the face of the dam without an origin of discharge. These conditions were common in 1985. Northern squawfish observed in the spill basin during periods of high discharge were either in a back-eddy along the spillgates or were located there during a period of spill closure.

The movements of northern squawfish were also monitored during short term spill closures to detemine how abrupt changes in discharge can affect their distribution. Four out of 5 northern squawfish monitored during short term spill closures in May, 1985, moved out of protected areas and into the main river channel shortly after the spillgates closed. Two of these fish who were initially located along the navigation lock wall moved into close proximity of the by-pass outflow and the Washington shore adult fishway entrance (Fig. 6). Those fish that moved into the main river channel were observed the following day back in protected areas after the spillgates were reopened. Small sample sizes precluded the use of statistical analyses on spill closure movements.

SUMMARY AND CONCLUSION

Northern squawfish were commonly observed in areas of low water velocity. They were associated with protected shoreline areas during periods of high water discharge, but moved into the main river channel and near the by-pass outflow when discharge decreased. These results imply that predation by northern squawfish at fish passage facilities may be reduced by placing smolt by-pass outflows in areas such that they are surrounded by high water velocity. The existing system at McNary Dam appears to limit predator-prey interactions only when the spillgates are open during high discharge rates. Without spillgate operations, the north side of the by-pass outflow becomes a large slackwater area where northern squawfish were often located. However, by late summer when northern squawfish are congregated near the dam, all juvenile salmonids collected at the by-pass facility are

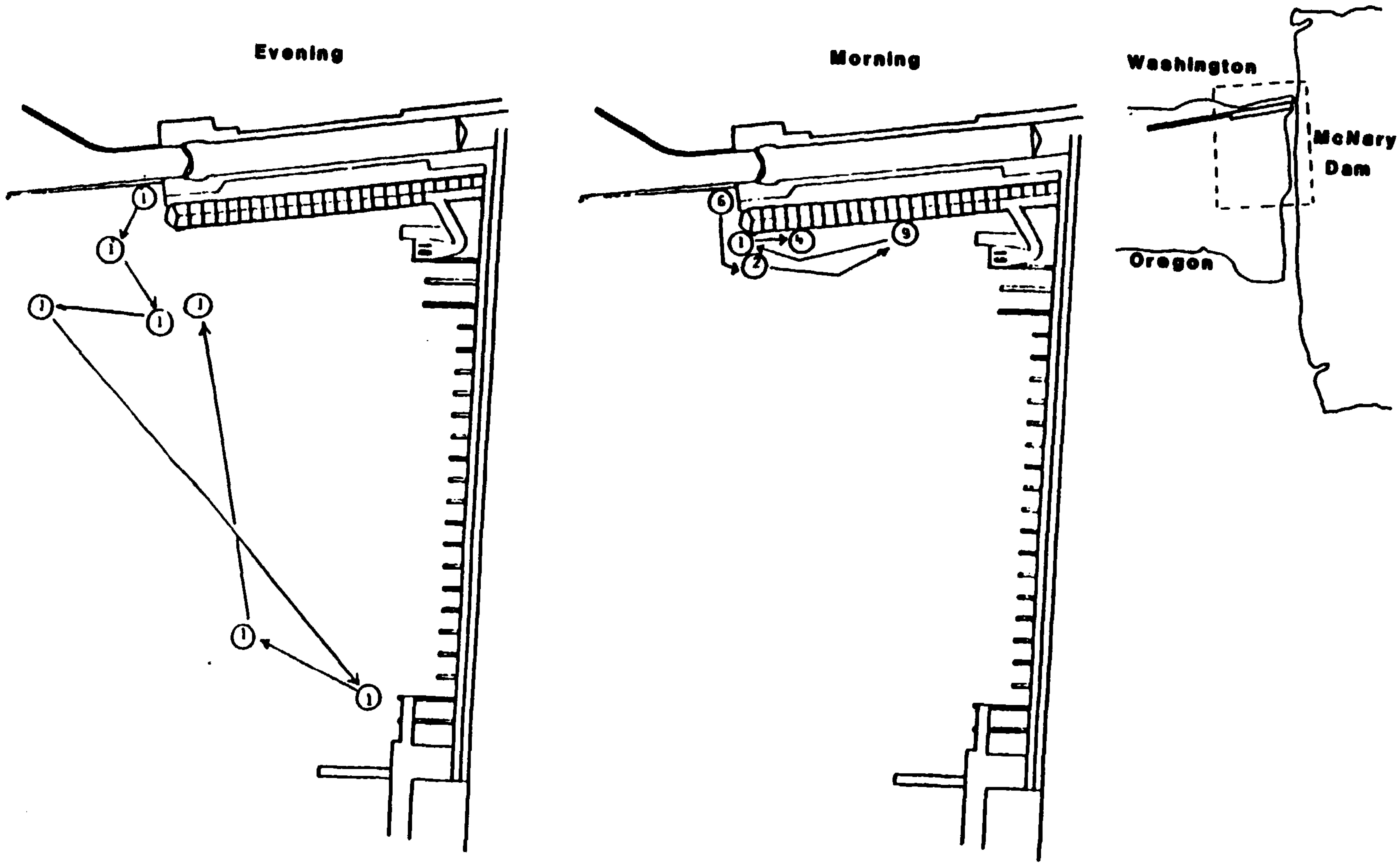

Figure 6. Movements of a radio-tagged northern squawfish after two spill closures (morning and evening) on 7 May and 31 May, 1985, McNary tailrace. Numbers within circles indicate the frequency of observations at each location.

transported by barge or truck; all oumigrants entering the tailrace do so through the turbines or adult fishways.

Squawfish seem to stage at flow shears along the turbine outflow and adult fishway entrances, and are likely to be taking advantage of outmigrants passing through these facilities. However, the effects of the flow regime on squawfish distributions imply that only those outmigrants who drift toward the exterior boundaries of high velocity areas are subject to spatial interaction with northern squawfish. No evidence was found to document the movement of northern squawfish into high flow areas where they might prey on juvenile outmigrants. Smolt by-pass facilities with outlets that open into high velocity turbine outflows are currently in use at Bonneville and John Day dams on the Columbia River. Predator distributions in these areas should be examined to evaluate the effectiveness of this design in reducing the interaction of northern squawfish and juvenile salmonids during dam passage. Flow velocities at by-pass outlets need to be considered in the future design and location of by-pass facilities.

REFERENCES

Anonymous, 1980. Predation Management for the Peripheral Canal Fish Facilities. Delta Fish Facilities Technical Coordinating Committee, Working Justification Paper No. 5. Sept. 1980.

Bates, D.W. 1970. Diversion and Collection of Juvenile Fish with Traveling Screens. U.S. Fish and Wildlife Service Fisheries Leaflet. 633 6 p. March 1970.

Gray, G.A., D.E. Palmer, B.L. Hilton, P.J. Connolly, H.C. Hansel, J.M. Beyer, and G.M. Sonneville. 1983. Feeding activity, rate of consumption, daily ration, and prey selection of major predators in the John Day Pool. Annual Report to the Bonneville Power Administration by U.S. Fish and wildlife Service, Contract Number DI-A179-82BP34796, Portland, OR, USA.

Hart L.G. and R.C. Summerfelt. 1975. Surgical Procedures for Implanting Ultrasonic Transmitters into Flathead Catfish (Pylodictis olivaris). Transactions of the American Fisheries Society. 104 (1): 56-59.

Vogel, D.A. and J.G. Smith. 1984. Fish Passage Action program for Red Bluff Diversion Dam. Annual Progress Report. Fisheries Assistance Office, U.S. Fish and Wildlife Service, Red Cluff, CA, USA.

Winter, J.D., V.B. Kuechle, D.B. Siniff, and J.R. Tester. 1978. Eguipnent and methods for radio-tracking freshwater fish. University of Minnesota Institute of Agriculture, Miscellaneous Report 152, St. Paul, MN, USA.